Turkish Journal of Zoology

Volume 37 | Number 1 Article 8

1-1-2013

Age and growth of swordfish (Xiphias gladius L.) in the Aegean Sea

OKAN AKYOL

TEVFİK CEYHAN

Turkish Journal of Zoology
http://journals.tubitak.gov.tr/zoology/
Research Article
Turk J Zool
(2013) 37: 59-64

doi:10.3906/zoo-1204-3

Age and growth of swordfish (*Xiphias gladius* L.) in the Aegean Sea

Okan AKYOL*, **Tevfik CEYHAN**
Faculty of Fisheries, Ege University, 35440 Urla, İzmir, Turkey

Received: 03.04.2012 • **Accepted:** 08.09.2012 • **Published Online:** 24.12.2012 • **Printed:** 21.01.2013

Abstract: Age and growth of swordfish, *Xiphias gladius*, were determined from 205 specimens (total n = 1408), collected from onboard a swordfish fishery fleet and from a wholesale fish market between June 2008 and July 2011. The length and weight distribution of all fish samples ranged from 51 to 242 cm and from 0.85 to 171.0 kg, respectively. The 70–80 cm lower jaw fork length range of swordfish had the highest ratio (approximately 57%). The length–weight relationship showed a positive allometric growth (b = 3.32; r^2 = 0.969). Age groups of swordfish in the Aegean Sea ranged between 0 and 4 years. Von Bertalanffy growth parameters were calculated as L_∞ = 283.6 ± 56.6 cm, K = 0.15 ± 0.05 year^{-1}, and t_0 = –2.09 ± 0.20 year^{-1}, and the index of phi-prime was Φ' = 9.4. The results show that there was overfishing of swordfish in the Aegean Sea.

Key words: Swordfish, *Xiphias gladius*, age, growth, Aegean Sea, Turkey

1. Introduction

Swordfish (*Xiphias gladius*) is a large, pelagic, oceanodromous species of high commercial value that is heavily exploited in the Atlantic Ocean and the Mediterranean Sea. It migrates toward temperate or cold waters in the summer and back to warm waters in the fall at a depth range of 0–800 m (Tserpes et al., 2003; Froese and Pauly, 2011).

The available information on the reproductive activity of the Mediterranean swordfish is rather limited. The reproductive period of the swordfish is between June and September, with a peak from the end of June to August in the Mediterranean; spawning is in the warmer parts of the water range, with migrations to the cooler waters for feeding (Nakamura, 1986). In the eastern Mediterranean, data from 1175 individuals from both sexes were used for the estimation of gonadosomatic index; the highest index (7.43) was observed in the Levantine basin in July (Tserpes et al., 2001). Like other billfish and tuna, swordfish are highly fecund migratory fish that grow quickly in their early years (by age 1, they may grow to 90 cm in lower jaw fork length) and become apex predators. They reach their maximum size (usually about 350 kg) at about 15 years of age (Ward et al., 2000).

Swordfish are captured using traditional pelagic gillnet (i.e. driftnet; the EU enforced a recommendation prohibiting the use of driftnets in 2002, and this gear has been banned since 2006 in Turkey as well as other Mediterranean countries), pelagic longline, harpoon, and some purse seines (Akyol, 2012). The catch statistics for swordfish in Turkey indicated that there were unstable catch totals ranging between 7 t in 1976 and 589 t in 1988 (FAO, 2011). In 2010, the total catch of swordfish was 13,764 t in the Mediterranean Sea (FAO, 2011) and 334 t in Turkey alone (TÜİK, 2012). Recently, more than 150 fishing boats, including albacore fishery fleets, participated in swordfish fishery in the Aegean and the Mediterranean seas (Akyol and Ceyhan, 2011).

Although Turkish swordfish fishery is an old activity, there are only a few studies on the biology of swordfish (Demir et al., 1956; Artüz, 1963; Alıçlı and Oray, 2001; Alıçlı, 2008; Alıçlı et al., 2012). Among the mentioned studies, only those of Artüz (1963), Alıçlı and Oray (2001), and Alıçlı et al. (2012) were concerned with age and growth of swordfish. One of the earliest attempts at ageing swordfish was carried out by Artüz (1963); the author examined cross-sections of dorsal fin spines of swordfish from the Sea of Marmara and found they contained rings, which were subsequently interpreted as age marks (Porter and Smith, 1990).

Attempts at ageing swordfish have been made using several methods, including modal analysis of length frequencies and examination of hard parts such as vertebrae, otoliths, and dorsal and anal fin ray sections (Castro-Longoria and Sosa-Nishizaki, 1998). However, determination of age may be difficult since the otoliths are very small and scales are missing in adults, but year rings have been successfully counted on cross-sections of the

* Correspondence: okan.akyol@ege.edu.tr

fin rays (Froese and Pauly, 2011). Tsimenides and Tserpes (1989) expressed that the use of anal spine sections seems to be a good method for ageing swordfish although several problems remain, particularly the existence of multiple bands in older animals.

In Turkey, fragmentary information exists on swordfish biology, especially age readings (Artüz, 1963; Alıçlı et al., 2012) and growth parameters (Alıçlı and Oray, 2001). Basic biological information is needed to underpin sustainable swordfish management in Turkish seas. Therefore, the main objective of this study was to analyze age, growth, and length–weight relationship of swordfish in the Aegean Sea.

2. Materials and methods

A total of 1408 swordfish were measured each month in the period from August 2008 to July 2011, some onboard swordfish fishery fleets, which used gillnets and longlines [technical details of these gears were given by Akyol et al. (2008) and Akyol and Ceyhan (2010)], and some from those brought to wholesale fish markets. There were 87 specimens in 2008 [August (2), September (14), October (24), November (12), December (35)], 782 specimens in 2009 [January (68), February (23), March (15), April (9), May (35), June (130), July (78), August (10), September (49), October (28), November (114), December (223)], 412 specimens in 2010 [January (59), February (106), March (119), April (50), November (23), December (55)], and 127 specimens in 2011 [January (59), February (24), March (29), April (5), July (10)]. The numbers of fish samples, separated according to the fishing gears used, are shown in Table 1. The specimens collected from the fishing areas of the Aegean Sea (Figure 1) were measured. The lower jaw fork length (LJFL) was measured to the nearest ±1 cm, and the whole body weighed (round weight = RW) to the nearest ±5 g. The sex of the swordfish could not be determined due to sales as uncut fish.

The length–weight relationship (LWR) of each fish was estimated based on power regression as $W = aL^b$, where W is the weight (g), L is the lower jaw fork length (cm), and a and b are constants.

Ageing was done by examination of a hard part, i.e. a cross-section of the second anal fin ray. Age determination protocol followed that of Tsimenides and Tserpes (1989) and Ehrhardt (1995). The readable second anal fin rays taken from 205 fish were sectioned above the condyle base and stored in plastic locked bags. For preparation of anal spines, each fin was dried in a drying oven for 3 days at 60 °C. Each dried spine, freed from skin and tissue, was placed in a plastic cylinder of either 1.5 cm or 3 cm (for bigger spines) diameter and 2 cm height, which was then filled with liquid polyester. These were left to dry at least 2 h. Transverse sections were cut out of each spine at a location equivalent to half of the maximum width of the condyle base measured above the line of maximum condyle width. Cuts were made using a Buehler Isomet low-speed saw with a Buehler series 15 HC diamond wafering blade. Two or 3 sections between 0.50 and 0.70 mm thick were immersed in 95% ethanol for 5 min and then placed in a labeled petri dish to air dry. The prepared spine sections were subsequently analyzed under a binocular microscope (SOIF) equipped with a camera at 10× magnification under reflected light and against a dark background. Images were captured and analyzed using Image Analyzer 1.0 software. On the sectioned spines, an opaque zone (mark) preceded by a translucent (hyaline) zone was assumed to be an age mark (Figure 2). Although the age readings were done by 2 readers, validation of growth increments could not be made due to absence of focus and the oblique shape of the spines. Moreover, slice diameters of spines differed in fish of the same size.

Nonseasonal growth parameters (L_∞, K, and t_0) were estimated with the von Bertalanffy growth formula (VBGF) in the FAO–ICLARM Stock Assessment Tools (FISAT) computer program (Gayanilo et al., 1994) using individual lengths-at-age. The von Bertalanffy growth equation for length, $L_t = L_\infty[1 - e^{-K(t - t0)}]$, where L_∞ is the asymptotic length, K the growth curve parameter, and t_0 the theoretical age when fish length would have been zero, was applied. Overall growth performance was estimated by the index Φ' (phi-prime test) (Pauly and Munro, 1984), $\Phi' = \ln K + 2\ln L_\infty$.

Table 1. Monthly number of swordfish samples according to the fishing gear used in the Aegean Sea (PS: purse seine, GN: gillnet, LL: longline).

	Months												
Fishing gear	1	2	3	4	5	6	7	8	9	10	11	12	Total
PS	178	100	151	50	-	-	-	-	31	41	106	148	805
GN	-	8	-	9	35	130	88	12	15	-	-	-	297
LL	8	45	12	5	-	-	-	-	17	11	43	165	306
Total	186	153	163	64	35	130	88	12	63	52	149	313	1408

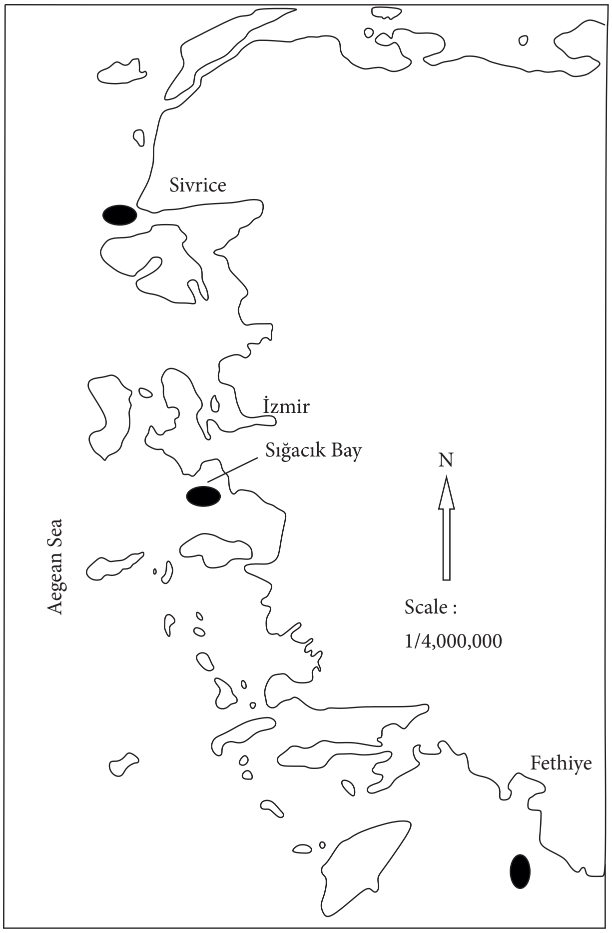

Figure 1. Map of the study areas.

3. Results

The length and weight distribution of all fish samples ranged from 51 to 242 cm and from 850 to 171,000 g, respectively (Table 2). The length distribution of all fish is indicated in Figure 3; the 70–80 cm length range had the highest rate (approximately 57%).

The length–weight relationship is shown in Figure 4. The LWR parameters (a, b, r^2) were computed as 0.0025 ± 0.031, 3.3196 ± 0.016, and 0.9692, respectively. The b value indicates a positive allometric growth ($b > 3$).

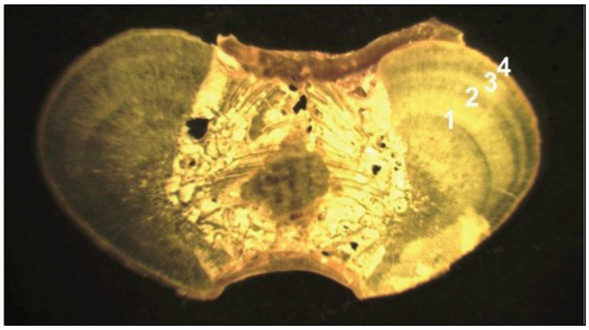

Figure 2. Cross-sectioned spine of 4-year-old swordfish, *Xiphias gladius* (172 cm LJFL).

Age groups ranged between 0 and 4, and mean LJFLs (and mean RWs) were 77.3 ± 0.8 cm (4744.7 ± 186 g), 106.4 ± 0.9 cm (14,704.8 ± 517 g), 128.1 ± 1.9 cm (29,090 ± 2162 g), 152.6 ± 3.3 cm (48,625 ± 2755 g), and 175.0 ± 5.2 cm (71,600 ± 6290 g), respectively (Table 3). The age group '0' was dominant (53.2%). The observed lengths of swordfish assigned to each group were used to fit the VBGF (Figure 5). Growth parameters with standard errors were calculated as L_∞ = 283.6 ± 56.6 cm, K = 0.15 ± 0.05 year^{-1}, and t_0 = –2.09 ± 0.20 year^{-1}, and the index of phi-prime was Φ' = 9.4.

There were no statistical differences between the observed and calculated mean lengths in all age groups (t-test, P > 0.05) (Table 4).

4. Discussion

The swordfish specimens were caught by pelagic gillnet, longline, and purse seine during the 3-year sampling period in the Aegean Sea. The length of specimens ranged from 51 to 242 cm, and the specimens under minimum landing size (MLS = 125 cm in Turkish Fisheries Regulation Notification no. 2/1, SÜR-KOOP, 2008) had the highest rate, at 91.7%. Approximately 57% of caught specimens were between 70 and 80 cm. Akyol and Ceyhan (2011) reported that gillnet was the most size-selective gear, while 65% of swordfish caught by longline and purse seine had a LJFL of less than 80 cm. Thus, the longlines and purse seines may have been responsible for the

Table 2. Range, mean with standard error (SE), median and mode of length (LJFL, cm), and round weight (RW, g) for swordfish, *Xiphias gladius*, in the Aegean Sea.

n = 1408	Length (cm)	Weight (g)
Range	51–242	850–171,000
Mean ± SE	94.9 ± 0.83	13,738 ± 464
Median	80	5500
Mode	74	3300

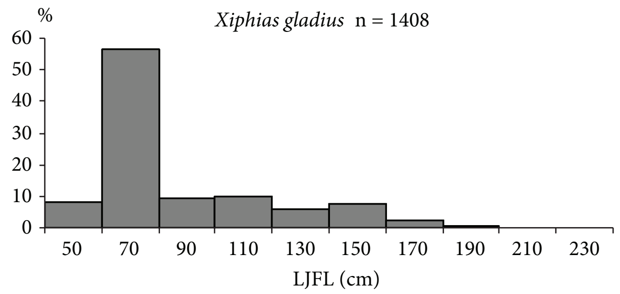

Figure 3. Length–frequency distribution for swordfish, *Xiphias gladius*, in the Aegean Sea.

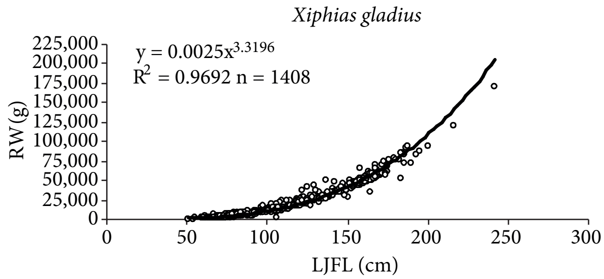

Figure 4. Length–weight relationship for swordfish, *Xiphias gladius*, in the Aegean Sea.

juvenile catch. Ceyhan and Akyol (2009) mentioned that gillnet was responsible for catching most of the larger fish (>130 cm), with a higher percentage (90%) in comparison with longline catches. A recent International Commission for the Conservation of Atlantic Tunas (ICCAT) report (SCRS/2006/163; ICCAT, 2011) recommended that technical modifications of the longline fishing gears, as well as modifications in the way they are operated, can be considered as additional technical measures for reducing the catch of juveniles. The working group recommended that these types of measures be considered as part of a Mediterranean swordfish management plan. Management measures aimed at reducing fleet capacity should also be considered as part of the Mediterranean swordfish management plan adopted by the Commission.

In the eastern Mediterranean, catch-at-sizes of swordfish were documented between 98 and 295 cm (n = 498; Artüz, 1963), 87.6 and 206.7 cm (n = 882; Tsimenides and Tserpes, 1989), 62 and 205 cm (n = 1100; Tserpes and Tsimenides, 1995), 52.5 and 219 cm (n = 794; Alıçlı and Oray, 2001), 67.5 and 176 cm (n = 212; Alıçlı, 2008), 60 and 240 cm (n = 175; Ceyhan and Akyol, 2009), and 87 and 188.5 cm (n = 87; Alıçlı et al., 2012). The striking issue here is that the size of swordfish has decreased gradually since 1963 (Artüz, 1963), even though they are fast-growing fish. Ward and Elscot (2000) emphasized that swordfish were remarkably fast-growing in their early years. Megalofonou et al. (1995) reported a growth rate of 2.3 cm day^{-1} for juvenile swordfish ranging in LJFL size from 51 to 74 cm.

The *b* coefficient of the LWR (*b* = 3.32) indicates positive allometric growth in the study. This value is close to others obtained in different eastern Mediterranean studies (Tsimenides and Tserpes, 1989; Alıçlı and Oray, 2001; Alıçlı et al., 2012)

Table 3. Age–length key for swordfish, *Xiphias gladius*, in the Aegean Sea.

LJFL (cm)	Age					Σ	Cumulative	Cum.%
	0	1	2	3	4			
60	12					12	12	5.85
70	58					58	70	34.14
80	30	1				31	101	49.27
90	9	12				21	122	59.51
100		35				35	157	76.59
110		22				22	179	87.32
120		3	6			9	188	91.71
130			4	1		5	193	94.15
140				2		2	195	95.12
150				4		4	199	97.07
160				3	1	4	203	99.02
170					1	1	204	99.51
180					1	1	205	100.00
Σn	109	73	10	10	3	205		
%n	53.2	35.6	4.9	4.9	1.5			
Min.	60.0	88.0	120.0	140.0	168.0			
Max.	98.0	124.0	138.0	167.0	185.0			
Mean	77.3	106.4	128.1	152.6	175.0			
± SE	± 0.8	± 0.9	± 1.9	± 3.3	± 5.2			

Table 4. Observed and calculated mean lengths (LJFL, cm) of swordfish, *Xiphias gladius*, for each age group.

Length Parameter	Value per age group (year)				
	0	1	2	3	4
$L_{obs.}$	77.3	106.4	128.1	152.6	175.0
$L_{calc.}$	76.3	105.2	130.0	151.4	169.8

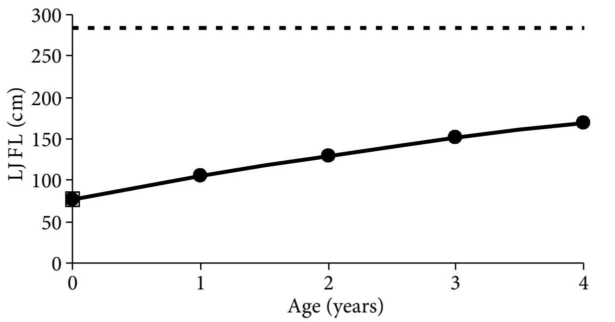

Figure 5. Von Bertalanffy growth curve fitted by length-at-age for swordfish, *Xiphias gladius*, in the Aegean Sea.

Although the maximum age of swordfish has been reported to be up to 10 years for the Mediterranean populations (Alıçlı and Oray, 2001; Valeiras et al., 2008), in this study, the age range was between 0 and 4. Furthermore, the age group '0' was the largest (53.2%). The swordfish population in the Aegean Sea is getting increasingly smaller. An intermediate asymptotic length (L_∞ = 283.6 cm) supports previous estimates for swordfish in the Mediterranean, and K and t_0 are also within the range of those of other populations (Table 5).

The last ICCAT Circular (No. 5058/2011) recommended that Mediterranean swordfish should not be caught (either as targeted fishery or as by-catch) or landed during the period from 1 October to 30 November, and during an additional period of 1 month between 15 February and 31 March. Additionally, swordfish should not be caught at less than 90 cm LJFL (or 10 kg RW). Turkish management measures for swordfish meet these recommendations in terms of MLS, but do not meet them exactly in terms of closed season.

In conclusion, although a MLS of 125 cm for swordfish is mandated in Turkish seas, most of the fish that are caught are under that MLS, mostly due to lack of enforcement. Purse seiners and some longliners are especially responsible for undersized fish catch (Akyol and Ceyhan, 2011). Decrease in size or age is a typical sign of heavy fishing pressure, and as shown by the present study and other studies in the area, there is over-fishing of swordfish. The fishery of swordfish has to be kept under strict control, and this should include sharing data with other Mediterranean countries. In addition, seasonal closure, which now covers October and November for swordfish, should be extended until March for juvenile protection.

Acknowledgments
This study was funded by the Scientific and Technological Research Council of Turkey (TÜBİTAK Project No. 108O210) and Ege University Science and Technology Center (EBİLTEM Project No. 2009/BIL/019).

Table 5. Growth parameters (L_∞, K, and t_0) of swordfish, *Xiphias gladius*, from the Mediterranean Sea.

Locality	Age	Sex	L_∞	K	t_0	Φ' [(*)]	Reference
Aegean Sea	0–7	F	220	0.25	– 1.52	9.4	Tsimenides and Tserpes (1989)
	0–6	M	194	0.34	– 1.22	9.5	
Aegean Sea	0–9	F	227	0.21	– 1.17	9.3	Tserpes and Tsimenides (1995)
	0–9	M	203	0.24	– 1.21	9.2	
	0–9	F + M	239	0.19	– 1.40	9.3	
Eastern Mediterranean	0–10	F + M	252	0.13	– 2.43	9.0	Alıçlı and Oray (2001)
Western Mediterranean	0–10	F	264	0.12	– 2.27	9.0	Valeiras et al. (2008)
	0–7	M	186	0.22	– 1.97	8.9	
Aegean Sea	0–4	F + M	284	0.15	– 2.09	9.4	Present study

[(*)], phi-prime test; this parameter was calculated from data from other studies.

References

Akyol, O. 2012. Swordfish (*Xiphias gladius*, Linnaeus, 1758) fishery. In: The State of the Turkish Fisheries (Eds. A. Tokaç, A.C. Gücü and B. Öztürk). Publication No. 35, TÜDAV, İstanbul, pp. 364–371.

Akyol, O. and Ceyhan, T. 2010. Pelagic longlines for swordfish used in Turkish seas. E.Ü. Su Ürünleri Dergisi 27(4): 149–156 [in Turkish].

Akyol, O. and Ceyhan, T. 2011. The Turkish swordfish fishery. Collect. Vol. Sci. Pap. ICCAT 66(4): 1471–1479.

Akyol, O., Karakulak, F.S., Ceyhan, T. and Dede, A. 2008. Driftnets used in Turkish seas and their regulations. E.Ü. Su Ürünleri Dergisi 25(2): 153–157 [in Turkish].

Alıçlı, T.Z. 2008. Biometric relationships and condition factor of swordfish, *Xiphias gladius* L., 1758. İ.Ü. Su Ürünleri Dergisi 23: 29–39.

Alıçlı, T.Z. and Oray, I.K. 2001, Age and growth of swordfish (*Xiphias gladius* L., 1758) in the eastern Mediterranean Sea. Collect. Vol. Sci. Pap. ICCAT 52(2): 698–707.

Alıçlı, Z., Oray, I.K., Karakulak, S.F. and Kahraman, A.E. 2012. Age, sex ratio, length–weight relationships and reproductive biology of Mediterranean swordfish, *Xiphias gladius* L., 1758, in the eastern Mediterranean. Afr. J. Biotechnol. 11: 3673–3680.

Artüz, M.I. 1963. Contribution to the knowledge of the biology of the swordfish (*Xiphias gladius* L.) in the Sea of Marmara. Proc. Gen. Coun. Medit. 7: 459–471.

Castro-Longoria, R. and Sosa-Nishizaki, O. 1998. Age determination of swordfish, *Xiphias gladius* L., from waters off Baja California, Mexico, using anal fin rays and otoliths. In: Biology and Fisheries of Swordfish, *Xiphias gladius* (Eds. I. Barrett, O. Sosa-Nishizaki and N. Bartoo). NOAA Tech. Rep., NMFS 142: 231–237.

Ceyhan, T. and Akyol, O. 2009. Swordfish (*Xiphias gladius* L.) fishery in Turkish Aegean Sea. Collect. Vol. Sci. Pap. ICCAT 64(6): 2069–2078.

Demir, M., Acara, A. and Arım, N. 1956. Investigations on swordfish (*Xiphias gladius* L.). Hidrobiologi Mecmuası, İ.Ü. Fen Fak. Hidr. Araş. Enst. Yayınlarından, Seri A 3: 137–143 [in Turkish].

Ehrhardt, N.M. 1995. On the age and growth of swordfish in the Northwest Atlantic Ocean. Col. Vol. Sci. Pap., ICCAT 44(2): 84–88.

FAO. 2011. FAO Fisheries and Aquaculture Department, Statistics and Information Service FishStatJ: Universal Software for Fishery Statistical Time Series. FAO, Rome.

Froese, R. and Pauly, D. (Eds.) 2011. FishBase. World Wide Web electronic publication. Available at www.fishbase.org, version 10/2011.

Gayanilo, F.C., Sparre, P. and Pauly, D. 1994. The FAO–ICLARM Stock Assessment Tools (FISAT) User's Guide. FAO Computerized Information Series, 6. FAO, Rome.

ICCAT. 2011. Report of the 2010 ICCAT Mediterranean Swordfish Assessment Meeting (Madrid, Spain – June 28 to July 2, 2010). Collect. Vol. Sci. Pap. ICCAT 66(4): 1405–1470.

Megalofonou, P., Dean, J.M., De Metrio, G., Wilson, C. and Berkeley, S. 1995. Age and growth of juvenile swordfish, *Xiphias gladius* Linnaeus, from the Mediterranean Sea. J. Exp. Mar. Biol. Ecol. 188(1): 79–88.

Nakamura, I. 1986. Xiphiidae. In: Fishes of the North-Eastern Atlantic and the Mediterranean (Eds. P.J.P. Whitehead, M.L. Bauchot, J.C. Hureau, J. Nielsen and E. Tortonese). Vol. II, UNESCO, Paris, pp. 1006–1007.

Pauly, D. and Munro, J.L. 1984. Once more on the comparison of growth fish and invertebrates. ICLARM Fishbyte 2(1): 1–21.

Porter, J.M. and Smith, S.C. 1990. Literature review of ageing in Atlantic swordfish, *Xiphias gladius*. ICCAT Working Document, SCRS/90/37, pp. 1–20.

SÜR-KOOP. 2008. Turkish Fishery Regulation Bulletin (2/1) for Marine and Inland Commercial Fisheries in Fishing Season 2008–2012, SÜR-KOOP, T.C. TKB-KKGM, R.G. Sayı: 26974, No: 2008/48, Ankara [in Turkish].

Tserpes, G., Peristeraki, P. and Di Natale, A. 2003. Swordfish abundance trends in the Mediterranean. CIESM Workshop Monographs No. 22. Mediterranean Biological Time Series, pp. 101–108.

Tserpes, G., Peristeraki, P. and Somarakis, S. 2001. On the reproduction of swordfish (*Xiphias gladius* L.) in the eastern Mediterranean. Collect. Vol. Sci. Pap. ICCAT 52(2): 740–744.

Tserpes, G. and Tsimenides, N. 1995. Determination of age and growth of swordfish, *Xiphias gladius* L., 1758, in the eastern Mediterranean using anal-fin spines. Fish. Bull. 93: 594–602.

Tsimenides, N. and Tserpes, G. 1989. Age determination and growth of swordfish *Xiphias gladius* L., 1758 in the Aegean Sea. Fish. Res. 8: 159–168.

TÜİK. 2012. Fishery Statistics 2010. Turkish Statistical Institute Official Webpage. Available at http://tuikapp.tuik.gov.tr/balikcilikdagitimapp/balikcilik.zul (accessed 13 June 2012).

Valeiras, X., de la Serna, J.M., Macias, D., Ruiz, M., Garcia-Barcelona, S., Gomez, M.J. and Ortiz de Urbina, J.M. 2008. Age and growth of swordfish (*Xiphias gladius*) in the Western Mediterranean Sea. Collect. Vol. Sci. Pap. ICCAT 62(4): 1112–1121.

Ward, P. and Elscot, S. 2000. Broadbill Swordfish: Status of World Fisheries. Bureau of Rural Sciences, Canberra.

Ward, P., Porter, J.M. and Elscot, S. 2000. Broadbill swordfish: status of established fisheries and lessons for developing fisheries. Fish and Fisheries 1: 317–336.