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Abstract.

A total of 450 anal fin spines from North Pacific swordfish were analyzed from years 2005 to 2006 for ageing and growth studies. The lower jaw fork lengths of the aged individuals ranged from 74 to 235 cm for the males and from 71 to 294 cm for the females. Fish ages ranged 0 to 13 years old and the mean lengths by age were calculated for males and females. Growth parameter estimates were calculated from 406 cut spine sections which provided readable growth annuli by sex.

The preliminary growth parameters based on standard VB growth function are the following: for males, L_∞ (asymptotic length)=271.4 cm, k (growth coefficient)=0.121, t_0 (age at zero length)=-1.543; for females, L_∞=376 cm, k=0.0701 , t_0=-2.162.

The relationships between LJFL and anal fin spine radius were calculated for both sexes. The trends in the monthly marginal increment ratio was not conclusive regarding growth bands formation along the year

Introduction.

Information on age and growth of swordfish (*Xiphias gladius*) is an important factor to assessing stock trends and has been used in several stocks. Most of the swordfish studies have been carried out in Atlantic waters (Berkeley and Houde, 1983; Riehl, 1984; Ehrhardt *et al*., 1996; Esteves *et al*., 1995; Arocha *et al.*, 2003). In the Pacific Ocean, there are several papers on growth biology (Castro-Longoria and Sosa-Hishizaki, 1998; Sun *et al*., 2002; Young and Drake, 2003; Young and Drake, 2004). Last two authors determined age and growth parameters using anal spines of swordfish sampled in western Pacific waters and described a different growth rates than the Atlantic's.

From 2005, sampling effort in the Spanish pelagic longline observer program was focused on collect swordfish anal fins to improve biological knowledge in Pacific waters. The aim of this paper is to present first results from the north Pacific fisheries from spine analysis and provide age-length keys and parameter estimates of swordfish growth in the area.

Material and methods.

Fish sampling.

Swordfish specimens were collected from Spanish drifting longliners at the north Pacific around 20-45ºN, 155-175ºE during a IEO research projects from 2005 to 2006. Sampling was done according to a random stratified design covering the length range of the species in the study area. Size LJFL (lower jaw fork length in cm) and sex were recorded from all sampled specimens. The analyzed samples were collected onboard from June to January.

Spine preparation.

Methodology based on Berkeley and Houde (1983), Ehrhardt *et al*. (1996), Esteves *et al*. (1995) and Tserpes and Tsimenides (1995) was used in this study. Anal fins of the sampled specimens were thawed in the laboratory and the second spine was removed. The second spine was immersed briefly in boiling water to clean the spine radius of tissue. These tissues were carefully removed with a scalpel and tweezers without causing damage to the surface of the spine. The spine was washed with water and left to dry completely. A cross section of 0.5 mm thick was cut using an ISOMED 5000 Cutter. Two cut points were used: one cut located at a distance equivalent to the maximum width of the condyle base, and a second point located midway between the above distance. Both distances were measured above the line of maximum condyle width. In each cut location of the spine, two consecutive cuts were made in order to choose the best one when taking the reading. The sections were washed in a 70% ethanol solution. They were later mounted onto labeled holders and embedded in Eukitt highly transparent mounting resin.

Age interpretation.

The clearest of the two sections was examined using a profile projector (model: Nikon 4C) with transmitted light at 20x – 40x magnification depending on the size of section. The distance from the focus to the distal edge of each growth band (annulus) was measured and recorded. Spine sections were read twice by two readers and unresolved differences in readings resulted in spine elimination. Alternative pairs of a translucent band and a opaque band were considered to be a year annuli. When present, multiple annuli and disappearance of the first annulus in older fish were carefully considered to assess the age classes.

Growth parameters.

Age length keys were produced for males, females and for the two sexes combined, and their mean lengths at age and standard deviations calculated. von Bertalanffy growth curves were preliminarily fitted to the data applying the standard von Bertalanffy growth function (von Bertalanffy, 1938). Growth parameters were computed for females and males using non-linear least square estimation.

Standard VB model: $L_t = L_\infty (1-e^{-k(t-t_0)})$

where,

L_t is length (LJFL) at age t;

L_∞ is asymptotic length;

t_0 is theoretical age at zero length;

Backcalculation.

The relationship between LJFL and anal fin spine radius (*S*) was determined by using two procedures:

- Standard linear regression: $LJFL = a+bS$
- Power function: $LJFL=aS^b$

Marginal increment ratio.

With the aim to determinate annuli formation and for validation purposes, the marginal increment ratio (MIR) was estimated for each spine by the following formula (Esteves *et al*., 1995; Sun *et al.*, 2002):

$MIR= (S-S_n)/(S_n-S_{n-1})$,

where,

S= spine radius;

S_n= distance from ray focus to band n;

S_{n-1}=distance from ray focus to band n-1.

Results and discussion.

A total of 406 sections of anal spines were aged successfully (167 males and 234 females). Other 5 aged spines were from not-sexed fish. 39 spines were unreadable due to multiple banding pattern or unidentifiable growth annuli. A summary of samples collected for this work is presented in Table 1.

Mean sizes by age for both sexes are presented in Table 2. Assigned ages of spine sections were from 0 to 13 years. 87% of males were 1-7 years old and 89% of females were 1-9 years old.

Growth parameter estimates are showed in table 3. The preliminary growth parameters based on standard VB growth function are the following: for males, L_∞ (asymptotic length)=271.4 cm, k (growth coefficient)=0.121, t_0 (age at zero length)=-1.543; for females, L_∞=376 cm, k=0.0701 , t_0=-2.162.

Ehrhardt (1992) reported that the von Bertalanffy growth function did not adequately represent swordfish growth. Tserpes and Tsimenides (1995), Arocha *et al.* (2003) and Sun *et al*., (2002) proposed Chapman's generalized model to estimate growth parameters. Our preliminary results will be improved in future and a generalized model calculated.

The predicted LJFL at age by sex using parameters estimates are showed in Table 5. Mean LJFL at age for present paper and other articles are presented also in Table 5. In Figure 1, growth curves by sex and different authors estimates of lengths at age data are plotted.

The preliminary results obtained suggest growth patterns generally similar to most obtained in other areas-oceans. Similarity was observed with the results provided for the westerns Pacific areas around Taiwan (Sun *et al.*, 2002) but important differences were observed between most studies and the slowest growth pattern reported from the western Pacific areas around Australia (Young and Drake, 2004). Sizes (LJFL) around 160 cm and 200 cm LJFL are achieved for females at 6 and 9 years old, respectively. However, these sizes are estimated at around 7 and 11-12 years old, respectively, for the western Pacific areas. Sun *et al*. (2002) estimates age 5 for females around 160 cm and age 9 female length agrees also with present study. Atlantic estimates show that females generally get 160 cm at 4 -5 years old. In this work differences in growth by sex are observed from age 6 (figure 1).

The monthly means of marginal increment ratio (MIR) are computed in Figure 2 (number of analyzed samples= 388 spines). The trends in the monthly marginal increment ratio and growth band formation along year were not conclusive, in part because of the sampling size and period (8 months: June to January). An annual basis sample collection will be desirable to define a more clear pattern in the formation of growth rings in Pacific swordfish. Sun *et al*. (2002) and Young and Drake (2004) found differences in MIR in summer months, which indicates the formation of one ring per year during the period from June to August (austral winter).

The complex behavior of the swordfish linked with their respective spawning -feeding migratory habits between sexes could produces an additional difficulty to annuli formation and to age interpretation from hard parts. Despite the complexity for tagging swordfish, the availability of representative conventional tag-recapture data by sex can be very useful for further growth validations, as it was the case for the North Atlantic swordfish.

Broad differences of some key biological parameters, such as growth or reproduction, are not initially expected among stocks of large migratory pelagic fish with very broad and frequently overlapped areas of distribution. The respective area-time sampling coverage and the different methodologies used could likely explain the different results reported among authors. Recent results about the global genetic structure of the swordfish indicate that the Mediterranean population is by far the most divergent one (Kotoulas *et al.* 2007). However, even in such case, the growth and reproductive parameters reported for the Mediterranean Sea are closer than previously thought in relation with those recently reported from other areas, such as the North Atlantic. Broader efforts on growth studies for the Pacific swordfish should be developed under appropriate projects.

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References.

Arocha, F., C. Moreno, L. Beerkircher, D.W. Lee and L. Marcano, 2003. Update on growth estimates for swordfish, *Xiphias gladius*, in the northwestern Atlantic. Col. Vol. Sci. Pap. ICCAT, 55 (4): 1416-1429.

Berkeley, S. A. and E.D. Houde. 1983. Age determination of broadbill swordfish, *Xiphias gladius*, from the Straits of Florida, using anal fin spine sections. NOAA Technical Report NMFS, 8: 137-143.

Castro-Longoria, R. and O. Sosa-Nishizaki, 1998. Age determination of swordfish, Xiphias gladius L., from waters off Baja California, Mexico, using anal fin rays and otoliths. U.S. Dep. Commer., NOAA Technical Report NMFS 142: 231-257.

Ehrhardt, N. 1992. Age and growth of swordfish, *Xiphias gladius*, in the northwestern Atlantic. Bull. Mar, Sci., 50(2):292-301.

Ehrhardt, N. M., R.J. Robbins and F. Arocha. 1996. Age validation and growth of swordfish, *Xiphias gladius,* in the northwest Atlantic. ICCAT Col. Vol. Sci. Pap. Vol. 45(2): 358-367.

Esteves, E., P. Simoes, H.M. Da Silva and J.P. Andrade. 1995. Ageing of swordfish, *Xiphias gladius* Linnaeus, 1758, from the Azores, using sagittae, anal-fin spine and vertebrae. Arquipélago, Ciencias Biológicas e Marinhas, 13A: 39-51.

Kotoulas, G., J. Mejuto, A. Antoniou, P. Kasapidis, G. Tserpes, C. Piccineti, P. Peristeraki, B. Garcia-Cortes, K. Oikonomaki, J.M. De la Serna & A. Magoulas, 2007. Global genetic structure of the swordfish (*Xiphias gladius*) as revealed by microsatellite markers. ICCAT Col. Vol. Sci. Pap. Vol. 61: 79-88.

Megalofonou, P., J.M. Dean, G. de Metrio, C. Wilson and S. Berkeley, 1995. Age and growth of juvenile swordfish, *Xiphias gladius,* from the Mediterranean Sea. Journal of Experimental Marine Biology and Ecology, 188:79-88.

Riehl, M. W., 1984. Age and growth estimation of northwest Atlantic broadbill swordfish, *Xiphias gladius*, using fin-spines. Thesis for Bachelor of Science with Honours in Biology, mount Allison University. 33pp.

Sun, C.L., S.P. Wang and S.Z. Yeh, 2002. Age and growth of the swordfish (Xiphias gladius L.) in the waters around Taiwan determined from anal-fin rays. Fishery Bulletin, 100(4): 822-835.

Tserpes, G. and N. Tsimenides, 1995. Determination of age and growth of swordfish, *Xiphias gladius* L., 1758, in the eastern Mediterranean using anal-fin spines. Fishery Bulletin, 93(3): 594-602.

Young, J. and A. Drake, 2003. Age and growth of broadbill swordfish (Xiphias gladius) from eastern Australian. 16th Meeting of the Standing Committee on Tuna and Billfish, 9-16 July 2003, Mooloolaba, Queensland, Australia. Working Paper BBRG-8.

Young, J. and A. Drake. 2004. Age and growth of broadbill swordfish (Xiphius gladius)from Australian waters. Final report for project 2001/014, Fisheries Research Development Corporation, Canberra, Australia.

Table 1. Summary of swordfish from Pacific Ocean used in this study (M: males; F: females; I: indeterminate).

	M	F	M+F+I
Number	167	234	406
Size range cm)	74-235	71-294	71-294
Age range (years)	1-13	1-13	1-13

Table 2. Summary statistics of male and female aged swordfish from Pacific Ocean.

Age_Males	n spines	Mean LJFL	LJFL range	Std. Error
1	14	81.9	74-95	1.61
2	28	104.2	77-127	2.67
3	27	128.5	105-153	2.20
4	24	139.4	124-155	1.90
5	19	151.8	132-166	4.21
6	19	168.3	144-187	2.35
7	14	179.4	160-201	3.08
8	5	191.4	174-203	4.82
9	7	213.1	193-230	5.05
10	3	210.7	185-235	14.45
11	4	202.5	195-210	3.23
12	1	224.0	224-224	
13	1	229.0	229-229	

Age_Females	n spines	Mean LJFL	LJFL range	Std. Error
1	13	81.8	71-92	1.46
2	25	103.3	75-127	2.62
3	29	123.7	103-149	2.14
4	42	140.7	118-176	2.04
5	22	157.3	135-200	5.23
6	29	171.7	150-210	3.03
7	17	185.1	167-208	2.79
8	18	195.9	170-220	3.60
9	13	212.1	194-248	3.97
10	11	222.2	195-245	7.39
11	6	228.7	217-250	4.59
12	3	238.3	227-244	5.67
13	3	270.0	253-294	12.34

Table 3. Parameter estimates for the standard von Bertalanffy for Pacific swordfish (n= 167 males and 234 females).

Growth Parameters	Standard von Bertalanffy Male	Female
L_∞	271.3926	376.3712
k	0.121777	0.070142
t0	-1.543204	-2.162656

Table 4. Predicted LJFL (low jaw fork lengths in cm) at age for swordfish from studies in the Atlantic, Mediterranean and Pacific.

	Ehrhardt et al., 1992		Arocha et al., 2003		Tserpes and Tsimenides, 1995	Young and Drake, 2004		Sun et al., 2002		This work	
AGE	N Atlantic		N Atlantic		East Mediterranean	Australian Pacific		Taiwan Pacific		North Pacific	
	M	F	M	F	All	M	F	M	F	M	F
1	89.7	89.8	109.0	109.9	89.1	73.0	75.4	88.6	90.4	72.3	74.9
2	117.0	118.9	128.7	131.6	114.9	91.4	93.9	115.0	116.2	95.1	95.3
3	137.3	142.9	140.1	144.1	134.2	108.4	109.5	133.8	136.5	115.3	114.3
4	153.4	161.3	151.9	160.3	150.5	121.5	124.4	145.2	150.4	133.2	132.1
5	168.9	177.2	159.6	173.1	162.4	133.1	136.3	154.4	162.9	149.1	148.6
6	181.8	189.6	167.7	186.2	174.4	145.7	150.3	161.4	175.3	163.1	164.1
7	195.3	204.4	178.8	199.4	186.8	158.1	160.3	167.8	186.4	175.5	178.4
8	206.1	214.7	187.0	203.5	198.3	166.5	172.0	176.9	195.8	186.5	191.9
9			194.3	213.6	199.4	175.6	175.0	185.2	204.6	196.2	204.4
10			200.0	227.4		176.0	191.7	191.6	214.2	204.8	216.0
11			205.0	238.4		180.6	196.0		220.6	212.5	226.9
12			246.0	244.8		189.8	208.6		226.6	219.2	237.0
13				235.0		196.6	214.5			225.2	246.4
14				239.5		195.0	219.4				
15				257.0			224.9				
16				262.0		210.0	224.2				

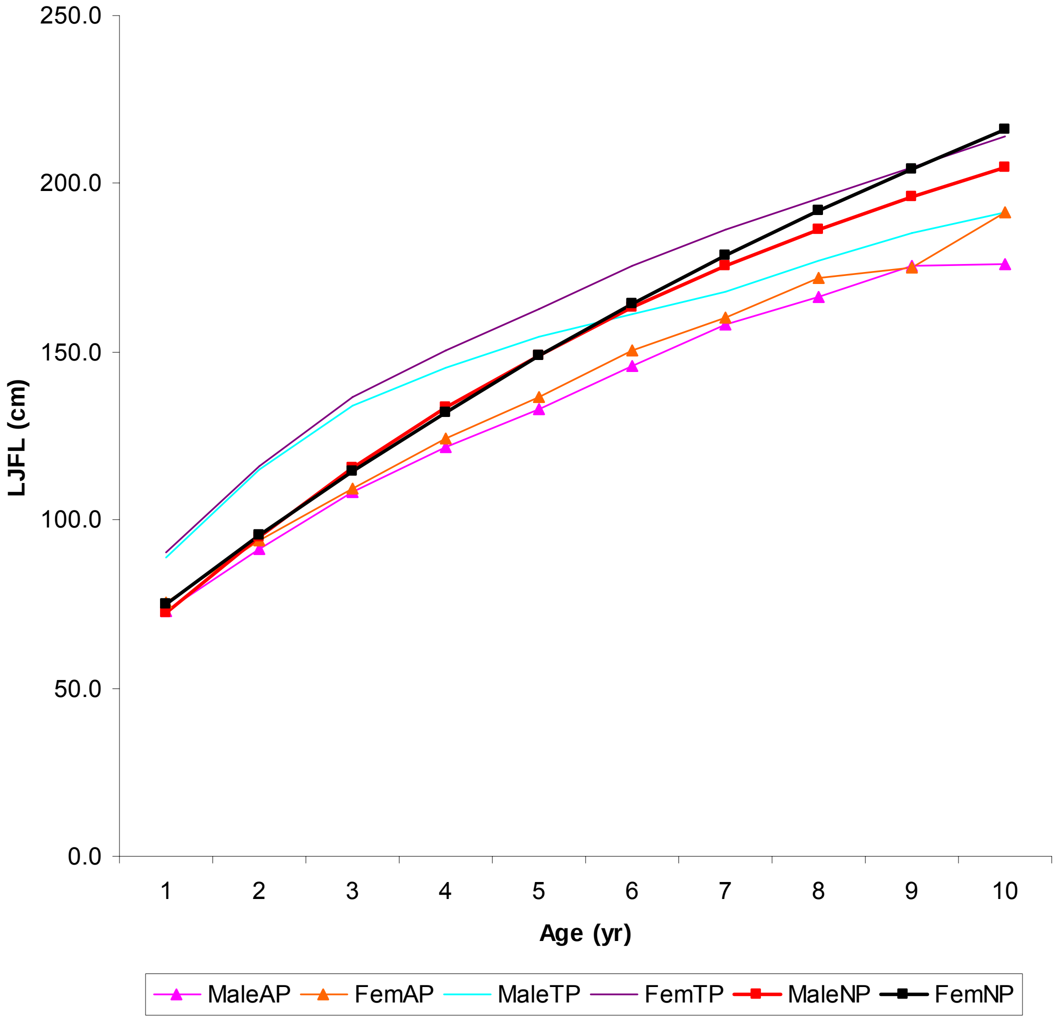

Figure 1. Growth curves by sexes for Pacific Ocean. AP: Australian Pacific; TP: Taiwan Pacific; NP: North Pacific (this document).

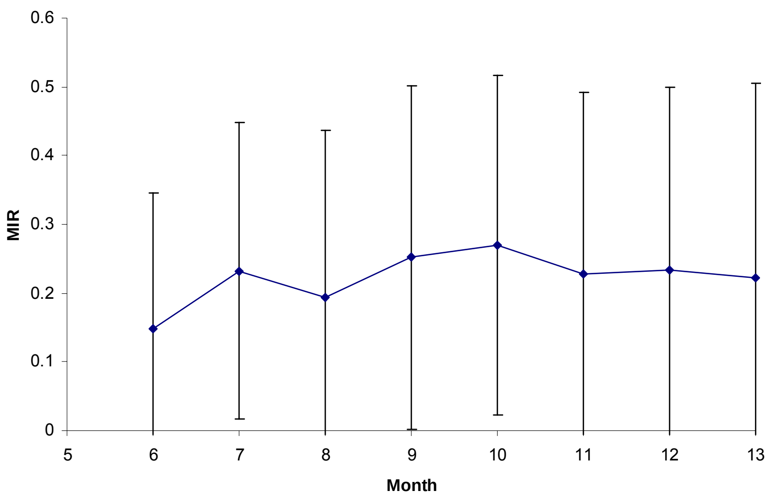

Figure 2. Monthly means of marginal increment ratio (MIR) of combined sexes and all ages combined.

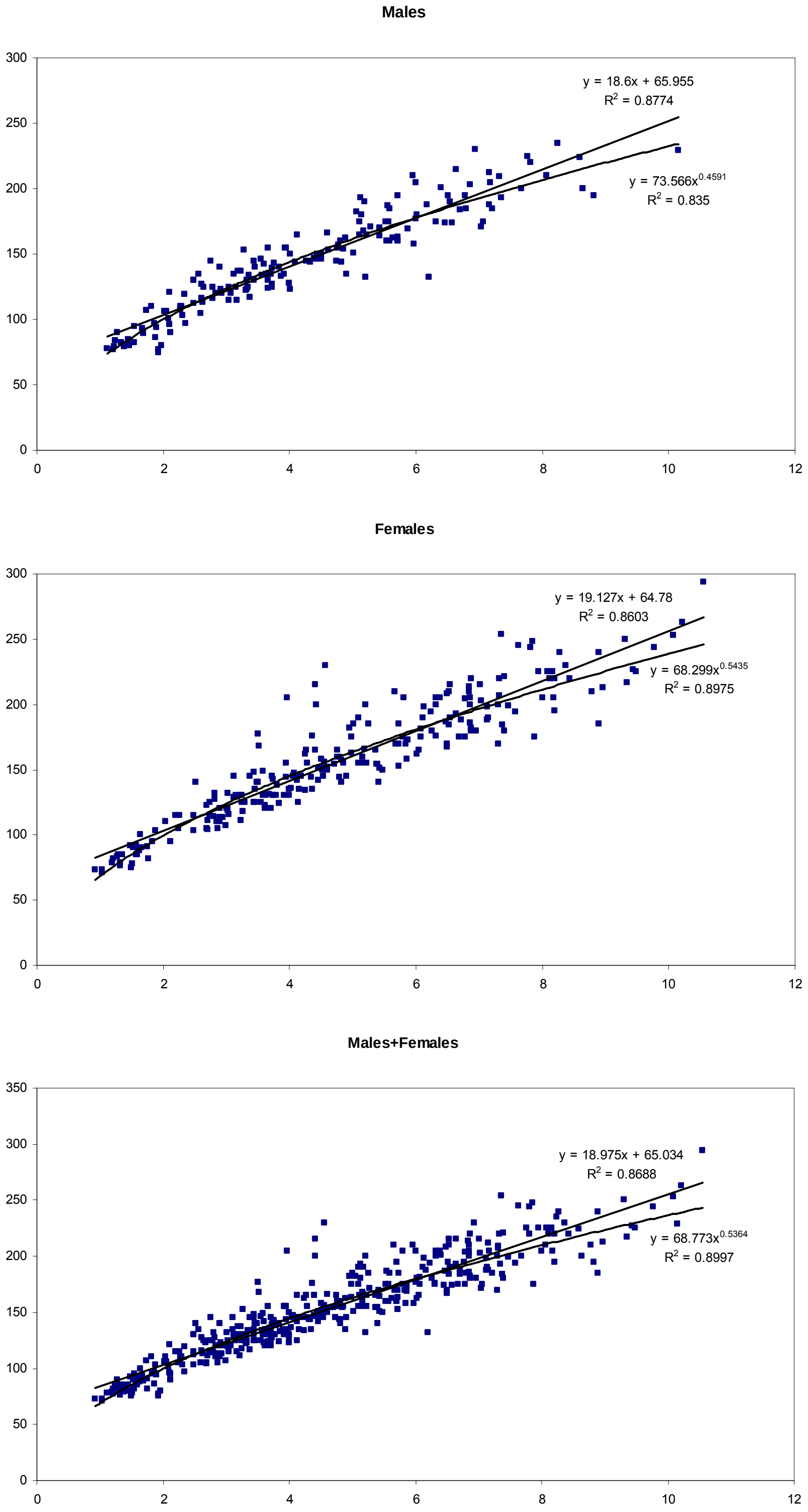

Figure 3. Relationship between LJFL and anal spine radius for male, female and both sexes swordfish from North Pacific Ocean.