AGEING OF SWORDFISH, *XIPHIAS GLADIUS* LINNAEUS, 1758, FROM THE AZORES, USING *SAGITTAE*, ANAL-FIN SPINES AND *VERTEBRAE*.

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ARQUIPÉLAGO

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Age was estimated from 155 calcified structures (*sagittae*, anal-fin spines and *vertebrae*) collected from swordfish, *Xiphias gladius*, caught in the Azores. The ease of collection and processing, legibility and precision among the structures were compared, to determine the most useful for age determination. Statistically significant linear relationships were obtained between the size of the structures, ring counts and lower jaw fork length. In 94.4% of the spine sections, 45% of the otoliths and 27.8% of the vertebral *centra* the replicate "age" estimates agreed in 2 out of 3 readings. The error of "age" estimates, as expressed by the coefficient of variation, varied between a *maximum* of 22.8% in *vertebrae* and *minima* of 8.9% and 7.5% in otoliths and spine sections respectively. A complex 1:2:3 ratio was derived for the relationship between the "ages" estimated from spine sections, *sagittae* and vertebral *centra*. Although growth seems to vary seasonally, marginal increment analyses could not establish the time of ring formation in any of the structures. We recommend second anal-fin spine sections for age determination of swordfish. Therefore, this structure should continue to be used in routine age and growth assessment programs of swordfish.

ESTEVES, EDUARDO, PATRÍCIA SIMÕES, HELDER M. DA SILVA & JOSÉ PEDRO ANDRADE 1995. Determinação de idade em espadarte, *Xiphias gladius* Linnaeus, 1758, dos Açores, usando *sagittae*, espinhas da barbatana anal e *vertebrae*. *Arquipélago*. Ciências Biológicas e Marinhas 13A: 39-51. Angra do Heroísmo. ISSN 0870-6581.

Determinaram-se as idades de espadartes, *Xiphias gladius* Linnaeus 1758, capturados nos Açores a partir de três estruturas ósseas diferentes (*sagittae* esquerdos, 2° espinhos da barbatana anal e vértebras; n=155). Comparam-se estas estruturas em termos de: facilidade de amostragem e processamento; leitura e interpretação de marcas de idade e repetibilidade das estimações de idade. Obtiveram-se relações lineares, estatisticamente significativas, entre as dimensões das peças, o número de anéis contados ("idades" estimadas) e o comprimento mandíbula-furca dos indivíduos. Em 94.4% das secções de espinhos, 45% dos otólitos e 27.8% dos corpos vertebrais, concordaram 2 dos 3 replicados das estimações de "idade". O erro das estimações, expresso pelo coeficiente de variação, variou entre um máximo de 22.8% nas vértebras e mínimos de 8.9% e 7.5% nos otólitos e espinhos, respectivamente. Obteve-se uma relação complexa (1:2:3, espinhos, *sagittae* e vértebras) entre o número de anéis contados ("idades" estimadas) a partir das três estruturas. O crescimento parece variar sazonalmente embora a análise de incrementos marginais não permita estabelecer um "modelo" de deposição de incrementos de crescimento/idade em qualquer das peças. Os resultados obtidos recomendam os espinhos para estudos de avaliação de idade e crescimento de espadarte.

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INTRODUCTION

The swordfish, *Xiphias gladius* Linnaeus 1758, is the most abundant commercial billfish species in the Atlantic, namely in the Macaronesian region. Synopses on the biology of this species are provided in PALKO et al. (1981) and NAKAMURA (1985).

Various methods, based on non-validated criteria, have been used for age determination of swordfish: otoliths (RADTKE & HURLEY 1983; WILSON & DEAN 1983; MEGALOFONOU et al. 1990a), fin spines (BERKELEY & HOUDE 1981, 1983; RIEHL 1984; MEGALOFONOU et al. 1990b; MOREIRA 1991; CHALABI 1993; CHALABI et al. 1994), tag-recapture data (RESTREPO 1990) and length frequency analysis (AZEVEDO 1990; HAIST & PORTER 1993). However, age determination and growth remain controversial, in spite of their importance for fish stock assessment.

Validation studies are time consuming. Meanwhile, age estimations should be compared routinely between structures (BEAMISH & MCFARLANE 1983), thus providing a measure of the (relative) precision and degree of confidence of the interpretations (CASSELMAN 1983), and permitting the selection of the hard part(s) to use regularly in age determination studies (NEILSON et al. 1994).

In this paper, *sagittae*, anal-fin spines and *vertebrae* were evaluated for ease of collection and processing, legibility and interpretation of growth patterns, and the precision of replicate age determination.

MATERIAL AND METHODS

Fish sampling and hard part processing

One hundred and ninety seven swordfish were sampled from scientific cruises onboard R/V "Arquipélago" from the University of the Azores (n=23), and from commercial landings in the Azores (n=174), between October 1992 and August 1994. Data collected for each fish included lower jaw fork length (LJFL to the lowest cm), sex (determined macroscopically, following MIYAKE (1990)) and date of capture. A total of 155 hard parts were removed from the fish sampled.

Labyrinths (n=45) were removed by sawing the fish head 4-5 cm behind the eye-orbits. The first 29 samples were stored dry and the remaining 16 were stored in 96% ethanol. The labyrinths and the otoliths were prepared for analysis following modified methods of WILSON & DEAN (1983) and PRINCE et al. (1986). The labyrinths were immersed in sodium hypoclorite (5-6%) for 9-12 h, and the otoliths were extracted. The otoliths were cleaned with xylene for 12-14 h and 96% ethanol for 24 h, and then stored in labelled plastic vials. The whole *sagittae* were chosen for the analysis because "sectioning" gave poor results. Moreover, they are widely used in most age determination studies of teleost fishes. *Sagittae* were observed under a compound stereoscope, with reflected light over a dark background. Images obtained with a video camera were analysed through image analysis software. The *sagittae* were mounted leaning on to a plasticine lump to expose the concave surface of the antirostra parallel to the focusing plane (LETA & KEIM 1982). The translucent rings were counted and measured with an optical micrometer (to 0.01 mm) from the core to the distal margin of each ring (On) and to the rim of the structure (OR).

The first anal fin was removed (n=78) and stored frozen. Each fin was thawed in boiling water for 5 min and the 2nd spine separated with a knife, cleaned with 96% ethanol and stored dry in labelled plastic bags. Sections, 0.5-1.0 mm thick, were cut near the condyle with a low speed saw, cleaned with 96% ethanol and stored in paper envelopes. Images were analysed using image analysis software in combination with a compound stereoscope equipped with a video camera. The spine radius (SR) and ring radius (Sr) were measured (to 0.01 mm) from the focus (convergence point of the radial striations) to the outer edge of the section and to the distal margin of each translucent ring, respectively (HEDGEPETH & JOLLEY JR. 1983; JOHNSON 1983; RIEHL 1984; PRINCE et al. 1986; EHRHARDT 1994). Narrow translucent rings coupled with broad opaque bands that continued around the entire lobe were presumed to be *annuli* (BERKELEY & HOUDE 1983; EHRHARDT 1994). Double or multiple rings were considered to be the same *annulus* and measured at the margin of the outermost ring (EHRHARDT 1994). Incomplete rings were not considered.

Thirty-two of the most anterior *vertebrae* were cut, transversely, near the occipital region of the *cranium*. The need for extensive dissection of the carcass when sampling other *vertebrae* precluded their use. Vertebral centra were cleaned of excess tissue and frozen. Four different methods of enhancing vertebral cone rings were attempted: direct examination without staining (DU BUIT 1977), "histological procedure" (DAIBER 1960), silver nitrate technique (STEVENS 1975), and red alizarin staining (BERRY 1978). The latter was chosen with some modifications, namely the use of concentrated staining fluid on dorso-ventrally cut *centra*, followed by a final wash with running tap water. The stained rings were counted and measured in the posterior cone, under a compound stereoscope with an optical micrometer using reflected light. The vertebral cone radius (VR) and ring radius (Vn) were measured laterally on the left half, between the focus and the distal margin of the *centra* and between the focus and the rim of each ring, respectively.

Three independent readings, separated at least 15 days apart, were performed by the same reader on each structure. All examinations were made without reference to fish length or prior interpretations.

Data analyses

The relationships between LJFL and structures radius were examined by regression analyses (RICKER 1973; SOKAL & ROHLF 1981; MURTEIRA 1993), considering males, females and unknown sex combined. The null hypothesis that the slope is equal to zero (H_0: $\beta=0$) was tested (SOKAL & ROHLF 1981). A paradigm of the ageing theory is that the number of increments in or on a hard part increases with the growth of the structure (BAGENAL 1974; BROTHERS 1983). To test this assumption, OR, ER and VR were modelled by linear regression against increment counts for each structure and the significance of the regressions values was tested (SOKAL & ROHLF 1981). All statistical inferences were based on a significance level of $\alpha=0.05$.

Direct comparisons of ring counts ("age" estimates) from corresponding hard parts (*sagittae*, anal-fin spine sections and *vertebrae*) were modelled with linear regression, and the slopes were tested to check for significant differences from parity (t-Student test with Ho: b=1, DIXON & MASEY JR. (1966)). In this analysis only females were considered as they represented the majority of the cases (60-77%).

The coefficient of variation (V), index of precision (D) (CHANG 1982) and average percent error (APE) (BEAMISH & FOURNIER 1981) were calculated for each "age group" and structure.

For *sagittae* and *vertebrae*, average "ages" were assigned because of the reduced or non existant agreement between replicate estimates. Exceptions were made to cases where at least two out of three replicate readings agreed.

The marginal increment ratio (*MIR*) was estimated for each specimen and structure according to the equation of HAYASHI (1976):

$$MIR = \frac{(R_t - r_n)}{(r_n - r_{n-1})}$$

, where R*t* is the structure radius and *rn* is the radius of the most recent ring. In order to calculate the MIR for each fish/structure, it was necessary for at least one complete translucent ring to be present. The mean value of MIR was calculated for each month and grouped into a type-year because of the scarcity of data available. *Minimum* values of MIR correspond to the time of opaque ring formation.

Length-at-"age" was back-calculated using Fraser-Lee's linear method (BAGENAL & TESCH

1978; CARLANDER 1981; FRANCIS 1990): $Ln - c = \frac{Sn}{S} * (L - c)$, where Ln is the LJFL at age "n", c is the intercept on the length axis from the geometric mean regression (RICKER 1973) of LJFL on structure radius (OR/VR/ER), Sn is the ring radius, S is the structure radius and L is the LJFL at capture.

Back-calculated and observed LJFL at "age" were compared between "age groups" and among structures using the Wilcoxon Sign Ranked test for paired samples with α=0.05 (CONOVER 1980). The unknown underlying data distribution and the small number of cases justified the use of non-parametrical statistics.

RESULTS

Hard parts and morphometric data were obtained from 197 specimens, ranging in length from 74 cm to 240 cm LJFL.

Table 1 shows the number of *sagittae*, anal fin spine sections and *vertebrae* sampled, processed and analysed. The highest percentage of readable structures was obtained for the spine sections (91%), followed by the vertebral *centra* (56.3%) and the *sagittae* (24.4%). The remaining structures were damaged or illegible and, therefore, were not considered for further analysis.

The relationships between OR, SR, and VR, and LJFL were best described by positive linear equations ($p<0.001$) (Fig. 1). Coefficient of determination (r^2) values were 0.717 for *sagittae*, 0.761 for spine sections and 0.832 for *vertebrae*. Intercept and slope values varied greatly among structures.

All structures analysed revealed growth rings. Three to ten translucent rings were observed on *sagittae antirostra* surface (specimens 126 cm-215 cm LJFL). On spine sections, 0 to 11 rings presumably *annuli* were counted (74-240 cm LJFL). In *vertebrae*, 3 to 24 stained rings, grouped in couples, were enumerated on posterior cones (108-215 cm LJFL) (Fig. 2). Assigned "ages" varied accordingly from 3 to 9, 0 to10, and 6 to 22 "years", in *sagittae*, anal-fin spines and *vertebrae*, respectively.

Table 1

Number of hardparts sampled, processed and analysed (and percentage of total number) for each structure considered in this study.

Structures	Left *sagittae*	Anal-fin spine sections	1st anterior *vertebrae* (posterior cone)
Sampled	45	78	32
Excluded		3 (3.9)	5 (15.6)
Treated	45 (100)	75 (96.1)	27 (84.4)
Damaged	29 (64.4)		9 (18.8)
Illegible	5 (11.1)	4 (5.1)	
Read	11 (24.4)	71 (91)	18 (56.3)

Ring counts increased with hard part growth for each of the structures studied. The relationships were linear and statistically significant ($p<0.001$) with coefficients of determination (r^2) ranging from 0.538 for *vertebrae* to 0.796 for *sagittae* (Fig. 3).

There was a significant positive linear relationship between ring counts (estimated "ages") in *sagittae* and *vertebrae* (r^2=0.961, p=0.003 and n=5), and in *vertebrae* and anal-fin spine sections (r^2=0.432, p=0.020 and n=14). The y-intercepts of these relationships were significantly different from zero ($p>0.05$), and the slopes did not differ from parity (slope=1; $p<0.05$) (Fig. 4).

The calculated values of the index of precision and the mean average percent error are shown in Table 2. Percent agreement between replicate estimates, in two out of three readings, was highest in anal-fin spine sections (94.4%). Lower values were obtained for *sagittae* (45%) and *vertebrae* (27.8%). The coefficient of variation (V) values ranged from 22.8% for stained ring counts in *vertebrae* to 7.5% for anal-fin spine sections and 8.9% for *sagittae*.

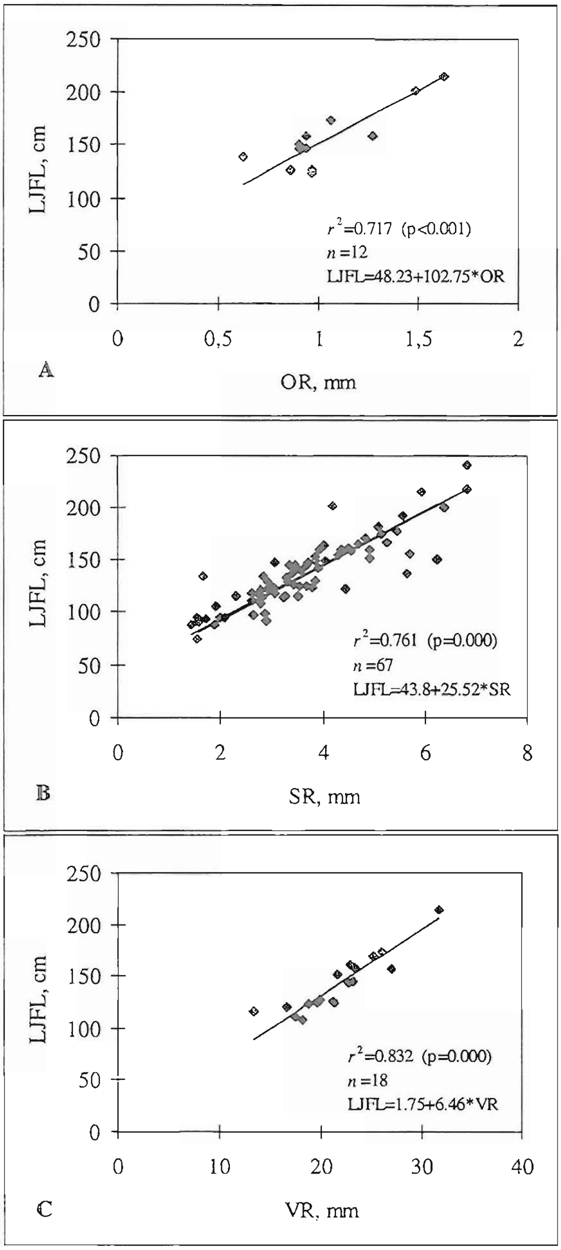

Fig. 1. Relationships between lower jaw fork length (LJFL, cm) and structure radius (OR, SR or VR, mm) for *sagittae* (A), anal-fin spine sections (B) and *vertebrae* (C) of swordfish.

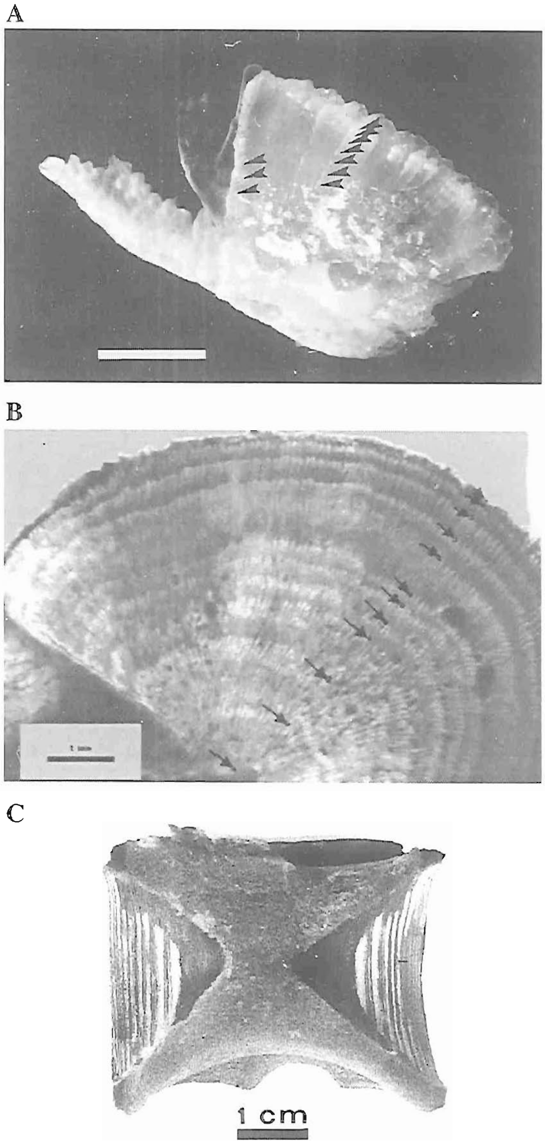

Fig. 2. Digitised images of hardparts sampled from swordfish caught off Azores. (A) left *sagitta antirostrum* from a 215 cm LJFL female (bar=1mm), (B) anal-fin spine section of a 200 cm LJFL female, and (C) vertebral *centra* of a 174 cm LJFL male. Arrows indicate rings quantified for "age" estimation.

Marginal increment ratios estimated for each structure are presented in Fig. 5. Monthly mean of MIR calculated from spine sections reached a *maximum* in August and a *minimum* in October. The values calculated for the other structures varied irregularly throughout the year.

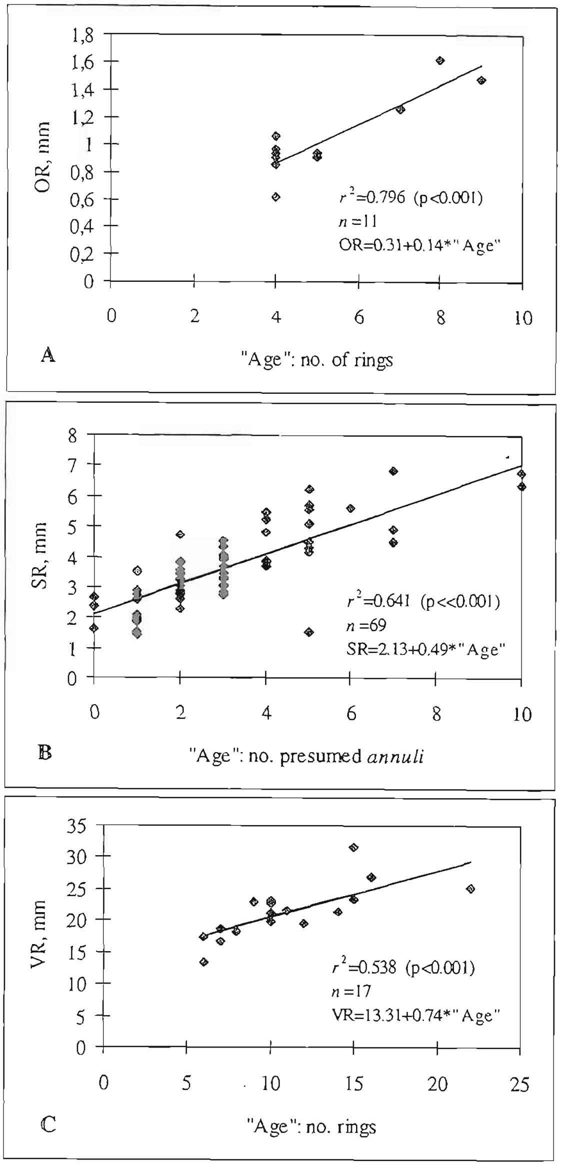

Fig. 3. Relationships between ring counts ("age" estimates) and structure radius (OR, SR and VR) based on (A) *sagittae*, (B) anal-fin spine sections and (C) vertebral *centra* of swordfish.

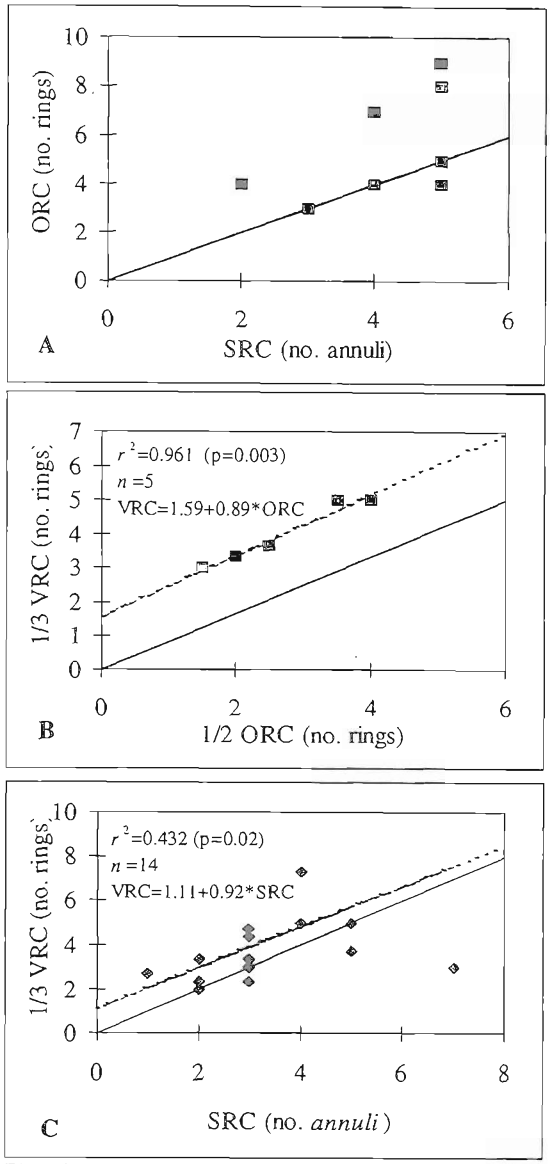

Fig. 4. Regression analysis between corresponding sagittal ring counts (ORC), anal-fin spine sections ring counts (SRC), and vertebral cone ring counts (VRC) for the same swordfish (full line: bisector; dotted line: regression line).

Mean back-calculated LJFL-at-"ages" in each structure were not significantly different from the respective lengths measured at capture (p<0.05). Mean differences increased gradually from 7.68 cm (±3.28 cm) in spine sections to 12.6 cm (±13.69 cm) in *sagittae* and 13.6 cm (± 10.04 cm) in *vertebrae.* Mean back-calculated LJFL based on spine sections were significantly greater (p>0.01) than back-calculated lengths from *sagittae* for all "age classes" (Fig. 6).

Table 2

Summary table of the coefficient of variance (V), index of precision (D), average percent error (APE) and percent agreement (2/3%) for each structure.

Structures	*V mean*	*D (rings) range*	*APE mean*	*2/3% mean*
Sagittae	8.9%	0.2-0.4	12.1%	45.0%
Anal-fin spine sections	7.5%	0.0-0.2	14.5%	94.4%
Vertebrae	22.8%	0.4-2.7	11.9%	27.8%

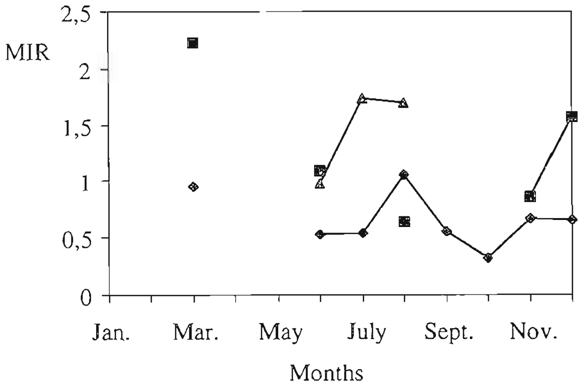

Fig. 5. Mean monthly marginal increment ratio (MIR) for swordfish.

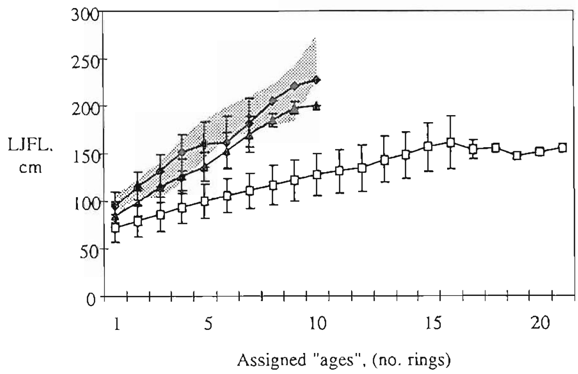

Fig. 6. Mean (±SD) back-calculated LJFL at "age" for Atlantic swordfish *Xiphias gladius* based on *sagittae* (filled triangles), anal-fin spine sections (closed diamonds) and *vertebrae* (empty squares). LJFL range values for each age referred in the literature are represented as an area.

DISCUSSION

The number of specimens sampled was small and the LJFL range restricted when compared to similar studies of swordfish (BERKELEY & HOUDE 1983; RADTKE & HURLEY 1983; RIEHL 1984; EHRHARDT 1992, 1994). The "sample truncation" is considered to be the most important source of error in the estimation of growth parameters and is related to both gear selectivity and cumulative effects of mortality (SMALE & TAYLOR 1987).

In order to reduce the variance of length-at-age, attempts should be made to quantify sex-specific growth patterns (HAIST & PORTER 1993). The number of specimens sexed in the present study precluded this analysis.

The percentages of processed and actually read hard parts (cf. Table 1) reflect the difficulties inheritant in age and growth studies of oceanic pelagic fishes described by CASSELMAN (1983), PRINCE et al. (1991) and NEILSON et al. (1994). RADTKE & HURLEY (1983) rejected 7.9% of the *sagittae* in their study of swordfish from the northwest Atlantic. The minute dimensions of the otoliths and their fragility, the techniques of conservation, extraction and manipulation are probably responsible for the reduced number of *sagittae* actually read. PRINCE et al. (1985) excluded 4.5% of the *vertebrae* of *Thunnus thynnus* sampled and LEE & YEH (1993) analysed 93.1% of the *vertebrae* of *T. alalunga* from south Atlantic. The extraction of the anal fin is relatively easier and the sectioning procedure is standardized in the literature which explains why 91% of the spine sections analysed in the present study were in a readable condition. BERKELEY & HOUDE (1983) and RIEHL (1984) obtained slightly larger percentages of rejected spine sections, 12.7% and 12% respectively.

The strong positive relationships between LJFL and hard part size, and between LJFL and ring counts support the use of these skeletal structures as a source of age and growth information.

The hard parts exhibited growth rings similar to those described in *Istiophorus platypterus* by

Table 3

Summary of lengths-at-age (LJFL, cm) published for Atlantic swordfish, *X. gladius*. Back-calculated LJFL from *vertebrae* obtained in this study were not included because they differ significantly from the remaining lengths. (M - males, F - females, or undetermined sex).

Age	BERKELEY & HOUDE (1983) Anal-fin spine		RIEHL (1984) Anal-fin spine		EHRHARDT (1990, 1992) Anal-fin spine		RADTKE & HURLEY (1983) *Sagittae*		WILSON & DEAN (1983) *Sagittae*		ANÓN. (1989) Tag-Recapture	RESTREPO (1990) Tag-Recapture	AZEVEDO (1990) Lengths frequencies	CHALABI (1993) Lengths frequencies	HAIST & PORTER (1993) Lengths frequencies	ESTEVES et al. (present study) Anal-fin spine	ESTEVES et al. (present study) *Sagittae*
	M	F	M	F	M	F	M	F	M	F							
1	98,9	97,2	106,2	99,3	89,7	89,9	84	73	116,9	122,9	87,1	84,98	88	79,9	100,3	94,1	84,9
2	119,3	119,8	122,9	115,8	117,0	118,9	98	95	123,3	130,6	113,2	124,90	111	99,3	119,9	115,9	98,9
3	135,4	140,9	136,8	130,8	137,3	142,9	110	114	130,2	138,8	137,4	142,23	133	103,3	137,3	131,9	115,1
4	148,5	158,6	148,4	144,4	153,4	161,3	122	131	137,4	147,5	158,4	165,40	152	119,3	152,6	150,8	126,7
5	161,6	174,5	158,1	156,8	168,9	177,2	133	147	145,0	156,8	176,0	184,04	170	142,5	166,2	160,3	135,9
6	172,8	187,6	166.1	168,1	181,8	189,6	143	160	161,5	177,1	190,1	198,48	186		178,1	161,3	152,3
7	180,3	202,2	172,9	178,2	185,3	204,4	153	172	170,4	188,2	201,2	209,37	201		188,7	183,2	169,7
8	185,1	216,2	178,5	187,5	206,1	214,7	161	183			209,8	217,43	215		198,1	205,0	184,7
9			183,1	195,5	234,1	241,6						223,32				221,4	197,6
10					235,3	274,1						227,59				228,4	199,4
11												230,65					
12												232,84					
13												234,41					
Local	Straits of Florida, USA		Northwest Atlantic		Northwest Atlantic		Northwest Atlantic, USA coast		Northwest Atlantic, USA coast		Atlantic Ocean	Atlantic Ocean	EEZ Portugal	EEZ Argelia	Atlantic Ocean	Azores	Azores

RADTKE & DEAN (1981) and PRINCE et al. (1986), and in swordfish by BERKELEY & HOUDE (1983), RADTKE & HURLEY (1983), WILSON & DEAN (1983) and ERHHARDT (1994). Data on *vertebrae* is restricted to the accounts of BERRY (1978) and PRINCE et al. (1985) in *T. thynnus*, JOHNSON (1983) in *Euthynnus alletteratus*, FÉRNANDEZ (1992), LABELLE et al. (1993) and LEE & YEH (1993) in *T. alalunga*, and NEILSON et al. (1994) in *T. atlanticus*. The range of the assigned "ages", given the respective LJFL range, supports the considerable longevity of swordfish reported by RADTKE & HURLEY (1983) and HOEY et al. (1990).

While validation of the temporal meaning of growth increments, was not in the scope of this study, partial verification was achieved. Precision was determined by means of comparisons of age estimates from corresponding hard parts as well as by means of measurement of error in replicate age estimates.

Percent agreement between replicate estimates, which was higher in spine sections when compared with *sagittae* and *vertebrae*, might be related to the clarity of the rings and the expertise of the readers involved in the interpretation of the growth marks.

Many of the percent agreement techniques commonly used in evaluating the precision of a set of age determinations do not evaluate precision equally for all species because these methods do not take into account the number of age classes in the fisheries (BEAMISH & FOURNIER 1981). The coefficient of variation method (CHANG 1982) is not independent of the age estimations and is based on the variances to test for differences, thus appearing well suited for swordfish.

In *sagittae* and spine sections, the values of the coefficient of variation were less than the 10% error limit proposed by POWERS (1983) for oceanic pelagic fishes. On the contrary, APE values for the three structures were higher than 10%. Values of APE calculated for *vertebrae* and *sagittae* are higher than those published for *sagittae* of Atlantic blue marlin, *Makaira nigricans* (HILL et al. 1989; PRINCE et al. 1991), *sagittae* sections of Mediterranean swordfish (MEGALOFONOU et al. 1990a) and *vertebrae* of Atlantic tunas, *T. thynnus* and *T. alalunga* (PRINCE et al. 1985; LABELLE et al. 1993), reflecting the number of cases in which only two out of three replicate readings agreed.

A complex 1:2:3 ratio was derived for the relationship between ring counts on spine sections, *sagittae* and *vertebrae*, respectively (c.f. Fig. 4). RIEHL (1984) attributed the 1:2 relation obtained between ages estimated from spine sections and *sagittae* of swordfish to the deposition on *sagittae* of an annual spawning mark. Nonetheless, WILSON & DEAN (1983) obtained 89% agreement between age estimates using *sagittae* and spine sections of Atlantic swordfish. BECKETT (1974) described otoliths as being too small for analysis. OVCHINNIKOV (1970) considered that otoliths were not sufficiently clear and did not include annual growth bands. The relation between ring counts in *vertebrae* and the other hard parts analysed may be explained by the deposition, in *vertebrae*, of both non-annual growth rings (BERRY 1978; LABELLE et al. 1993) and/or spawning mark(s). BECKETT (1974) stated that bands observed on vertebral centra can not be interpreted.

The pattern of mean monthly MIR based on swordfish spine sections seems to agree with the variation described by BERKELEY & HOUDE (1983), for the Straits of Florida, EHRHARDT (1992), for the northwestern Atlantic, and TSERPES & TSIMENIDES (1995), for the eastern Mediterranean, with a *maximum* in the Summer and *minima* in the Spring and Fall. However, the scarcity and discontinuity of the data analysed in this study do not clarify previous interpretations.

Although not statistically different, back-calculated LJFL-at-"age" tend to be higher than the respective lengths measured at capture. This is, at least partially, the result of the occurrence of some growth between time of ring formation and capture. The differences between back-calculated LJFL based on *sagittae* and spine sections might be related to obvious differences in hard part dimensions and shapes, namely the minute size and curvature of the otoliths.

However, one cannot rule out the possibility that the differences are artefacts resulting from small sample sizes. In *vertebrae*, smaller growth increments resulted in smaller back-calculated LJFL.

LJFL back-calculated from *sagittae* and spine sections lie within the lengths range referred to in the literature (Table 3). Differences are probably due to deficiencies/errors/scarcity of the biological material available or even to racial characteristics of the specimens (JOHNSON 1983). In general, the similarity between the results of this study and those published by other authors for distinct geographic regions may confirm the north Atlantic single stock hypothesis suggested by ALVARADO BREMER et al. (1994).

Comparatively, anal-fin 2nd spines are relatively easier to collect and prepare, with sections including clear and interpretable rings. The precision of "age" estimates is acceptable, suggesting that spines sections should be used for swordfish age and growth studies. One possible disadvantage, which has been reported for swordfish (BERKELEY & HOUDE 1983; RIEHL 1984; EHRHARDT 1992; TSERPES & TSIMENIDES 1995), is the loss of the first one or two *annuli* on spine sections of older fish as a result of internal matrix vascularization. In the present study, it was not noticeable. Instead specimens with up to 3 rings had the internal matrix of the spine sections "globulised", which might be related to the emptying of lipidic globules during the dry storing.

Otoliths, despite being more difficult to interpret and less precise than the method described here, should now be analysed as sections in order to establish criteria for age determination. The complexity of the external characteristics of the otoliths, the difficulty in identifying the first ring (RADTKE & HURLEY 1983) and the growth of the otolith *rostrum* in two directions (PRINCE et al. 1986) are still important problems to overcome prior to the use of otoliths in Istiophoridae and Xiphiidae.

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