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Research Article

Species catch composition, length structure and reproductive indices of swordfish (*Xiphias gladius*) at Easter Island zone

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ABSTRACT. The species composition, size distribution, and gonadal index (GI) of swordfish (*Xiphias gladius*) are reported from catches obtained by longliners in the zone of Easter Island in the southeastern Pacific. Five cruises were made during the summer season between 2001 and 2006 completing a total of 150 fishing sets. A total of 3,781 fish belonging to 24 species were registered, of which 17 were commercial and 6 were bycatch. Of the total, 44.1% were swordfish, 28.3% sharks, 12.1% marlins, 8.4% tunas and 7.1% other teleosts. Amongst the sharks the most important species was the blue shark (*Prionace glauca*, 16.5%) followed by the brown shark (*Carcharhinus* spp., 6.9%). Amongst the tunas and istiophorids, striped marlin (*Tetrapturus audax*, 8.0%) and yellowfin tuna (*Thunnus albacares*, 4.9%) were also important (≥ 4% in number). The number of units by species, the nominal yield in number and weight and the gutted average weight are reported in addition to size statistics. The population structure of swordfish was dominated by males and differences in the average length between sexes were not found. Individuals with high values of GI were observed during every survey, mainly during December-February which suggests a reproductive area for this species. The blue shark showed a predominance of males, and differences in the average length between sexes were observed, possibly due to a spatial and temporal segregation.

Keywords: *Xiphias gladius*, swordfish, gonadal index, species composition, Easter Island, southeastern Pacific.

Composición de especies, estructura de tallas e índices reproductivos de pez espada (*Xiphias gladius*) en la zona de isla de Pascua

RESUMEN. Se reportan la composición de especies, estructura de talla, y el índice gonádico (IG) de pez espada (*Xiphias gladius*), desde capturas obtenidas por embarcaciones palangreras en la zona de isla de Pascua en el Pacífico suroriental. En el período estival entre 2001 y 2006, se realizaron cinco cruceros completando un total de 150 lances de pesca. Se registró un total de 3.781 peces pertenecientes a 24 especies, de las cuales 17 fueron comerciales y seis incidentales. Del total, 44,1% fue pez espada, 28,3% tiburones, 12,1% marlines, 8,4% atunes y 7,1% otros teleósteos. Entre los tiburones, la especie más relevante fue el tiburón azulejo (*Prionace glauca,* 16,5%), seguido por el tiburón jaquetón (*Carcharhinus* spp., 6,9%). Entre los atunes e istiofóridos, el marlín rayado (*Tetrapturus audax*, 8,0%) y el atún aleta amarilla (*Thunnus albacares*, 4,9%) fueron también importantes (≥ 4% en número). Se reporta el número de ejemplares por especie, su rendimiento nominal en número y peso, y el peso promedio eviscerado, además de los estadísticos descriptivos de talla. La estructura poblacional de pez espada estuvo dominada por machos y no se registraron diferencias en las tallas medias entre sexos. Se observaron ejemplares con altos valores de IG durante todos los cruceros, principalmente durante diciembre-febrero, lo que sugiere un área reproductiva para esta especie. El tiburón azulejo mostró una predominancia de machos, y se observaron diferencias en las tallas medias entre sexos, posiblemente debido a una segregación espacial y temporal.

Palabras clave: *Xiphias gladius*, pez espada, índice gonádico, composición de especies, isla de Pascua, Pacífico sureste.

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INTRODUCTION

The early Chilean swordfish fishery (1930-1985) consisted of an artisanal harpoon fleet that operated mainly off the country's northern and central coasts (Barbieri *et al*., 1990). The following years saw the introduction of gillnets and the use of larger, more automated vessels, which permitted fishing between 27º and 40ºS within the Economic Exclusive Zone (EEZ). According to Barbieri *et al*. (1998), as of 1989, artisanal landings decreased in conjunction with the rising importance of the industrial fleet, which has longer vessels and mechanized operating systems for fishing and freezing the catches. This fleet relies on surface longlines; these are lines with hooks and live bait that are suspended from the surface and can reach up to 70 km in length (Barbieri *et al*., 1998; Ward *et al*., 2000; Yáñez *et al*., 2003).

The swordfish harpoon fishery was largely seasonal and the fishing season off northern and central Chile lasted only a few months. However, the implementation of gillnets and the use of satellite sea surface temperature images for seeking out fishing zones prolonged the fishing season through September-October of each year. Likewise, the industrial longline fleet, whose fishing trips last up to two months, extended the fishing season until November and December and expanded the fishing zone beyond the EEZ, reaching up to 800 nm from the coast (Barbieri *et al*., 1998). At present, the industrial fleet halts activities in summer due to low yields in the traditional fishing zones off the Chilean coast. Nonetheless, the coinciding interests of private businesses and government in some research projects have encouraged some companies with freezer vessels to explore the oceanic area around Isla de Pascua (Easter Island) in late spring and summer in search of new fishing zones and yields that would allow these vessels to operate year-round.

Regarding other oceanic areas with active swordfish fisheries (Ovchinnikov, 1970; Beckett, 1974; Palko *et al*., 1981; De Metrio *et al*., 1989; Ward & Elscot, 2000), very little is known about the swordfish fishery in the southeastern Pacific in terms of both the species present and vulnerable to the fishing gear as well as their relative abundances and biological parameters. With the exception of the works done using information from the Japanese tuna fleet (Shingu *et al*., 1974; Miyabe & Bayliff, 1987; Nishikawa & Shimizu, 1991; Uosaki & Bayliff, 1999; Okamoto & Bayliff, 2003), or evaluation studies done mainly by multinational organisms (Bartoo & Coan, 1989; Joseph *et al*., 1994; Hinton & Deriso, 1998; Hinton & Bayliff, 2002; Hinton *et al*., 2005), no background information is available on the swordfish fishery in the open ocean off Chile. A study done by Zárate (1997) identified a possible swordfish reproduction zone in the southeastern Pacific in the area surrounding Isla de Pascua Nonetheless, as this area is not usually visited by commercial Chilean vessels, the species catch composition, population structure, and reproductive information required to validate the hypothesis of swordfish reproduction in this area are not known.

For the conservation of highly migratory species exploited in international waters, it is important to have updated biological-fishery information for managing fisheries such as that of swordfish. Therefore, the objectives of the present study were to characterize the catches and yields of longline swordfish vessels and the reproductive aspects of the target species, in the waters surrounding Isla de Pascua and Isla Salas y Gómez, where exploratory campaigns were carried out between 2001 and 2006.

MATERIALS AND METHODS

The study area included the fishing zone of the EEZ and the high seas adjacent to Isla de Pascua and Isla Salas y Gómez (15º-35ºS; 90º-120ºW). This area was prospected during five summertime campaigns from 2001 to 2005-2006 (Fig. 1). Each fishing campaign was carried out by an industrial longline freezer vessel (Table 1). American-type surface longlines (Florida style) were used; these are horizontal longlines in which a mother line (polyamide monofilament) is suspended by buoys at the surface; 5 monofilament gangions with 60-75 g swivel and balanced Mustad-type hooks (9/0) are placed at regular intervals (40-50 m) between each buoy. Squid (*Illex argentinus*) was

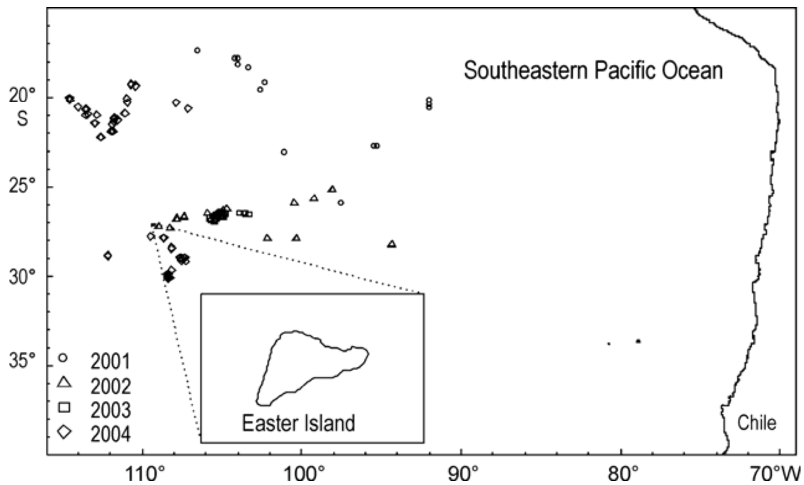

Figure 1. Spatial distribution of the fishing sets in Easter Island area between 2001 and 2006.

Figura 1. Distribución espacial de los lances de pesca realizados en la zona de isla de Pascua entre 2001 y 2006.

Table 1. Period prospecting, effort and total catch for each cruise to the area of Easter Island.

Tabla 1. Período de prospección, esfuerzo desplegado y captura total obtenida en cada campaña a la zona de isla de Pascua.

		Cruise (year)				
		2001	2002	2003	2004	2005-2006
Season		Jan-Mar	Jan-Feb	Jan-Feb	Oct-Dec	Dec-Feb
Effort	Nº sets	22	20	24	38	46
	Nº hooks	30,910	24,481	29,193	31,710	38,766
Total catch	Nº specimens	428	524	536	951	1342
	Weight (kg)	19,168	19,018	19,635	36,175	55,503

the main bait used, along with chemical lights (lightsticks) for visual attraction. Information on the operational regime was recorded for each set, that is, the position and time of setting and retrieval, and the number of hooks used. In the 2002 and 2004 campaigns, the effective catch depth (m) and temperature (ºC) were recorded using MICREL P2T600 sensors that were configured to record the variables every 30 s throughout the entire fishing period.

All the ichthyofauna caught was identified to the species level using FAO keys and manuals (Collette & Nauen, 1983; Compagno, 1984a, 1984b; Nakamura, 1985) and were then recorded (census sampling). The eviscerated weight of the species of commercial interest was determined on industrial scales or, in their absence, with conversion tables based on the length of the specimen. In order to determine the relative importance of the target species and bycatch, we calculated the nominal yield in number of individuals and eviscerated weight (kg) for every 1,000 hooks set (ind or kg 1,000 hook^{-1}). In order to compare the nominal swordfish yield between each of the campaigns carried out (years), a one-way analysis of variance was performed (ANOVA).

For swordfish and marlins, the length was measured (rounded to the lowest centimeter) from the lower jaw to the fork of the caudal fin (LJFL), whereas for tuna and teleost fishes, the fork length (FL) was recorded. In the case of the sharks, the length was measured from the nose to the fork of the caudal fin (FL). Histograms of frequency were obtained for the target species and most frequent bycatch species (≥ 4% in number). One-way ANOVA was used to compare the average sizes of both swordfish and blue sharks per campaign and sex. For swordfish, the sex was determined through macroscopic observation of the gonads, whereas in the elasmobranchs, it was established by the presence of gonopods. The sex ratio of the swordfish was determined as the percentage of females with respect to the total sexed specimens. The female gonads were weighed *in situ* using a scale with precision to the gram; for specimens over the size of first sexual maturity (165 cm LJFL; Zárate, 1997), the gonadic index (GI) was calculated using the following expression, modified from Kume & Joseph (1969):

$$IG = \left(\frac{w}{LMIH^{3}} \right) \cdot 10^{4}$$

where *w* corresponds to the weight of the gonad (g) and LJFL to the lower jaw-fork length (cm). The calculations were done for each specimen, with stratified results per year and month.

RESULTS

Spatially, the fishing activities of the five campaigns covered the entire study area, with certain clusters of sets to the east and northwest of Isla de Pascua (Fig. 1). A total of 150 fishing sets were completed, in which 155,060 hooks were set. The number of hooks per set ranged from 320 to 1,800, with an average (standard deviation; SD) of 1,033.7 (SD = 323.6). Information registered by sensors during 44 fishing sets (29%) indicated that the effective catch depth oscillated between 34.2 and 176.8 m (average = 54.7 m; SD = 21.8), and an average water temperature of 21.8ºC (SD = 1.8ºC) in a range of 15.8 to 25.4ºC.

In total, 3,781 fish were caught: 1,667 (44.1%) were swordfish, 1,071 (28.3%) sharks, 456 (12.1%) marlins, 318 (8.4%) tuna, and 269 (7.1%) other teleosts. Of the sharks, the most important species was the blue shark (*Prionace glauca*) (n = 622; 16.5% of the total catch), followed by the brown sharks (*Carcharhinus* spp.) (n = 262; 6.9%). Among the elasmobranchs, the observers also identified the pelagic stingray (*Pteroplatytrygon violacea*) and the cookie-cutter shark (*Isistius brasiliensis*). These individuals were immediately discarded and, thus, it was not possible to include them in the totals. Of the tunas and istiophorids, the striped marlin (*Tetrapturus audax*) (n = 301; 8.0%) and the yellowfin tuna (*Thunnus albacares*) (n = 185; 4.9%) were the most important species. Table 2 shows the species catch composition and nominal catch rates in number and weight.

The nominal fishing yield for all species reached 964.1 kg · 1,000 hook^{-1} (24.4 ind · 1,000 hook^{-1}), with the swordfish having the greatest total yield (587.9 kg 1,000 hook^{-1}; 10.8 ind · 1,000 hook^{-1}), followed by the blue shark (106.4 kg · 1,000 hook^{-1}; 4.0 ind · 1,000 hook^{-1}), and the striped marlin (64.6 kg · 1,000 hook^{-1}; 1.9 ind · 1,000 hook^{-1}) (Table 2). No significant differences were observed in the 2001 to 2003 swordfish yields (ANOVA, $F_{2,63} = 1.55$; $p = 0.22$). On the other hand, during the 2004 and 2005-2006 campaigns, although the yields were very similar, they differed from the results obtained in previous years, probably due to the experience accumulated in the previous campaigns.

The total number of specimens measured in all the campaigns reached 3,528, with swordfish constituting 1,816 (51.5%). The swordfish catches were mostly male, with a global sex ratio of 40.1% females. The sex ratio at size (Fig. 2) indicated a predominance of males to 255 cm LJFL; from this size on, females predominated. No differences were observed in the average sizes of swordfish by sex (ANOVA, $F_{1,1.744} = 1.99$; $p = 0.16$). This tendency was maintained in all seasons except for the campaign done between December 2005 and February 2006, in which the average size was greater for the females (ANOVA, $F_{1,464} = 9.91$; $p < 0.01$). When the average sizes were grouped by sex and compared annually, significant differences were found (ANOVA, $F_{4,1.741} = 10.35$; $p < 0.01$), with catches of larger specimens mostly in 2005-2006. The range of grouped sizes fluctuated between 75 and 325 cm LJFL, with an average of 170.2 cm (SD = 38.5) (Table 3). The size structure (Fig. 3a) was relatively symmetrical and multimodal, with the principle modes centered on 150 and 175 cm LJFL in males (Fig. 3b) and 145 and 165 cm in females (Fig. 3c). Male blue sharks were predominant in most seasons, with a global sexual proportion of 43.1% of females. Differences were observed in the average sizes between sexes (ANOVA, $F_{1,559} = 221.06$; $p < 0.001$), with averages 223.1 cm FL (males) and 186.0 cm FL (females). For males, the FL varied between 115 and 278 cm (n = 319) and for females between 105 and 275 cm (n = 242). The size frequency histogram (Fig. 3d) showed three main modes: mostly females at 175 cm (Fig. 3f) and mostly males at 210 and 260 cm (Fig. 3e). It should be pointed out that females showed exclusive predominance up to 195 cm, after which the males predominated. For striped marlin, the average LJFL was 215.0 cm (SD = 24.5; n = 227), ranging from 119 to 319 cm. A leptokurtic frequency distribution was observed, with a mode centered on 210 cm LJFL (Fig. 4a). The average size of the brown sharks

Table 2. Catch, nominal yield and average eviscerated weight of the species retained during the fishing trips to the study zone.

Tabla 2. Captura, rendimiento nominal y peso eviscerado promedio de las especies retenidas durante los viajes de pesca a la zona de estudio.

Common name	Scientific name	Catch				Catch rate		Average eviscerated weight (kg)
		Number	(%)	Weight (kg)	(%)	(kg · 1.000 hooks^{-1})	(ind. · 1.000 hooks^{-1})	
Swordfish	*Xiphias gladius*	1,667	44.1	91,155	61.0	587.9	10.8	54.7
Blue shark	*Prionace glauca*	622	16.5	16,502	11.0	106.4	4.0	26.5
Striped marlin	*Tetrapturus audax*	301	8.0	10,012	6.7	64.6	1.9	33.3
Brown sharks	*Carcharhinus* spp.	262	6.9	8,106	5.4	52.3	1.7	30.9
Yellowfin tuna	*Thunnus albacares*	185	4.9	4,408	2,9	28.4	1.2	23.8
Shortfin mako shark	*Isurus oxyrinchus*	153	4.0	9,311	6.2	60.0	1.0	60.9
Dolphinfish	*Coryphaena hippurus*	127	3.4	666	0.4	4.3	0.8	5.2
Shortbill spearfish	*Tetrapturus angustirostris*	103	2.7	1,236	0.8	8.0	0.7	12.0
Bigeye tuna	*Thunnus obesus*	83	2.2	3,050	2.0	19.7	0.5	36.7
Black oilfish	*Lepidocybium* sp.	51	1.3	363	0.2	2.3	0.3	7.1
Albacore tuna	*Thunnus alalunga*	50	1.3	963	0.6	6.2	0.3	19.3
Wahoo	*Acantocybium* sp.	45	1.2	402	0.3	2.6	0.3	8.9
Black marlin	*Makaira indica*	43	1.1	1,300	0.9	8.4	0.3	30.2
Oilfish	*Ruvettus* sp.	30	0.8	215	0.1	1.4	0.2	7.2
Thresher sharks	*Alopias* spp.	29	0.8	1,000	0.7	6.4	0.2	34.5
Opah	*Lampris* sp.	16	0.4	247	0.2	1.6	0.1	15.4
Sailfish	*Istiophorus* sp.	9	0.2	375	0.3	2.4	0.1	41.7
Porbeagle shark	*Lamna nasus*	5	0.1	188	0.1	1.2	0.0	37.6
	Total	3,781	100	149,499	100	964.1	24.4	

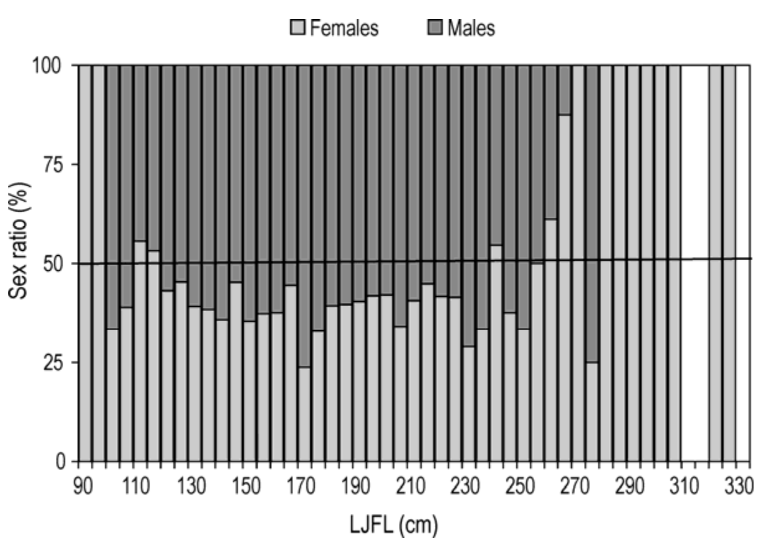

Figure 2. Sex ratios at swordfish size (percentage of females). LJFL: lower jaw to the fork of the caudal fin.

Figura 2. Proporción sexual a la talla de pez espada (porcentaje de hembras). LJFL: longitud desde la mandíbula inferior a la horquilla de la aleta caudal.

Table 3. Descriptive length statistics of the main species captured in the study area. LJFL: lower jaw to the fork of the caudal fin.

Tabla 3. Estadísticos descriptivos de talla de las principales especies capturadas en el área de estudio. LJFL: longitud desde la mandíbula inferior a la horquilla de la aleta caudal.

		LJFL (cm)				
Common name	Scientific name	Minimun	Maximun	Mean	Standard deviation	n
Yelowfin tuna	*Thunnus albacares*	65	167	119.8	27.5	191
Albacore tuna	*Thunnus alalunga*	76	135	103.4	11.4	52
Black oilfish	*Lepidocybium* sp.	56	146	108.5	23.7	44
Bigeye tuna	*Thunnus obesus*	72	201	126.8	29.1	81
Dolphinfish	*Coryphaena hippurus*	80	135	99.4	13.7	57
Black marlin	*Makaira indica*	125	295	211.5	29.7	42
Striped marlin	*Tetrapturus audaz*	119	319	215.0	24.5	227
Shortbill spearfish	*Tetrapturus angustirostris*	150	263	170.1	21.3	49
Shortfin mako shark	*Isurus oxyrinchus*	97	308	210.4	34.1	166
Porbeagle shark	*Lamna nasus*	180	220	200.0	28.3	2
Swordfish	*Xiphias gladius*	75	325	170.2	38.5	1,816
Opah	*Lampris* sp.	98	106	102.3	4.0	3
Sailfish	*Istiophorus* sp.	195	227	210.6	13.1	7
Wahoo	*Acantocybium* sp.	105	178	141.2	19.0	40
Blue shark	*Prionace glauca*	50	278	206.4	35.0	580
Brown sharks	*Carcharhinus* spp.	119	263	182.6	30.0	140
Thresher sharks	*Alopias* spp.	148	235	190.9	21.6	31

was 182.6 cm FL (SD = 30.0; n = 140) with a somewhat symmetrical and multimodal frequency distribution; the principle mode was 170 cm FL (Fig. 4b). The sexual proportions did not differ, with 49.6% (n = 139) being female. The yellowfin tuna averaged 119.8 cm FL (SD = 27.5, n = 191), ranging in size from 65 to 167 cm, with the principle mode of the size frequency distribution centered on 140 cm FL (Fig. 4c). The last highly represented species in the catches was the shortfin mako shark (*Isurus oxyrinchus*), which presented an average FL of 210.4 cm (SD = 34.1; n = 166), and a size structure with principle modes at 160 and 230 cm FL (Fig. 4d). As with *P. glauca*, the sexual proportion favored males, with 30.9% females (n = 152).

A total of 670 females were sampled for a reproductive analysis of the swordfish. Of these, 343 corresponded to specimens longer than the size at first sexual maturity. The maximum GI values were over 7 in all the campaigns, although the indicators of centrality for the annual GI (medians) were not very high (0.6-1.7) (Fig. 5a). On a monthly scale (Fig. 5b), the behavior of the indicator was similar, with the medians ranging between 0.6 in November (n = 72) and 2.7 in March (n = 5). The greatest individual observations of GI were concentrated from December to February and then declined in March (Fig. 5b).

DISCUSSION

Relatively few publications on longline pelagic fisheries have covered the species catch composition. In the five fishing campaigns studied herein, 23 fish species were caught, of which 17 are considered to be commercial and six incidental. These latter bycatch species were immediately discarded and included the pelagic stingray, the cookie-cutter shark, “barracudas” (*Gempilus* sp. and *Alepisaurus* sp.), an amberjack (*Seriola* sp.), and the skipjack tuna (*Katsuwonus pelamis*). Barría *et al*. (2005) reported the presence of 35 species caught by the Chilean surface longline fishing fleet in 2004 in the traditional fishing zones: 22 teleost fishes, 9 cartilaginous fishes, and 6 species from other

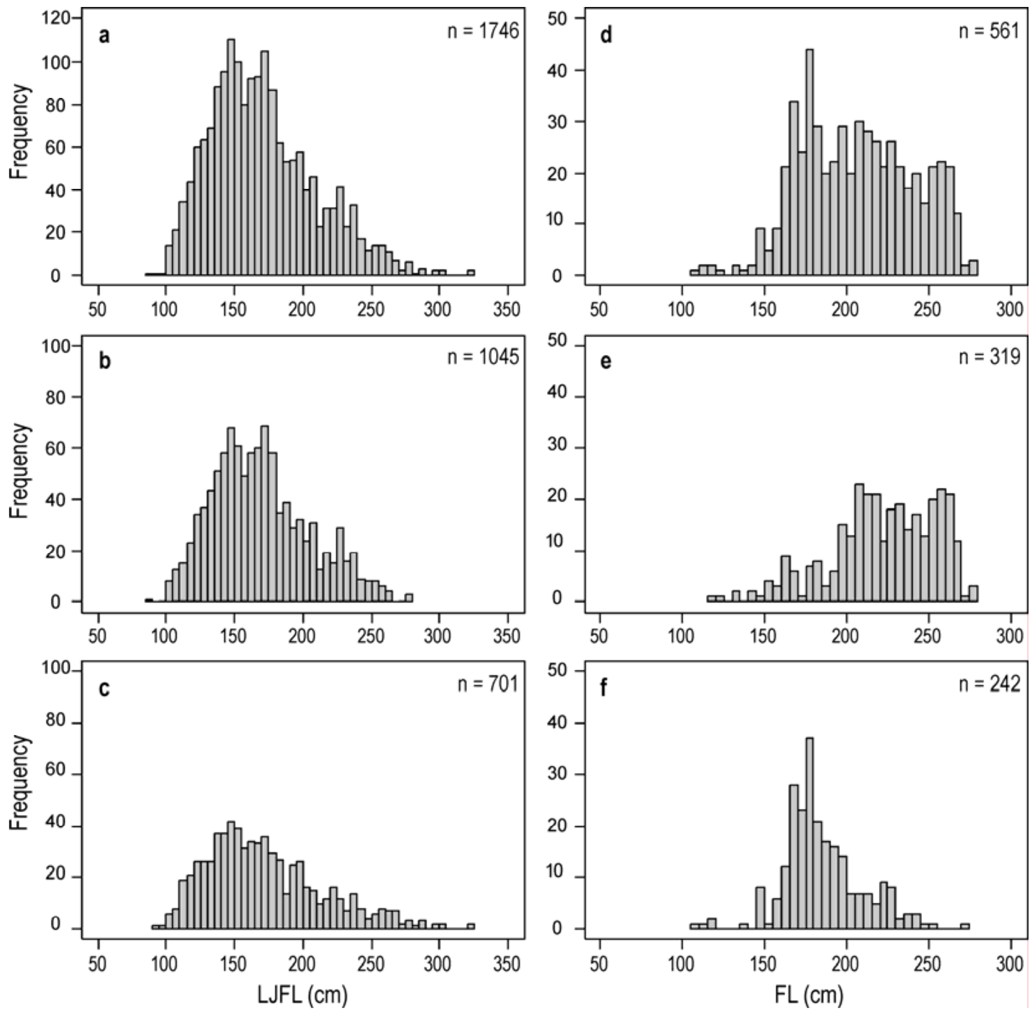

Figure 3. Length-frequency distribution of swordfish: a) both sexes, b) males, c) females, and blue shark: d) both sexes, e) males, f) females. LJFL: lower jaw to the fork of the caudal fin, FL: fork length.

Figura 3. Distribución de frecuencia de tallas de pez espada: a) sexos agrupados, b) machos, c) hembras, y tiburón azulejo: d) sexos agrupados, e) machos, f) hembras. LJFL: longitud desde la mandíbula inferior a la horquilla de la aleta caudal, FL: longitud horquilla.

groups such as cephalopods, mammals, birds, and turtles. The results presented herein show a lower number of species in the oceanic zone off Chile than in the more coastal zone. Nonetheless, these results must be considered carefully since the oceanic fishing effort was significantly lower than that in the common fishing zones. Moreover, it is also possible that the vulnerability of some species could change due to different conditions of the physical environment. In the swordfish fishery of the Atlantic Ocean (Uruguayan EEZ and international waters), 50 species have been recorded: 27 teleost fishes, 15 cartilaginous fishes, and eight other species of birds, mammals, and turtles (Marín *et al*., 1998). On the other hand, landings of the Spanish longline swordfish fishery, as reported by Buencuerpo *et al*. (1998), included 25 species, the most common being the shortfin mako shark, the blue shark, and swordfish.

The analysis per species indicated that swordfish made up approximately 45% of the total catches in number; the sharks (mostly blue shark), marlins, and tuna, respectively constituted 28%, 12%, and 8%. The most important species in the bycatch of the swordfish fishery carried out in the traditional fishing zones of the Chilean fleet were the blue shark (57.5%) and the shortfin mako shark (18.1%) (Barría *et al*., 2005). The numerical dominance observed for swordfish in this study agrees with that reported by Beerkircher *et al*. (2002) for the pelagic longline fishery on the south-

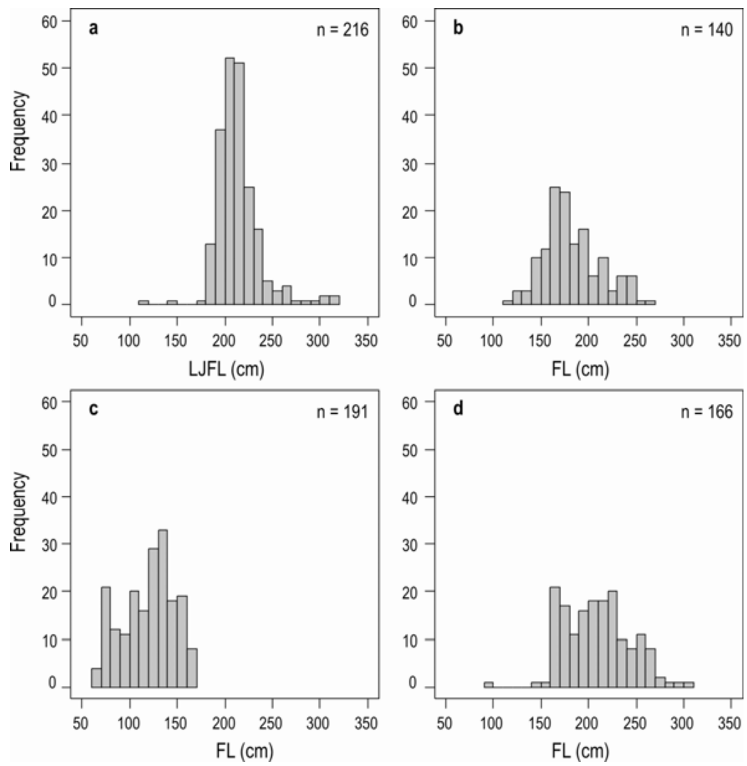

Figure 4. Length-frequency distribution of a) striped marlin, b) brown shark, c) yellowfin tuna, and d) shortfin mako shark. FL: fork length, LJFL: lower jaw to the fork of the caudal fin.

Figura 4. Distribución de frecuencia de tallas de a) marlin rayado, b) tiburón jaquetón, c) atún aleta amarilla, y d) marrajo dientudo. FL: longitud horquilla, LJFL: longitude desde la mandíbula inferior a la horquilla de la aleta caudal.

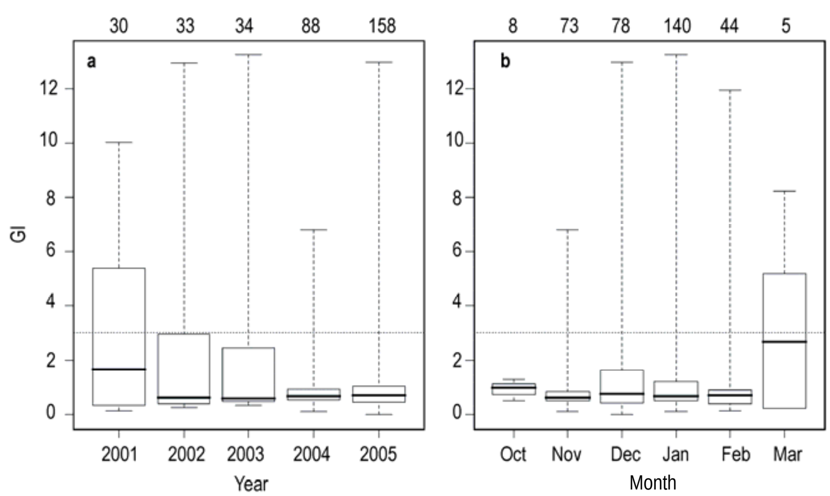

Figure 5. Box-plot of swordfish gonadal index (GI) by a) year and b) month. Middle points represent the median value, the box indicates the 25 and 75 percentiles and the whiskers the total range. The sample sizes are shown above.

Figura 5. Índice gonádico (GI) de pez espada por a) año y b) mes. Se muestran las medianas, rango intercuartílico y rango total. En la parte superior se presentan los tamaños muestrales.

eastern coast of the United States (22º-35ºN, 71º-82ºW). In that area, swordfish made up 40% of the catches, whereas elasmobranchs, tuna, and marlins were respectively 15%, 13%, and 4%. The shark *Carcharhinus falciformis* was the dominant elasmobranch species (31.4%). On the contrary, Buencuerpo *et al*. (1998) reported a greater proportion of sharks in the catches from the Strait of Gibraltar in the East Atlantic. There, the most common species were the blue shark (67%), swordfish (17%), and shortfin mako shark (12%). Kotas *et al*. (2000) reported catches off South Brazil that were 69% sharks and 31% teleosts. Of these sharks, the blue shark represented 50% the total catch, whereas swordfish were only 14% of the bony fishes.

The difference in the proportion of teleost fishes (principally swordfish) and elasmobranchs could be due in part to the longline design. For example, the North American fleet uses monofilament (polyamide) leaders, whereas the Spanish fleet uses wire. This probably has an important effect on the retention of sharks and the species catch composition (Berkeley *et al*., 1981; Marín *et al*., 1998; Kotas *et al*. 2000). Recently, Kerstetter & Graves (2006), working in the North Atlantic, also found differences in the catch compositions depending on the type of hook used and the season of the year. With a circular-type hook, records showed 35% elasmobranchs (principally pelagic stingrays and blue sharks), followed by tuna (24%), other teleost fishes (19%), and swordfish (17%). When "J" type hooks were used, however, the greatest catches corresponded to swordfish (65%), followed by teleost fishes (19%), principally *Lepidocybium flavobrunneum*, and sharks and rays (10%). Another source of variability in the composition of the long-line catches corresponds to the fishery target species. Lins *et al*. (2005) studied the catches of both local and foreign longline fleets off north-eastern Brazil, finding that the catches consisted mainly of bigeye tuna (39%), yellowfin tuna (36%), and swordfish (23%). These results denote the strong intentions of the foreign fleets (oriental) to catch tuna rather than swordfish. Thus, both the constitution of the gear and the spatial-temporal variability can produce significant differences in the composition and number of species in the catches. Future studies are needed around Isla de Pascua to evaluate the presence and relative abundance of the fish populations that inhabit this region in other seasons of the year.

In the study area, global swordfish yields were greater (587.9 kg or 10.8 ind · 1,000 hook^{-1}) than the value recorded by the Chilean industrial fleet in 2005 (497 kg · 1,000 hook^{-1}) (Barría *et al*., 2006). Nonetheless, given the results of the monthly fleet operation – a minimum yield in December (309 kg · 1,000 hook^{-1}) and a maximum in November (729 kg · 1,000 hook^{-1}) – the yield in this area is intermediate. In the North Atlantic, Stone & Dixon (2001) reported an average of 38.8 ind ~1,440 hook^{-1}, whereas Kerstetter & Graves (2006) and Marín *et al*. (1998) found catch rates of 9.0 to 33.7 ind · 1,000 hook^{-1} and 0.7 to 8.7 ind · 1000 hook^{-1}, respectively.

When using the sizes of first sexual maturity estimated by Zárate (1997), the catches off Isla de Pascua consisted of juvenile and adult swordfish specimens, with similar size structures and principle modes for both sexes. The swordfish population structure was dominated by males, with a total sexual proportion of 40.1% females. The analysis of the sexual proportion by size range indicated that the percentage of males is predominant in sizes smaller than 240 cm LJFL, after which the female proportion is predominant. Similar results have been found by Guitart-Manday (1964 *fide* Taylor & Murphy, 1992), Mejuto *et al.* (1995) and Arocha & Lee (1996). It has been established that swordfish over 220 to 230 cm are generally females, since the males have a lower growth rate and a shorter life span (Suzuki & Miyabe, 1990; Taylor & Murphy, 1992). The difference in the sexual proportion was also explained by a change in behavior in the spawning period as a result of a change in the catchability or availability of the mature females (De Martini *et al*., 2000). Since the present work only includes observations from spring and summer, it was not possible to determine seasonal changes in the sexual proportion. Nevertheless, unlike that reported by Barría *et al*. (2005) for the traditional fishing zones close to the continent, where the monthly sexual proportion is around 50% (or slightly greater) for females, these results suggest a sexual segregation, probably associated with a reproductive zone of this species (Taylor & Murphy, 1992; Arocha & Lee, 1996; De Martini *et al*., 2000).

From a macroscopic point of view, swordfish reproduction in the Eastern Pacific has been studied by diverse authors (Kume & Joseph, 1969; Uchiyama & Shomura, 1974; Weber & Goldberg, 1986; Miyabe & Bayliff, 1987; Nakano & Bayliff, 1992; García-Cortés & Mejuto, 2002). Nonetheless, the criteria for calculating reproductive indexes vary between authors, who use different measures of length (*e.g.* LJFL *vs*. eye-fork length, EFL) and different sizes at first sexual maturity for the fish. For example, Kume & Joseph (1969) consider females to be mature when they have gonad indexes ≥ 3 using the EFL, or ≥ 2.09 when using the LJFL, according to the transformation of Mejuto & García-Cortés (2003). Other authors such as

Arocha *et al*. (1994) and Macias *et al*. (2005), who studied swordfish reproduction in the Atlantic and Mediterranean, respectively, qualify specimens as mature with a GI ≥ 3. However, the average value of this indicator is used for both groups (size, spatial, or seasonal) and individual specimens. In general, these indexes should be used with care if they are not complemented with a histological analysis (DeVlaming *et al*., 1982).

According to this information, the results obtained in the present study indicate specimens with advanced states of gonad development in the five fishing campaigns. This confirms the report by Zárate (1997) for 1992 to 1993; this author used histology to identify fishes with a high degree of sexual maturity, probably about to spawning, between November and December around Isla de Pascua. The results presented herein show that this zone is a recurrent area for swordfish reproduction in the southeastern Pacific. Nonetheless, and as reported by Zárate (1997), our study revealed relatively few females in reproductive conditions; this justifies maintaining a reproductive monitoring program in this area for several seasons.

The blue shark presented a higher proportion of males. Spatially and seasonally, the segregation of pelagic sharks by sex and size has been documented by Nakano (1994) in the Pacific. Hazin *et al.* (1994) indicated that females might segregate away from males towards shallower and warmer waters to facilitate the reproductive process. The size structure between sexes also showed differences in its composition, with a significant male predominance over 220 cm FL. Thus, considering the size of first maturity for females and males (Pratt, 1979), the catches were principally made up of adult males and a lesser proportion of adult females. Differentiated growth was also observed in which the females attained a larger size. This characteristic is rather widespread within the elasmobranchs and is attributed to a reproductive strategy, since the females need to be larger in size in order to maintain their offspring. Previous studies have indicated that the blue shark is one of the most productive and abundant species among the pelagic sharks (Cortés, 2000; Campana *et al*., 2005). The results presented show that, although it is an important species within the catches, its yield is relatively low (4.0 ind · 1,000 hook^{-1}) in this area and period. The catch rates for the blue shark in the North Atlantic seem to be greater. For example, Campana *et al.* (2005), through a literature review, estimated an average catch rate of 18.4 ind · 1,000 hook^{-1}. Nonetheless, the variability in the Atlantic is high, with catch rates between 5.1 and 40 ind · 1,000 hook^{-1}. On the other hand, off South Brazil, Kotas *et al*. (2000) observed catches of 3.4 to 40.6 ind · 1,000 hook^{-1}. In the waters off New Zealand, Francis *et al*. (2001) recorded large interannual variability between fleets and regions, with average values of 1.15 to 114 ind · 1,000 hook^{-1} and typical values of 15 ind · 1,000 hook^{-1}. In Australian waters, the average catch was 5.5 ind · 1,000 hook^{-1}, but occasionally reached 100 specimens (Stevens, 1992).

The short-fin mako shark presented an elevated yield in weight (60.0 kg · 1,000 hook^{-1}). Although the catch rate was low, these individuals presented a considerable average eviscerated weight. This species seems to be more abundant in the Atlantic, where in some areas it reaches more than 10% of the catches (Buencuerpo *et al*., 1998). In the North American longline fleet of the Caribbean and the Gulf of Mexico in the Atlantic, the catch indexes reported by Cramer (1996) oscillated between 3.52 and 11.86 (ind · 1,000 hook^{-1}) from 1985 to 1996. However, recent studies in the eastern North Atlantic, with information from longline vessels that operated between 1992 and 2003, report values between 0.1 and 1.1 ind · 1,000 hook^{-1} (Beerkircher, 2005).

In general, factors such as the intensity of the fishing effort and the longline design could influence the catches of this type of fishery. Information on tuna and istiophorid yields is scarce. Stone & Dixon, (2001) report yields of 6.0 ind · 1.440 hook^{-1} for *Tetrapturus albidus* and 1.0 ind · 1,440 hook^{-1} for the yellowfin tuna, whereas Kerstetter & Graves (2006) report a catch rate between 6.4 and 10.7 ind · 1.440 hook^{-1} for the yellowfin tuna, but note that this is highly influenced by the season and type of hook used. In the future, it will be necessary to perform studies aimed at researching the trend in the catch rates of the target species, as well as in the bycatch, given the increasing effort of diverse fleets in this area. On the other hand, special emphasis is given the identification and quantification of the species found in this zone, especially for the bycatch, since this information will be fundamental at the moment of evaluating the real impact of fishing on the community structure.

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REFERENCES

Arocha, F., D. Lee &. J. Grubich. 1994. Observation on sex ratio, maturity stages, and fecundity estimates of the swordfish, *Xiphias gladius*, in the northwest Atlantic Ocean. ICCAT Col. Vol. Sci. Pap., 42(1): 309-318.

Arocha, F. & D. Lee. 1996. Maturity at size, reproductive seasonality, spawning frecuency, fecundity and sex ratio in swordfish from the Northwest Atlantic. ICCAT Col. Vol. Sci. Pap., 45(2): 350-357.

Barbieri, M.A., E. Yáñez, L. Ariz & A. González. 1990. La pesquería del pez espada: tendencias y perspectivas. In: M.A. Barbieri (ed.). Perspectivas de la actividad pesquera en Chile, Escuela de Ciencias del Mar, UCV, Valparaíso, pp. 195-214.

Barbieri, M.A., C. Canales, V. Correa, M. Donoso, A. González, B. Leiva, A. Montiel & E. Yáñez. 1998. Development and present state of the swordfish, *Xiphias gladius*, fishery in Chile. In: I. Barret, O. Sosa-Nishizaki & N. Bartoo (eds.). Biology and fisheries of swordfish, *Xiphias gladius*. Papers from the International Symposium on Pacific Swordfish, Ensenada, Mexico, 11-14 December 1994. US Dep. of Commer., NOAA Tech Rep. NMFS, 142: 1-10.

Barría, P., M. Donoso, J. Azócar, F. Cerna, M. Nilo, E. Palta, H. Miranda & V. Catasti. 2005. Programa seguimiento del estado de situación de las principales pesquerías nacionales. Investigación situación pesquerías de recursos altamente migratorios, 2004. Informe final Fase II. IFOP-SUBPESCA, 171 pp.

Barría, P., M. Donoso, J. Azócar, F. Cerna, H. Miranda & V. Catasti. 2006. Programa seguimiento del estado de situación de las principales pesquerías nacionales. Investigación Situación Pesquerías de Recursos Altamente Migratorios, 2005. Informe final. IFOP-SUBPESCA, 140 pp.

Bartoo, N. & A. Coan, Jr. 1989. An assessment of the Pacific swordfish resource. In: R.H. Stroud (ed.). Planing the future of billfishes: research and management in the 90s and beyond. Proceedings of the Second International Billfish Symposium, Kailua-Kona, Hawaii, August 1-5, 1988, Part 1: Fishery and Stock Synopses, Data Needs and Management, pp. 137-151.

Beerkircher, L. 2005. Characteristics of blue, *Prionace glauca*, and shortfin mako, *Isurus Oxyrinchus*, shark by catch observed on pelagic longlines in the northwest Atlantic, 1992-2003. ICCAT Col. Vol. Sci. Pap., 58(3): 1019-1033.

Beerkircher, R., E. Cortés & M. Shivji. 2002. Characteristics of shark bycatch observed on pelagic longlines off the southeastern United States, 1992-2000. Mar. Fish. Rev., 64(4): 40-49.

Beckett, J. 1974. Biology of swordfish, *Xiphias gladius* L., in the northwest Atlantic Ocean. In: R. Shomura & F. Williams (eds.). Proceedings International Billfish Symposium. Part 2, review and contributed papers. NOAA Tech. Rep. NMFS SSRF 675, pp. 103-106.

Berkeley, S.A., E.W. Irby & J.W. Jolly. 1981. Florida's commercial swordfish fishery: longline gear and methods. Univ. Miami Sea Grant Prog. Mar. Advis. Bull. MAP−14, 23 pp.

Buencuerpo, V., S. Rios & J. Morón. 1998. Pelagic sharks associated with the swordfish, *Xiphias gladius*, fisheries in the eastern North Atlantic Ocean and the Strait of Gibraltar. US Fish. Bull., 96: 667-685.

Campana, S., L. Marks, W. Joyce & N. Kohler. 2005. Catch, by-catch and indices of population status of blue shark (*Prionace glauca*) in the Canadian Atlantic. ICCAT Col. Vol. Sci. Pap., 58(3): 891-934.

Collette, B. & C. Nauen. 1983. FAO species catalogue. Vol. 2. Scombrids of the world. FAO Fish. Synop., 125: 137 pp.

Compagno, L. 1984a. FAO species catalogue. Vol. 4. Sharks of the world. Part. 1. Hexanchiformes to Lamniformes. FAO Fish. Synop., 125: 1-249.

Compagno, L. 1984b. FAO species catalogue. Vol. 4. Sharks of the world. Part. 2. Carcharhiniformes. FAO Fish. Synop., 125: 1-249 pp.

Cortés, E. 2000. Life history patterns and correlations in sharks. Reviews Fish. Sci., 8: 299-344.

Cramer, J. 1996. Recent trends in the catch of undersized swordfish by the U.S. pelagic longline fishery. Mar. Fish. Rev., 58: 24-32.

De Martini, E., J. Uchiyama & H. Williams. 2000. Sexual maturity, sex ratio, and size composition of swordfish, *Xiphias gladius*, caught by the Hawaii-based pelagic longline fishery. US Fish. Bull., 98: 489-506.

De Metrio, G., P. Megalofonou, S. Tselas & N. Tsimenides. 1989. Fishery and biology of the swordfish *Xiphias gladius* in the Greek waters. FAO Fish Rep., 412: 135-140.

DeVlaming, V., G. Grossman & F. Chapman. 1982. On the use of the gonadosomatic index. Comp. Biochem. Physiol., 73A: 31-39.

Francis, M., L. Griggs & S. Baird. 2001. Pelagic shark bycatch in the New Zealand tuna longline fishery. Mar. Freshw. Res., 52: 165-178.

García-Cortés, B. & J. Mejuto. 2002. Patrones de sex-ratio y de índices gonadales del pez espada (*Xiphias gladius*) capturado por la flota española de palangre de superficie en el océano Pacífico este. Doc. BSTC/02. Santiago, 14 pp.

Hazin, F., C. Boeckmann, E. Leal, K. Otsuka & K. Kihara. 1994. Reproduction of the blue shark. *Prionace glauca*, in the southwestern equatorial Atlantic Ocean. Fish. Sci., 60(5): 487-491.

Hinton, M. & R. Deriso. 1998. Distribution and stock assessment of swordfish, *Xiphias gladius*, in the eastern Pacific Ocean from catch and effort data standarized on biological and environmental factors. US Nat. Mar. Fish. Serv., NOAA Tech. Rep. NMFS 142, 161-179.

Hinton, M. & W. Bayliff. 2002**.** Assessment of swordfish in the eastern Pacific Ocean. Inter. Amer. Trop. Tuna Comm. Stock Assessment Report, 2: 297-338.

Hinton, M., W. Bayliff & J. Suter. 2005. Assessment of swordfish in the eastern Pacific Ocean. Inter. Amer. Trop. Tuna Comm. Stock Assessment Report, 5: 291-326.

Joseph, J., W. Bayliff & M. Hinton. 1994. A review of information on the biology, fisheries, marketing and utilization, fishing regulations, and stock assessment of swordfish, *Xiphias gladius* in the Pacific Ocean. Inter. Amer. Trop. Tuna Comm. Int. Rep., 24: 81 pp.

Kerstetter, D. & J. Graves. 2006. Effects of circle versus J-style hooks on target and non-target species in a pelagic longline fishery. Fish. Res., 80: 239-250.

Kotas, E., S. dos Santos, V. Guedes, J. Meneses, J. Dias & C. Fernández. 2000. Observations on shark by-catch in the monofilament longline fishery off southern Brazil and the national ban of finning. Shark Conference 2000 Online Documents. Honolulu, Hawaii February 21-24. http://pacfish.org/sharcon/ documents/kotas.html. Revised: 15 November 2006.

Kume, S. & J. Joseph. 1969. Size composition and sexual maturity of billfishes caught by the Japanese longline fishery in the eastern Pacific Ocean east of 130°W. Bull. Far Seas Fish. Res. Lab., 2: 115-162.

Lins, J., J. Vasconcelos, P. Travassos, J. Garcia Jr. & J. Aldatz. 2005. Length-weight relationships and length-length conversions of tunas and swordfish in the northeast of Brazil. Int. ICCAT Col. Vol. Sci. Pap., 58(5): 1724-1728.

Macías, D., A. Hattour, J.M. de la Serna, M.J. Gómez-Vives & D. Godoy. 2005. Reproductive characteristics of swordfish (*Xiphias gladius*) caught in the Southwestern Mediterranean during 2003. ICCAT Col. Vol. Sci. Pap., 58(2): 454-469.

Marin, Y.H., F. Brum, L.C. Barea & J.F. Chocca. 1998. Incidental catch associated with swordfish longline fisheries in the south-west Atlantic Ocean. Mar. Freshw. Res., 49(7): 633-639.

Mejuto, J. & B. García-Cortés. 2003. A description of a posible spawning area of the swordfish (*Xiphias gladius*) in the Tropical Northwest Atlantic. ICCAT Col. Vol. Sci. Pap., 55(4): 1449-1458.

Mejuto, J., J. de la Serna & B. García. 1995. An overview of the sex ratio at size of the swordfish (*Xiphias gladius*) around the world: similarity between different strata. Int. Comm. Conserv. Atl. Tunas, ICCAT Col. Vol. Sci. Pap., 44(3): 197-205.

Miyabe, N. & W. Bayliff. 1987. A review of the Japanese longline fishery for tunas and billfishes in the eastern Pacific Ocean, 1971-1980. Inter-Amer. Trop. Tuna Comm., Bull., 19(1): 1-163.

Nakamura, I. 1985. FAO species catalogue. Billfishes of the world. Vol 5. FAO Spec. Synop., 125: 65 pp.

Nakano, H. 1994. Age, reproduction and migration of blue shark in the North Pacific Ocean. Bull. Natl. Res. Inst. Far Seas Fish., 31: 141-219.

Nakano, H. & W. Bayliff. 1992. A review of the Japanese longline fishery for tunas and billfishes in the eastern Pacific Ocean, 1981-1987. Inter-Am. Trop. Tuna Comm. Bull., 20(5): 183-355.

Nishikawa, O. & M. Shimizu. 1991. Spatial and temporal CPUE trends and stock unit inferred from them for the Pacific swordfish caught by the Japanese tuna longline fishery. Nat. Res. Inst. Far Seas Fish. Bull., 28: 75-89.

Okamoto, H. & W. Bayliff. 2003. Análisis de la pesquería palangrera japonesa de atunes y peces picudos en el océano Pacífico oriental, 1993-1997. CIAT Bull., 22(4): 389-431.

Ovchinnikov, V. 1970. Swordfishes and billfishes in the Atlantic Ocean: ecology and morphology. Kaliningrad Atlantic Scientific Research Institute for Fisheries Oceanography, 77 pp.

Palko, B.J., G.L Beardsley & W.J. Richards. 1981. Synopsis of the biology of the swordfish, *Xiphias gladius*, in the Indian and Pacific Oceans. NOAA Tech. Rep. NMFS Circ. 441: 21 pp.

Pratt, H.L. 1979. Reproduction in the blue shark, *Prionace glauca*. US Fish. Bull., 77: 445-470.

Stone, H. & L. Dixon. 2001. A comparison of catches of swordfish, *Xiphias gladius*, and other pelagic species from Canadian longline gear configured with alternating monofilament and multifilament nylon gangions. US Fish. Bull., 99: 210-216.

Suzuki, Z. & N. Miyabe. 1990. Heterogeneous sex ratio of the Atlantic swordfish and the implication to cohort analysis. ICCAT Col. Vol. Sci. Pap., 32(2): 377-386.

Stevens, J.D. 1992. Blue and mako shark bycatch in the Japanese longline fishery off southeastern Australia. Aust. J. Mar. Fresh. Res., 43: 227-236.

Taylor, R. & M. Murphy. 1992. Reproductive biology of the swordfish *Xiphias gladius* in the Straits of Florida and adjacent waters. US Fish. Bull., 90: 809-816.

Uosaki, K. & W. Bayliff. 1999. A review of the Japanese longline fishery for tunas and billfishes in the eastern Pacific Ocean, 1988-1992. Inter-Am. Trop. Tuna Comm. Bull., 21: 273-488.

Uchiyama, J. & R. Shomura. 1974. Maturation and fecundity of swordfish, *Xiphias gladius*, from Hawaiian waters. In: R. Shomura & F. Williams (eds.). Proceedings of the International Billfish Symposium Kailua-Kona, Hawaii, 9-12 August, 1972. Part 2. Review and contributed papers, NOAA Tech. Rep. NMFS SSRF, 675: 142-148.

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

Weber, E. & S. Goldberg. 1986. The sex ratio and gonad indices of swordfish, *Xiphias gladius*, caught off the coast of Southern California in 1978. US Fish. Bull., 84(1): 185-186.

Yabe, H., S. Ueyanagi, S. Kikawa & H. Watanabe. 1959. Study on the life-history of the swordfish. Nanki Reg. Fish. Es. Lab., Rep., 10: 107-150.

Yáñez, E., M.A. Barbieri, F. Ponce, M. Donoso, C. Canales, R. Toro & J. Acevedo. 2003. Monitoreo y evaluación de la pesquería chilena de pez espada. In: E. Yáñez (ed.). Actividad pesquera y de acuicultura en Chile. Escuela de Ciencias del Mar, PUCV, Valparaíso, pp. 143-155.

Zárate, P. 1997. Biología reproductiva del pez espada, *Xiphias gladius* (Linnaeus 1758) en aguas chilenas. Tesis, Facultad de Ciencias del Mar, Universidad Católica del Norte, Coquimbo, 111 pp.

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