SEX RATIO PATTERNS AND GONADAL INDICES OF THE SWORDFISH (*XIPHIAS GLADIUS*) CAUGHT BY THE SPANISH SURFACE LONGLINE FLEET IN THE INDIAN OCEAN.

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ABSTRACT

This paper presents a description of the overall sex ratio and sex ratio at size for the swordfish (Xiphias gladius) caught by the Spanish surface longline fleet operating in the Indian Ocean. The results obtained from the sampling of 23,648 swordfish specimens point to differences in sex ratio values both overall and by size class, among the different areas of the Indian Ocean analysed. In addition, an analysis of the gonad size and weight of female swordfish specimens resulted in gonadal indices (GI), based on different definitions and their equivalences. The results would suggest that specimens in the northwestern area of the Indian Ocean would be in advanced stages of maturation-reproduction and on the verge of spawning, which would suggest that this area is the most conducive to maturation and spawning processes as compared to other zones.

***Key words**: gonadal index, reproduction, sex ratio, swordfish*

INTRODUCTION

From September, 1993 to August, 1994, the Spanish surface longline fleet targeting the swordfish (*Xiphias gladius*), carried out their first fishery prospecting survey in the West Indian Ocean (FAO 51) with a total of 5 commercial vessels. In October of 1999, two other vessels began an experimental pilot program in international waters in the proximity of 60ºE (FAO51). (GARCÍA-CORTÉS & MEJUTO 2000; GARCÍA-CORTÉS *et al. in press* –WPB-03-03–). In the fishery prospecting surveys and the commercial fishery activity, scientific observers were on board the ships to monitor the fishery activity from a scientific point of view as well as to collect biological data, with a mean coverage of specimens sampled of around 50% of the total number of fish caught.

A number of studies have reported that swordfish spawn in the Pacific Ocean in spring-summer north of the Equator; in winter, south of the Equator and all year round in equatorial latitudes with boundaries between 25º-30º N and 10º S. Spawning did not occur to the east of 100º W (KUME & JOSEPH 1969; MIYABE & BAYLIFF 1987; NAKANO & BAYLIFF 1992). Other studies would suggest that female swordfish do not present advanced stages of reproduction except in some possible cases in certain areas of the NE and SE Pacific (MEJUTO & GARCÍA-CORTÉS 2003a), and no spawning was found to take place on the East Pacific coast (WEBER & GOLDBERG 1986; RAMON & CASTRO-LONGORIA 1994). Some of these papers would imply that the larval distribution of the swordfish seems to be more prevalent in equatorial waters west of 120º W with sea surface temperatures (SST) above 23º-24ºC, which would indicate that fishes have a preference for the tropical West Pacific as a spawning ground (MATSUMOTO & KAZAMA 1974; NISHIKAWA & UEYANAGI 1974; NISHIKAWA *et al*. 1978, 1985).

The preference of swordfish for reproductive areas in tropical or subtropical zones located in the western zones of oceans is not new, as this behaviour has already been reported in the Northwest and Southwest Atlantic as well as in the West Indian Ocean (MEJUTO *et al*. 1994; 1995; MEJUTO & GARCÍA 1997; MEJUTO & GARCÍA-CORTÉS 2003b; AROCHA & LEE 1996) and specifically during the period from October to April around Reunion Island (POISSON & TAQUET 2000; POISSON *et al.* 2001).

This paper will attempt to shed light on the overall sex ratio (SRo) in certain areas of the Indian Ocean, although the SRo is not generally considered to be an appropriate indicator for the detection of spatial-temporal differences in the distribution of the swordfish by sex. For this reason, an analysis of sex ratio at size (SRs) has also been carried out on the swordfish, whose spatial and temporal variability has been reported previously by several authors in different oceans (BECKET 1974; HOEY 1986, 1991; GARCÍA & MEJUTO 1988; LEE 1992).

The differences in sex ratio between the different size classes (SRs) are considered to be most likely due to a possible growth and/or natural differential age-related mortality between males and females (ANONYMOUS 1986, 1988). However other factors, such as differential migratory behaviour and differential distribution by sex owing to varying oceanographic requirements of swordfish related to their size-sex and reproductive physiology may also be able to explain the characteristic spatial-temporal variations detected in several oceans. In keeping with this, HOEY (1986) proposed a differential migratory hypothesis between males and females of the Atlantic called "*size-temperature* *mediated sexual segregation*", which was later confirmed in works by other authors. This led to the proposal of three general patterns in sex ratio at size, basically associated with the geographic-oceanographic-physiological aspects, known generically as "*spawning*", "*feeding*" and "*transition*" (MEJUTO *et al*. 1998; MEJUTO 1999). These patterns defined in the SRs have led to the definition of the so-called "*biological regions*" for the Atlantic swordfish for the purpose of preparing data for stock assessment (ANONYMOUS 1999). In this sense, studies that provided an overview of the sex ratios and gonadal indices in the Atlantic, Indian and Pacific Oceans have already postulated the possible geographic distribution of the swordfish into "biological regions" in the different oceans observing sex ratio and gonadal index patterns which are characteristic of reproductive areas similar to those observed in the Atlantic and in some areas of the NW Indian Ocean (MEJUTO *et al*. 1995).

Despite the fact that the swordfish appears to have populations structured into different stocks between oceans and probably within each ocean, it is very likely that their physiological-oceanographic requirements are similar in all of these oceans. Therefore, knowledge of the biology and behaviour of this species in a region or ocean, which, although geographically different from our preferential area of interest, may be a keystone in helping to interpret these biological, physiological and behavioural aspects, both on a local and global level.

The wide-ranging geographic distribution of the swordfish in each ocean, along with the generally limited activity of most of the fleets, represent an additional drawback in obtaining samples with a broad spatial-temporal coverage. This is why overall studies on reproduction and the distribution of males and females have been difficult to tackle. Recent analyses have tried to focus on these aspects in broad terms, including data from Atlantic zones (North and South), West Indian and East Pacific Oceans (MEJUTO *et al*. 1995), pointing, in some cases, to typical patterns that are common to all oceans.

The information compiled in this paper comes exclusively from the activity of Spanish surface longline vessels operating in the Indian Ocean, which limits the representativenes of the samples, as the data were not collected from wide areas/time periods. This presents an additional drawback when interpreting the results and attempting to make generalisations. It is essential to have access to other information sources from other fleets from join research project among scientist and a comparison with papers and experiences from other areas to be able to draw some general conclusions on the behaviour of this species.

This document does not attempt to define with accuracy the size at first sexual maturity, rather it offers a preliminary analysis of the sex ratios, gonadal stages and different gonadal indices (GIs) traditionally defined in this species (KUME & JOSEPH 1969; HINTON *et al*. 1997) to determine the reproductive state of female swordfish and to provide a better definition of the spatial-temporal spawning pattern of this species in the Indian Ocean.

MATERIAL AND METHODS

The data used in this paper are based on information obtained through scientific monitoring in the Indian Ocean from the time when Spanish vessels first began their fishery activity there. The data came from the observer program carried out on board surface longliners by the IEO (Spanish Institute of Oceanography), in addition to information provided by the experimental fishery prospecting surveys that took place in areas and time periods when the Spanish fleet does not usually carry out its commercial activity or does so only sporadically. Other information was obtained through fishery log-books filled in voluntarily, providing data on catch, effort, etc, as well as the individual weight of each fish captured and other sources of information such as those collected by the RIM (Information and Sampling Network) (surveys, landings, transfers, etc.) and processed according to the standard methodology recommended for these types of fleets (MIYAKE 1990), in 5ºx5º/month formats. The total information obtained covers the periods from 1993-94 and 1998-2002.

The specimens sampled to obtain biological information were caught between 0º N-30º S and 35º-75º E. This broad-ranging area of the Indian Ocean where the data were collected was divided into five zones for analysis (figure 1), taking into account different criteria such as geographical location, sea surface temperature (ANONYMOUS 1977), the size distribution obtained for the total number of fishes caught and the resulting overall sex ratios by 5ºx5º squares : IND51: 10º N-5º S/40º-55º E; IND52: 10º-20º S/35º-55º E; IND53: 25º-35º S/20º-55º E; IND54: 20º-35º S;/60º-80º E; IND55: 00º-15º S/ 60º-80º E.

On the other hand, and in terms of the availability and processing of the information, part of it is described and analysed in time periods covering several years: one period contains data on fish catches in areas of the Indian Ocean located more to the west, pertaining to the first pilot actions carried out from 1993-94. Sometimes, the data that were less abundant and more sporadic were allotted to the nearest square having more fishery activity, to obtain a larger sample size. The second period defined contains the information pertaining to the 1998-2002 period.

The size of the swordfish was obtained on board by measuring the lower jaw-fork length (LJFL) to the lowest centimetre. They were then grouped into 5 cm size classes adjusted to the lowest limit of each class (MIYAKE & HAYASI 1978). Graphs of the size distributions (LJFL cm) of the fishes captured were drawn up by geographic zone. The cumulative percentage of the size classes by zone was also calculated to facilitate the comparison of the distributions. The eye-fork length (EFL) was also calculated by applying the equation $EFL = -8.259+0.930*LJFL$, (TAYLOR & MURPHY 1992).

During the processing of the fish on board, (emptying cavities and removing gills, fins, tails, head, etc), the scientific observers identified '*de visu*' the sex of each swordfish specimen. Previously standardised sex identification criteria was established to avoid bias among observers, particularly in the smallest sizes, which are the most prone to error when the observer is not properly trained.

The analysis of the sex ratios did not take into account the time variable due to the scarcity of available data in certain zones and time periods, owing to the seasonal nature of the exploitation model of the fishery by this fleet. A temporal definition by years combined made it possible to substantially increase the number of available observations by spatial strata, and therefore, increase the number of samples in most of the size classes from each zone.

The overall sex ratio was obtained for all the sizes combined (SRo) by square and zone, as well as the sex ratio at size (SRs) for each zone because the area factor generally appears to have a greater impact on the variability in the sex ratio at size (SRs) (MEJUTO *et al.* 1994, 1995; TURNER *et al.* 1996). The sex ratios were defined based on the samples obtained: SR = [females /(males+females)]*100, (MEJUTO *et al.* 1995).

To gain insight into the reproductive state of the females sampled and the variations in the proportions of the different maturity stages, the gonadal state in females was divided into 6 gonadal stages (stage 1: primordial; stage 2: immature, without oocytes; stage 3: developed but opaque oocytes; stage 4: transparent oocytes; stage 5: spawning and stage 6: post-spawning). Female gonads were also weighed on board with dynamometers having an accuracy of approximately 15 grams which, along with the individual size obtained to the lowest centimetre, allowed us to use two types of gonadal indices (GIs) for females:

GI1 =(Wg / LJFL ^3)*10^4 (MEJUTO & GARCÍA-CORTÉS 2003a), based on KUME & JOSEPH (1969). GI2= ln Wg / ln EFL, (HINTON *et al.* 1997), where, Wg = weight of the two female gonads in grams. LJFL=lower jaw-fork length in cm. EFL= eye-fork length in cm.

The values GI1 >= 2.09 (equivalent to 3.0 threshold defined by KUME & JOSEPH 1969) and GI2 >= 1.375 (defined by HINTON *et al.* 1997) would be an *a priori* indication of females in an active reproductive stage, according to the respective authors.

We decided to analyse the different gonadal indices (GIs) obtained, restricted to swordfish females equal to or greater than 150 cm LJFL (or 131 cm EFL), a size which is close to the minimum size at maturity of females in the Atlantic Ocean (AROCHA 1997). A size of 175 cm LJFL (154 cm EFL) pertains to the size at first sexual maturity in the North Atlantic (AROCHA & LEE 1996), while the size at first sexual maturity based on an examination of 601 female specimens in the Indian Ocean was estimated to be 143 cm EFL (160 cm LJFL) (DeMARTINI 1999).

The maximum, minimum and average GI values per size class were calculated for each geographic zone and their confidence intervals (95%) were determined and shown on a graph for the above mentioned periods – the first period from 1993-1994 and the other period from 1998-2002.

Values of GI maximums and averages were tentatively obtained per quarter and zone, however the number of observations at times was not sufficient to be able to make comparisons between quarters or between years. Therefore, the final GI analyses cover each defined zone and all the years combined.

The paired values GI1 and GI2 were compared using a non-linear regression analysis with *Marquardt's* algorithm (Statgraphics *plus ver.* 5.1), to obtain approximate equivalences between the two values for the sub-set of samples from each geographic zone of the Indian Ocean.

RESULTS AND DISCUSSION

During the 1993-2002 period a total of 23,648 swordfish from the Indian Ocean were sexed, with a size range of 50-300 cm (LJFL). Forty-two percent of the observations pertained to zone IND51 with a total of 10,018 individuals sampled; almost 19% were from zone IND52 with 4,418 fishes sampled, 15% from the IND53 zone with 3,663 specimens sampled, 16% from the IND54 zone with 3,818 fishes sampled and approximately 7% came from the IND55 zone where 1,731 specimens were examined.

Figure 2 shows the size distribution (LJFL cm) by males and females combined of the total catch taken by the fleet, for all the years combined and zones classified. The cumulative percentage of the distribution by geographic zone was also obtained to facilitate the comparison of the distributions (figure 3). Considerable differences were observed in size distributions among the different zones. The cumulative percentage representing 50% of the size distributions in zones IND53 and IND54 was defined among the 155-160 cm LJFL size classes. For the other group in zones farther to the north, this percentage was found among the smaller size classes 135-140 cm LJFL.

Table 1 summarises the number of fishes sampled by sex and total number, in addition to the overall sex ratio values (SRo), by 5ºx5º square for all the years combined. Although the SRo is not considered to be an appropriate indicator for the detection of differences in distribution by sex, as it is dependent upon the size range under observation, nevertheless, it could on occasion, be useful in providing a preliminary visual diagnosis to detect differences between the zones analysed (MEJUTO *et al.* 1995).

Table 2 presents the number of fishes sampled and the overall sex ratio (SRo) values for each defined zone. The SRo values were found to favour males in zone IND51 (SRo = 29.5%), and were around 50% in zones IND52 and IND55, and between 65-75% in zones IND53 and IND54. For lack of a wider sampling range and a significance test, these SRo values along with the size distributions obtained would support, *a priori*, the hypothesis that these are differences in distribution by sex of the population between the geographic zones, based on the specimens taken using this fishing gear. The high variability of the SRo was also detected in individuals caught by other fleets in the Indian Ocean (ANONYMOUS 2001).

The resulting SRs values (sex ratio at size LJFL cm) for the Indian Ocean zones as a whole would indicate that the females are predominant starting at 155 cm (figure 4). However, if we observe the SRs at size (LJFL cm) for each geographic zone, it is possible to see that there are major differences between zones (figure 5). In zone IND51 the sex ratio pattern shows that the percentage of females is clearly less than 50% in sizes smaller than 165 cm, which is a pattern that could be defined as resembling the trend characteristic of the reproduction areas in other oceans (MEJUTO *et al.* 1995; AROCHA & LEE 1996). In zone IND52 the percentage of females is slightly under 50% for sizes smaller than 155 cm. In zone IND55 the percentage of females is around 50% in all the size classes and in zones IND53 and IND54 females are present with a percentage of above the 50% for all the size classes sampled (table 3).

Moreover, these SRs results in zone IND51 were corroborated by the high GI values found, which would suggest that this zone may be a possible spawning ground. As this is a zone located in the West Indian Ocean, it would be expected to have favourable conditions that are conducive to maturation and spawning processes. A comparison of the results obtained using this fishing gear with the results of other gears carried out in the same zones (deep longline, drifnets fishery) would be extremely useful in providing insight into these aspects.

By observing the SRs values by areas in other oceans, we were able to detect patterns that are characteristic of the SRs of the reproduction areas ("spawning" type biological region), with clearly a greater relative presence of males in the catch taken by surface longliners. However, the cause of this characteristic pattern in the SRs favouring males at certain sizes is still not clear, since it could stem from changes in the local relative abundance (or catchability) between the two sexes, without being able to determine which sex (or the two combined) is the cause of this characteristic SRs pattern. Some possible explanations for this might be that males and females behave differently or because females are found in the deeper waters and are therefore less accessible to the surface longline gear. The SRs value that clearly favours males of specific sizes, as is the case in the so-called "spawning" grounds of the Atlantic Ocean, might be due, for instance, to the increase in the absolute abundance (or catchability) of males and/or a decrease in the absolute abundance (or catchability) of females on a local level.

A comparative study of catch per unit of effort (CPUE in number of fishes), by sex, (assumed to be the local abundances of each sex) was performed by contrasting two broad regions of the Atlantic: a region considered being a 'feeding' ground and a region considered generally to be a 'spawning' ground. The results show that the abundance of females was practically identical in the two regions, while the abundance of males differed greatly because males were at least three times more abundant in the 'spawning' than in the 'feeding' region. If we compare the relative abundance in number of fishes by sex between the two regions, opposing values are found. Whereas in the spawning region, 63 % of the abundance in number pertains to males, the feeding region accounts for only 37 %.

Biological Region	Mean CPUEn ♂	Mean CPUEn ♀	Ratio (♂ / ♀)
'Spawning' CI 90%	14.48 (63%) (9.14-19.82)	8.51 (37%) (6.24-10.77)	1.70
'Feeding' CI 90%	4.81 (37%) (3.29-6.32)	8.30 (63%) (4.66-11.94)	0.58
Spawning / Feeding	3.01	1.02	

Mean abundances and CI 90% in number of fishes per one thousand hooks (CPUEn) in two zones of the Atlantic with sex ratios characteristic of spawning and feeding grounds respectively (from MEJUTO *et al*. 1995)

This would suggest, as a plausible hypothesis, that when we find characteristic SRs patterns in certain sizes favouring males, to the disadvantage of female SRs values, as is reported in this paper and in other oceans, this may be primarily attributed to an increase in the local abundance (or catchability) of males in this particular size range. This size range accumulates a considerable variety of ages in males, owing to the typical growth in males, with a smaller L_{∞} and a lower growth rate than females once they attain adult size.

For the purpose of comparing zones and the data set obtained from the 6,870 females equal to or greater than 150 cm LJFL (131 cm EFL), graphs are provided with average GIs shown by size class and their respective confidence intervals (95%) in the two periods (1993-1994 and 1998-2002), for the zones for which data was available (figure 6). The graph representing zone IND51 stands out because of the high average GIs obtained for the size class sampled. This did not occur in the other zones, with the exception of a few sporadic cases that are seen in some maximum GIs.

The maximum and average GIs, confidence intervals (95%) and sampling size for each zone defined were calculated for a total of 6,870 female swordfish specimens equal to or greater than 150 cm LJFL (131 cm EFL). Tables 4 and 5 summarise the results by zone for each quarter and all the years combined respectively. The size range used in this study was restricted to 150-300 cm LJFL (131-271 cm EFL).

Although the sampling in some of the zones did not cover all the quarters, the average GI1 and GI2 resulting from the quarters in which samples were collected, suggest that there may be a possible spawning ground all year round in zone IND51, confirming previous reports (MEJUTO *et al.* 1995). As a average percentage during these quarters, 60% of the females exhibited higher GIs than the previously established threshold. In zones IND52, IND53 and IND55 the resulting

GIs were generally lower than the thresholds defined as indicators of spawning, at least during the quarters when sampling was carried out. The high GI1 during the 4th quarter in zone IND52 was based only on 6 females, so this datum is not considered to be representative. In the 4th quarter in zone IND54 only the average GI1 presented high results (2.367) and did not match the average GI2 value (1.283). In this zone and quarter only around 30% of the females exhibited GI values above the threshold. In the end, to increase the number of individuals sampled per area, it proved to be more satisfactory to combine the quarters as well.

For zone IND51 data were available for 1,458 females between 150-260 cm LJFL (131-234 cm EFL). The results showed high values for ave. and max. GI1 (5.140 y 29.514) and ave. and max. GI2 (1.456 y 1.913). Of these 1,458 females, 865 specimens (59.3%) had a GI1 equal to or greater than the threshold value. Similarly, 875 females (60.0%) either surpassed or equalled the GI2 threshold value.

For zone IND52 data were available for 884 females between 150-209 cm LJFL (130-238 cm EFL), giving rise to values of ave. GI1= 1.696 and max GI1= 16.649; ave. GI2= 1.275 and max GI2= 1.778. Of these 884 females, 176 (19.91%) had a GI1 equal to or greater than the threshold value and 231 (26.13%) had a GI2 equal to or greater than the GI2 threshold value.

For zone IND53 data were available for 2,357 females between 150-300 cm LJFL (131- 273 cm EFL). The results showed values for ave. GI1= 1.696 and max GI1= 16.649; ave. GI2= 1.275 and max GI2= 1.778. Of these 2,357 females, 32 (1.36%) had a GI1 equal to or greater than the threshold value and 58 (2.46%) had a GI2 equal to or greater than the GI2 threshold value.

For zone IND54 data were available for 1,781 females between 150-238 cm LJFL (130-213 cm EFL). Slightly higher ave. and max GI1 values (1.334 and 14.860 respectively) were found, while the opposite occurred with the ave. and max GI2 values (1.275 and 1.778). Of these females, 225 (12.63%) and 232 (13.02%) had GI1 and GI2 values equal to or greater than the thresholds defined in each case.

For zone IND55 data were available for 390 females between 150-252 cm LJFL (130- 226 cm EFL). The results showed values for ave. GI1= 1.197 and max GI1= 13.320; ave. GI2= 1.200 and max GI2= 1.750. Of these females, 31 (7.94%) and 32 (8.20%) had an GI1 and an GI2 values equal to or greater than the thresholds defined in each case.

For the set of samples examined from all years and zones combined, 98% of the females with an value of GI1>=2.09 had exhibited values that were equal to or greater than the GI2 threshold (1.375) and 91% of the specimens with an GI2>=1.375 coincided with or surpassed the GI1 threshold value (2.09). In terms of the size range analysed, the two defined gonadal indices are in almost total agreement, which would suggest that both thresholds could be indicative of spawning females or females on the verge of spawning. However this agreement between both thresholds was no observed for females caught in the eastern areas of the Pacific ocean (MEJUTO & GARCÍA-CORTÉS 2003a). These contradictory findings would imply that the size range analysed in the two cases and/or the varying degrees of maturity observed in the zones might have an effect on the respective results. Earlier findings indicated that a comparison of the threshold values defined for the different GIs should be interpreted with caution when these data come from sets of samples with different size ranges and originate from different geographic zones or oceans.

The paired values of GI1 *versus* GI2 were fitted to the same data set per zone. The preliminary fits of linear regression were, in general, satisfactory for specimens having low gonadal indices (GI1<2.09 or GI2<1.375). However, as was to be expected, the fits proved less satisfactory for specimens with GIs above these threshold values, with a greater variability in the maturity stage. Final adjustments by non-linear regression procedures allowed us to calculate relations by the zones defined (table 6). The relations pertaining to each zone present a high R^2 (84%-97%), even for the possible spawning ground, zone IND51 (96.7%) The residual analyses exhibited greater variability in the high GIs (figure 7).

It was not possible to tabulate the qualitative '*de visu'* information from the different gonadal stages of the females analysed for the data set from the 1993-94 period, therefore we could not calculate the variation in the proportion of the different maturity stages. After reviewing the reports drawn up by the fishery prospecting surveys carried out during this period, in zone IND51 the scientific observers who examined the gonads '*de visu'* confirmed the presence of oocytes in the hydrated stage for practically all of the females greater than or equal to 150 cm LJFL. This observation was not generally reflected in the other zones studied during this period (IND52, IND53, IND55). We were, however, able to tabulate this information for the data collected on 3,761 females greater than or equal to 150 cm LJFL during the 1998-2002 period only for zones IND52, IND53, IND54 and IND55 (table 7). Only a few isolated females (roughly 1%) were found to be in the spawning stage or close to it (stages 4 and 5), which would suggest that in these zones and during the time period analysed, females are often sexually inactive or in the post-spawning stage.

It was not yet possible to validate the agreement between the scales established for gonadal stages (qualitative index) and the GI values (quantitative index) from the available data on gonadal stages by '*de visu*' observations and the GIs.

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Table 1. Number of fish sampled (F:females; M:males); percentage of females and percentage of males, by 5ºx5º square (lat:latitude; Long: Longitude; NE: northeast; SE:southeast) for all years combined.

	lat	Long	F	M	F+M	%F	%M
NE	00	055	20	23	43	46,5	53,5
	05	055	233	354	587	39,7	60,3
	10	055	33	27	60	55,0	45,0
	Total NE		**286**	**404**	**690**	**41,4**	**58,6**
SE	00	045	23	43	66	34,8	65,2
	00	050	1104	3348	4452	24,8	75,2
	00	055	378	1399	1777	21,3	78,7
	Total 00		**1505**	**4790**	**6295**	**23,9**	**76,1**
SE	05	040	307	517	824	37,3	62,7
		045	361	290	651	55,5	44,5
		050	88	193	281	31,3	68,7
		055	406	871	1277	31,8	68,2
		060	66	236	302	21,9	78,1
		075	314	226	540	58,1	41,9
	Total 05		**1542**	**2333**	**3875**	**39,8**	**60,2**
SE	10	040	224	271	495	45,3	54,7
		045	59	54	113	52,2	47,8
		050	385	641	1026	37,5	62,5
		055	7	18	25	28,0	72,0
		060	110	37	147	74,8	25,2
		065	70	40	110	63,6	36,4
		070	73	42	115	63,5	36,5
	Total 10		**928**	**1103**	**2031**	**45,7**	**54,3**
SE	15	035	260	186	446	58,3	41,7
		040	137	110	247	55,5	44,5
		065	312	205	517	60,3	39,7
	Total 15		**709**	**501**	**1210**	**58,6**	**41,4**
SE	20	035	552	371	923	59,8	40,2
		040	451	348	799	56,4	43,6
		045	212	132	344	61,6	38,4
		060	121	117	238	50,8	49,2
		065	766	481	1247	61,4	38,6
		070	185	85	270	68,5	31,5
	Total 20		**2287**	**1534**	**3821**	**59,9**	**40,1**
SE	25	035	627	250	877	71,5	28,5
		040	261	94	355	73,5	26,5
		045	573	152	725	79,0	21,0
		050	158	59	217	72,8	27,2
		055	245	80	325	75,4	24,6
		060	224	55	279	80,3	19,7
		065	296	117	413	71,7	28,3
		070	386	145	531	72,7	27,3
		075	198	86	284	69,7	30,3
	Total 25		**2968**	**1038**	**4006**	**74,1**	**25,9**
SE	30	035	436	121	557	78,3	21,7
		040	494	113	607	81,4	18,6
		070	363	193	556	65,3	34,7
	Total 30		**1293**	**427**	**1720**	**75,2**	**24,8**
	Total SE		**11232**	**11726**	**22958**	**48,9**	**51,1**
	TOTAL		**11518**	**12130**	**23648**	**48,7**	**51,3**

Table 2. Number of fish sampled by sex (F:females; M:males) and percentage values by sex, zone and all years combined.

ZONE	**IND51**		**IND52**		**IND53**		**IND54**		**IND55**	
SEX	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**
# samp.	2953	7065	2287	2131	2794	869	2539	1279	945	786
%	29,5	70,5	51,8	48,2	76,3	23,7	66,5	33,5	54,6	45,4

Table 3. Values of overall sex ratio (SRo) and sex ratio at size LJFL cm (SRs) for the swordfish obtained in the zones defined of the Indian Ocean for all years combined.

	IND51	IND52	IND53	IND54	IND55
SRo	**0,29**	**0,52**	**0,76**	**0,66**	**0,55**
T050				0,00	
T055					
T060					
T065		50,00	50,00		
T070	34,78	36,84	33,33	0,00	0,00
T075	40,98	55,17	71,43	0,00	0,00
T080	48,84	36,92	33,33		77,78
T085	48,82	43,75	50,00	50,00	41,18
T090	44,51	55,36	41,18	71,43	53,33
T095	45,62	58,48	46,67	76,47	39,06
T100	39,18	41,30	55,00	75,00	46,46
T105	39,92	46,08	58,73	70,00	59,15
T110	41,18	49,27	65,12	76,47	52,83
T115	35,81	48,82	62,50	71,00	57,35
T120	25,38	40,34	69,39	58,97	46,59
T125	14,81	35,34	70,39	76,23	49,07
T130	10,84	30,95	76,58	66,41	46,62
T135	9,77	37,63	71,43	57,62	51,52
T140	9,56	40,00	79,73	57,46	50,38
T145	12,61	44,21	81,90	54,88	47,58
T150	15,11	47,67	79,09	65,00	52,87
T155	26,79	58,70	76,21	62,50	51,61
T160	39,07	57,47	79,82	63,95	65,22
T165	50,19	63,41	71,68	57,21	66,04
T170	62,33	64,03	67,33	55,36	65,22
T175	77,10	72,88	76,51	56,77	67,39
T180	82,50	77,14	70,76	58,19	69,23
T185	91,76	87,65	86,86	59,17	66,67
T190	95,95	94,64	76,22	55,87	59,09
T195	98,04	90,70	83,72	72,73	75,00
T200	100,00	94,74	87,70	82,44	89,47
T205	100,00	94,59	91,36	95,08	100,00
T210	100,00	96,15	98,00	93,98	100,00
T215	100,00	100,00	100,00	100,00	100,00
T220	100,00	100,00	97,62	97,67	100,00
T225	100,00	100,00	100,00	100,00	100,00
T230	100,00	100,00	100,00	100,00	100,00
T235	100,00	100,00	100,00	83,33	
T240	100,00	100,00	100,00	100,00	100,00
T245		100,00	100,00	100,00	100,00
T250	100,00	100,00	100,00	100,00	100,00
T255	100,00		100,00		
T260	100,00	100,00	66,67	100,00	
T265	100,00	100,00	100,00	100,00	
T270			100,00		
T275					
T280					
T285					
T290		100,00			
T295					
T300			100,00		
T305					

Table 4. Gonad Index values calculated according to the different definitions expressed for females greater than 150 cm (LJFL) by zones defined and quarters. Average (ave. GI), maximum (max. GI), standard deviation (St.dev), confidence interval (CI(95%)) and number of females sampled (# samp.)

		IND51		IND52		IND53		IND54		IND55	
Quarter	type data	IG1	IG2	IG1	IG2	IG1	IG2	IG1	IG2	IG1	IG2
1	ave. GI	4,602	1,435	1,453	1,247	1,139	1,233	1,361	1,205		
	max. GI	18,953	1,848	7,202	1,646	5,686	1,613	14,160	1,760		
	CI(95%)	0,294	0,016	0,414	0,043	0,098	0,016	0,283	0,025		
	St. dev	4,162	0,229	1,450	0,152	0,602	0,097	1,933	0,171		
	# samp.	771	771	47	47	144	144	179	179		
2	ave. GI	3,281	1,400	1,782	1,288	0,869	1,186	0,665	1,143		
	max. GI	10,474	1,755	16,649	1,778	7,700	1,670	2,190	1,410		
	CI(95%)	0,753	0,052	0,138	0,013	0,023	0,005	0,026	0,010		
	St. dev	2,688	0,187	1,841	0,169	0,486	0,106	0,225	0,088		
	# samp.	49	49	682	682	1754	1754	295	295		
3	ave. GI			1,278	1,217	0,854	1,169	0,568	1,116		
	max. GI			9,720	1,700	3,750	1,530	1,350	1,330		
	CI(95%)			0,205	0,023	0,042	0,011	0,015	0,007		
	St. dev			1,274	0,142	0,464	0,126	0,190	0,096		
	# samp.			149	149	459	459	644	644		
4	ave. GI	5,933	1,485	4,153	1,364			2,367	1,283	1,197	1,200
	max. GI	29,514	1,913	12,138	1,767			14,860	1,780	13,320	1,750
	CI(95%)	0,371	0,020	4,172	0,238			0,219	0,017	0,135	0,013
	St. dev	4,779	0,257	5,214	0,297			2,879	0,226	1,361	0,136
	# samp.	638	638	6	6			663	663	390	390

Table 5. Gonadal Index values for females greater than 150 cm (LJFL) for the geographic zones defined for all quarters-years combined. Average (ave. GI), maximum (max. GI), confidence interval (CI(95%)), standard deviation (St. dev) and number of females sampled (# samp.)

	IND51		IND52		IND53		IND54		IND55	
type data	IG1	IG2	IG1	IG2	IG1	IG2	IG1	IG2	IG1	IG2
ave. GI	5,140	1,456	1,696	1,275	0,883	1,185	1,334	1,192	1,197	1,200
max. GI	29,514	1,913	16,649	1,778	7,700	1,670	14,860	1,780	13,320	1,750
CI(95%)	0,229	0,012	0,118	0,011	0,020	0,004	0,095	0,008	0,135	0,013
St. dev	4,464	0,242	1,797	0,167	0,494	0,110	2,040	0,179	1,361	0,136
# samp.	1458	1458	884	884	2357	2357	1781	1781	390	390

Table 6. Gonadal Index GI1-GI2 relationships using a non linear regression model for female swordfish from geographic zones defined in the Indian Ocean. (n: number of individuals; a: intercept; b: slope; r^2: R-squared (percent)).

Zone	*n*	a	b	*r2*
IND51	1458	0,178978	7,54102	96,7
IND52	884	0,194829	7,18782	95,1
IND53	2357	0,272475	6,04499	84,8
IND54	1781	0,191287	7,38447	97,5
IND55	390	0,242941	6,86528	96,0

Table 7. Total number of swordfish females >=150 cm LJFL sampled (# tot. Fish), number of females (# Fish) and percentage of females (%Fish) found in the 6 different gonadal stages defined for 'de visu' evaluation (01-06), by geographic zone in the Indian Ocean for the 1998-2002 period.

ZONE	IND52	IND52	IND52	IND52	IND52	IND52	IND52
EST. GON.	01	02	03	04	05	06	Total
# tot. Fish	149	149	149	149	149	149	149
# Fish	0	141	7	0	0	1	149
% Fish	0,00	94,63	4,70	0,00	0,00	0,67	100,00
ZONE	IND53	IND53	IND53	IND53	IND53	IND53	IND53
EST. GON.	01	02	03	04	05	06	Total
# tot. Fish	1452	1452	1452	1452	1452	1452	1452
# Fish	568	861	21	1	0	1	1452
% Fish	39,12	59,30	1,45	0,07	0,00	0,07	100,00
ZONE	IND54	IND54	IND54	IND54	IND54	IND54	IND54
EST. GON.	01	02	03	04	05	06	Total
# tot. Fish	1781	1781	1781	1781	1781	1781	1781
# Fish	270	1281	102	31	2	95	1781
% Fish	15,16	71,90	5,72	1,74	0,11	5,33	100,00
ZONE	IND55	IND55	IND55	IND55	IND55	IND55	IND55
EST. GON.	01	02	03	04	05	06	Total
# tot. Fish	377	377	377	377	377	377	377
# Fish	239	95	21	3	0	19	377
% Fish	63,40	25,20	5,57	0,80	0,00	5,04	100,00

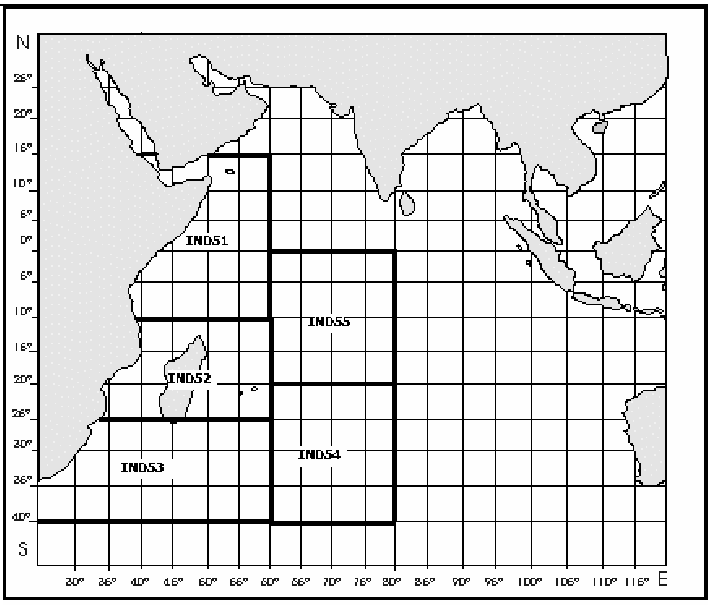


Figure 1. Geographic zones defined in the Indian Ocean for the final stratification and analysis of data.

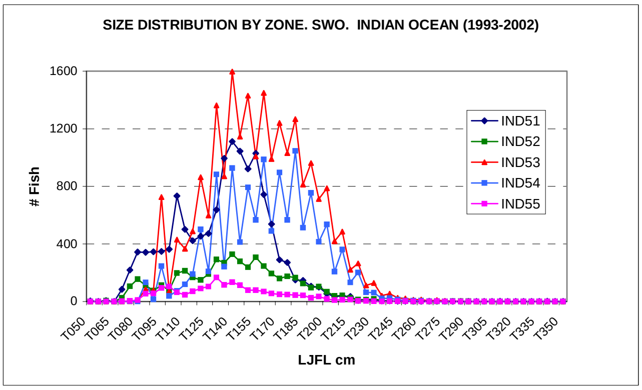


Figure 2. Total swordfish size distribution (LJFL cm) by combined sex for the geographic zone defined in the Indian Ocean for all years combined.

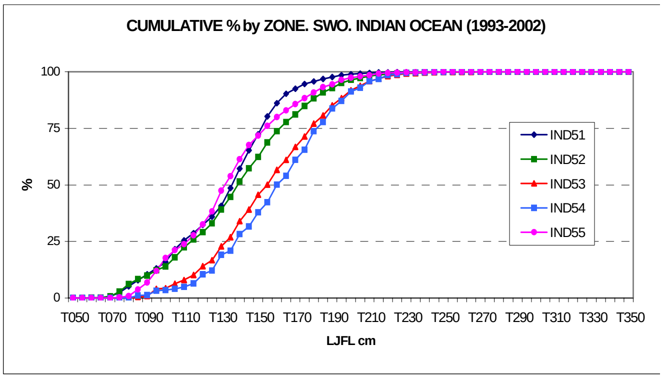


Figure 3. Total swordfish size distribution (LJFL cm) expressed in cumulative percentage by geographic zone of the Indian Ocean, for all years combined.

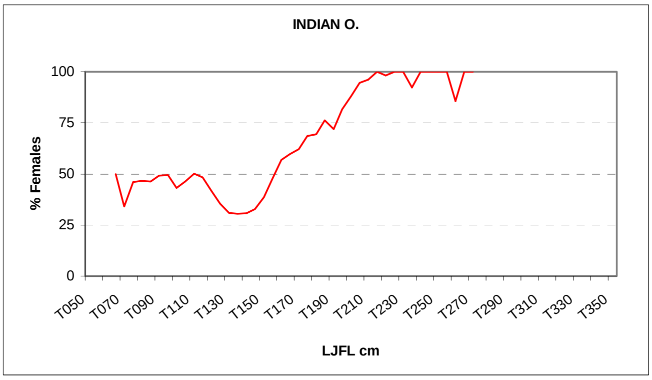


Figure 4. Overall pattern of sex ratio at size for the swordfish (percentage of females) in combined geographic zones examined from the Indian Ocean.

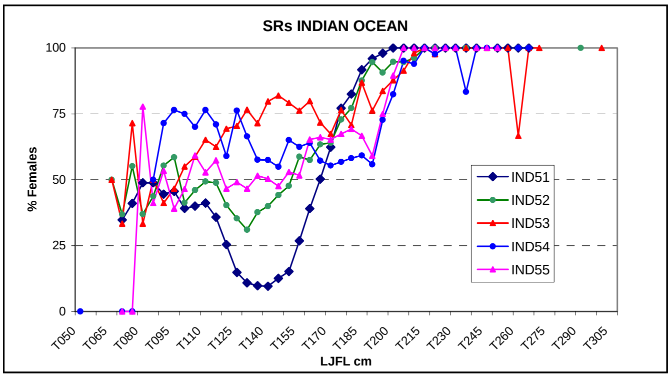


Figure 5. Pattern of sex ratio at size for the swordfish (percentage of females) calculated for the geographic zones defined in the Indian Ocean, for all the years combined.

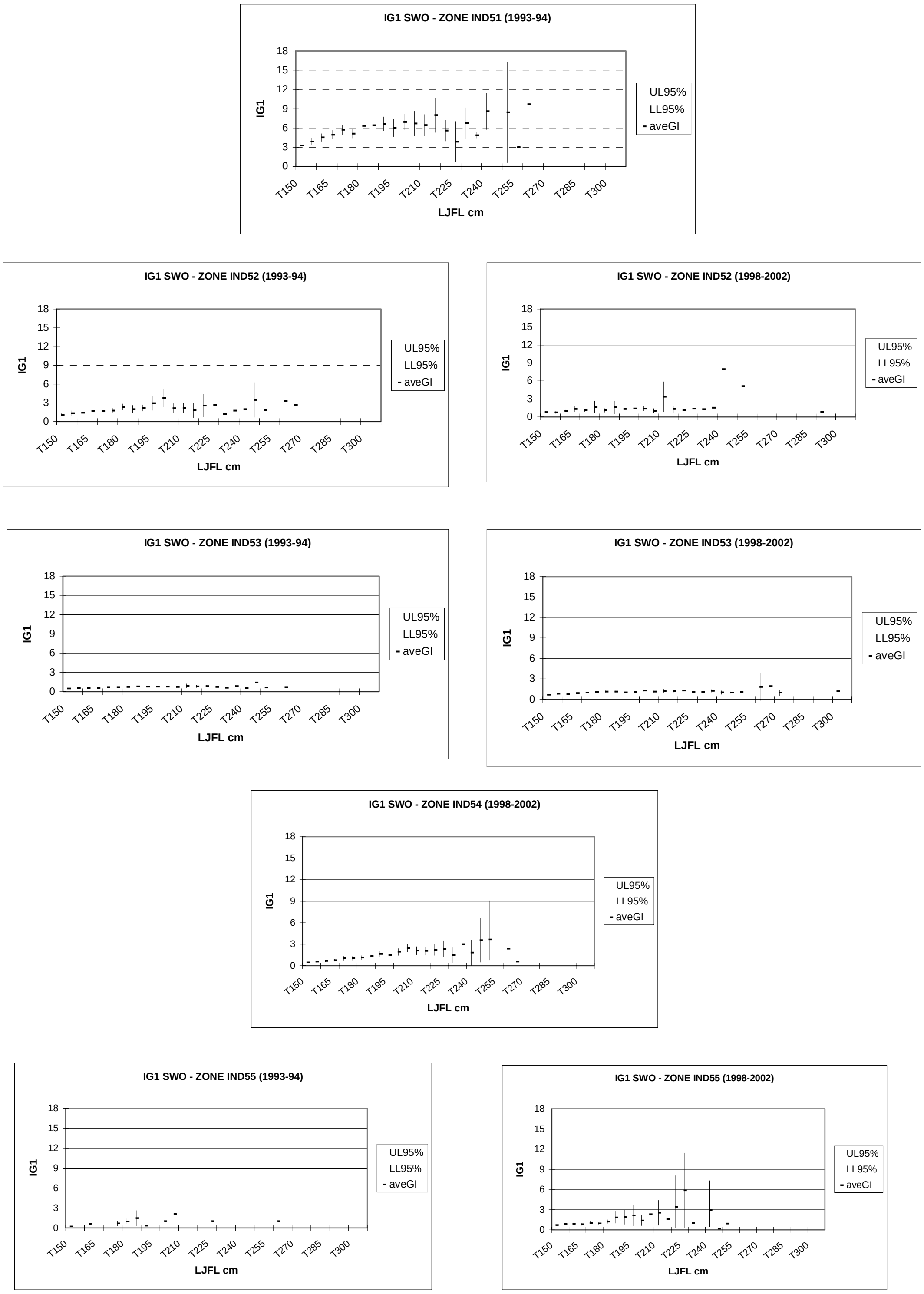
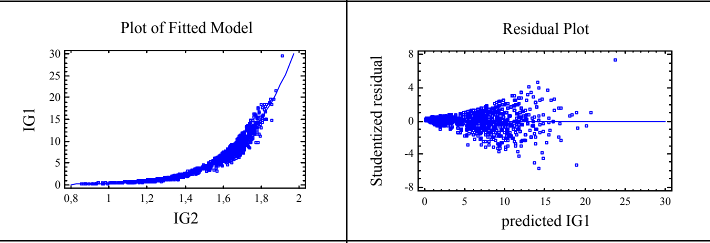
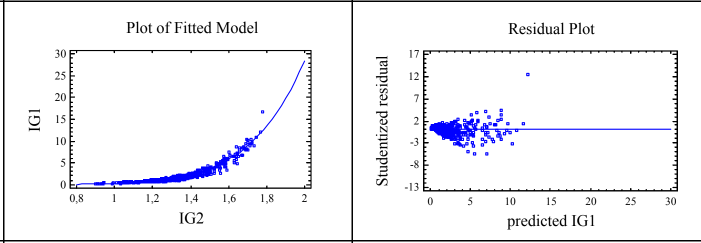


Figure 6. Average Gonadal Index values (ave GI) and their confidence intervals at 95% (UL95%: upper limit; LL95%: lower limit) by size class (LJFL cm), by geographic zone and for each time period analysed.

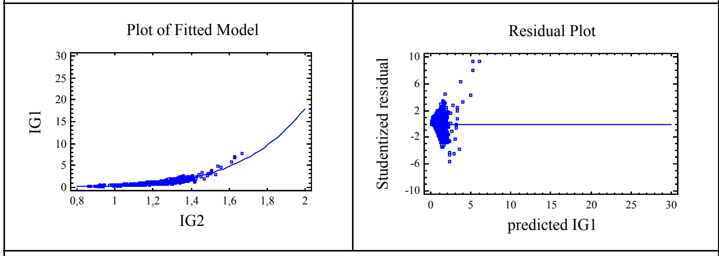
ZONE IND51



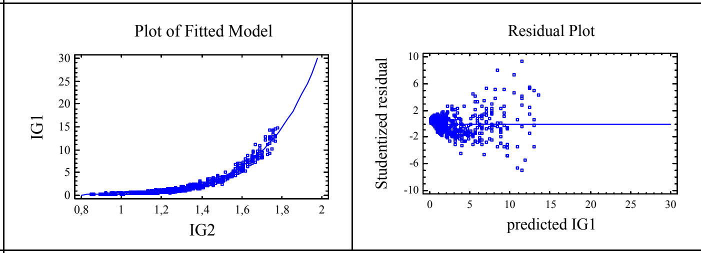
ZONE IND52



ZONE IND53



ZONE IND54



ZONE IND55

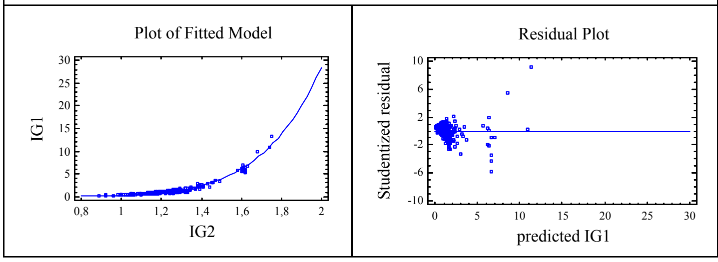


Figure 7. Fit of the Gonad Index values (GI1 and GI2) for swordfish and the resulting residuals after applying a non-linear regression model by geographic zone defined from the Indian Ocean.