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SIZE SEGREGATION, SEX RATIOS PATTERNS OF THE SWORDFISH (*Xiphias gladius*) CAUGHT BY THE SPANISH SURFACE LONGLINE FLEET IN AREAS OUT OF THE ATLANTIC OCEAN AND METHODOLOGICAL DISCUSSION ON GONADAL INDICES.

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ABSTRACT

This paper presents a description of the overall sex ratio at size for the swordfish (Xiphias gladius) caught by the Spanish surface longline fleet in some areas outside of the Atlantic (Pacific Ocean) which could be very useful for comparison with some Atlantic patterns described in previous papers. The results obtained from the sampling of 9693 swordfish specimens point to differences in sex ratio values, both overall and by size class as in the case of the Atlantic areas, between the areas of the NE Pacific (warm waters) and the SE Pacific (temperate waters). In addition, an analysis of the gonad weight of 3150 female swordfish specimens, resulted in gonad indices (GI), using different definitions, which are inter-related and preliminary equivalences were obtained. As in the case of the East Atlantic areas, the results suggest that swordfish females from the areas under study were not generally found to be in an advanced stage of reproduction, barring a few possible cases, which would imply that they were about to spawn. This result agrees with the situation observed in the eastern areas of the Atlantic where spawning females were not detected until now, suggesting that the spawning of the female swordfish is more rare or sporadic in eastern areas of the Oceans probably because of the more favourable thermal surface layer structure in westerns areas.

RÉSUMÉ

Le présent document fournit une description du sex-ratio global et du sex-ratio par classe de taille global obtenus pour l'espadon (Xiphias gladius) capturé par la flottille palangrière de surface espagnole dans des zones à l'extérieur de l'Atlantique (océan Pacifique), lesquels pourraient s'avérer utiles pour effectuer une comparaison avec certains schémas atlantiques décrits dans des documents antérieurs. Les résultats obtenus de l'échantillonnage de 9.693 spécimens d'espadon suggèrent des différences dans les valeurs du sex-ratio, à la fois global et par classe de taille, comme c'est le cas dans l'Atlantique, entre les zones du Pacifique nord-est (eaux chaudes) et le Pacifique sud-est (eaux tempérées). En outre, une analyse du poids des gonades de 3.150 spécimens femelles d'espadon a fourni des indices gonadiques (GI), selon différentes définitions, qui sont étroitement liés, et des équivalences préliminaires ont été obtenues. Comme dans le cas de zones de l'Atlantique est, les résultats suggèrent que les femelles d'espadon originaires des zones sous étude ne se trouvaient pas, en règle générale, à un stade avancé de reproduction, à l'exception de quelques cas éventuels. Les résultats confirment la situation observée dans les zones de l'Atlantique est où, à ce jour, il n'a pas été détecté de femelles en état de frai, ce qui suggère que la reproduction des femelles d'espadon est plus rare ou sporadique dans les zones est des océans, probablement en raison de la structure thermique plus favorable des couches superficielles dans les zones de l'ouest.

RESUMEN

Se presenta una descripción del sex ratio global y del sex ratio por clase de talla obtenido para el pez espada (Xiphias gladius) capturado por la flota española de palangre de superficie en áreas fuera del Atlántico (Océano Pacífico) los cuales son de utilidad a efectos comparativos con datos del Atlántico descritos en documentos anteriores. Los resultados obtenidos a partir de

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9693 peces espada muestreados sugieren diferencias en los valores de sex ratio, tanto global como por clase de talla como ocurre en el Atlántico, entre zonas del Pacífico NE (en aguas cálidas), y del Pacífico SE (aguas templadas). Además, a partir del peso de las gónadas de 3150 hembras de pez espada analizadas, se obtuvieron índices gonadales (IG), según distintas definiciones, que son relacionados entre si y obtenidas equivalencias preliminares. Como en el caso de áreas del Atlántico Este, los resultados sugieren que las hembras de pez espada de las áreas estudiadas generalmente no presentaban avanzado estado de reproducción, salvo algunos posibles casos,. Los resultados confirman la situación observada en las áreas del Atlántico Este donde no fueron detectadas hasta el momento hembras en puesta, lo que sugiere que la puesta de las hembras de pez espada es más rara o esporádica en las regiones del Este de los océanos, probablemente debido a una estructura térmica más favorables de las capas superficiales en las áreas del Oeste.

KEYWORDS

Swordfish, reproduction, sex ratio, gonadal index.

1. INTRODUCTION.

Although the swordfish would appear to have populations structured into different stocks among the different oceans and probably even within each ocean, this species very likely has similar physiological and oceanographic requirements in all of these oceans. Therefore information on the biology and behaviour of this species in a region or an ocean, regardless of whether it is geographically different from our preferential area of interest, may be a keystone in helping us to interpret these biological, physiological and behavioural characteristics, both on a local and global level.

The broad geographic distribution of the swordfish along with the generally limited geographic activity of most fleets is another drawback in obtaining samples covering a wide-ranging area on a spatial and temporal level. This is why it has been difficult to begin to carry out overall studies on reproduction and sex distribution. Recent analyses have attempted to focus on these aspects in a broad perspective, including data from Atlantic zones (North and South), the West Indian Ocean and the East Pacific (Mejuto et al., 1995), pointing, in some cases to common characteristic patterns among oceans.

During both the fishery prospecting surveys and the commercial fishery activity in the Pacific, scientific observers were on board the ships to monitor the fishery activity both from a scientific point of view as well as to collect biological data. The average annual observation time in this Ocean accounts for approximately 10% of the fishery effort (Mejuto & García, 1998; Mejuto & García-Cortés, 2001, in press).

A number of studies have described the spawning of the swordfish 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 cut-off points between 25º-30º N and 10º S. Spawning did not take place to the East of 100º W (Kume & Joseph, 1969; Miyabe & Bayliff, 1987, Nakano & Bayliff, 1992), nor did these fish spawn on the East Pacific coast (Weber & Goldberg, 1986; Ramon & Castro-Longoria, 1994). These works would suggest that the distribution of swordfish larvae is more prevalent in equatorial waters west of 120ºW with sea surface temperatures (SST) above 23º-24ºC, which would indicate that the fishes have a preference for the tropical West Pacific as a spawning ground (Matsumoto & Kazama, 1974; Nishikawa & Ueyanagi, 1974; Nishikawa et al., 1978, 1985).

So, the preference of swordfish for spawning grounds in tropical or subtropical zones to the West of the oceans is not new, as this behaviour has already been also reported in the Northwest and Southwest Atlantic as well as the in West Indian Ocean (Mejuto et al., 1994, 1995; Mejuto & García, 1997; Arocha & Lee, 1996).

Taking into account these limitations, in this document we attempt to shed light on the overall sex ratio (SRo) in specific areas of the Pacific Ocean, even though 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, we also examine the different sex ratios at size of the swordfish (SRs), whose spatial and temporal variability has been previously studied by several authors in the different oceans (Becket, 1974; Hoey, 1986, 1991; García & Mejuto, 1988; Lee, 1992). These patterns obtained could be very useful for comparison with other previously reported areas of the Atlantic and Indian Ocean.

The differences in sex ratio between the different size classes (SRs) have been considered as probably being due to possible natural differential growth and/or mortality by age between males and females (Anonymous, 1986, 1988). Other factors, however, such as differential migratory behaviour and differential distribution by sex, owing to the different oceanographic requirements of the swordfish associated with their size-sex and reproductive physiology, may explain the characteristic spatial and temporal variations that have been found in some oceans. In keeping with this, Hoey (1986) put forth a migratory hypothesis differentiating between males and females called "*size-temperature mediated sexual segregation*", which was later confirmed in works by other authors. This led them to suggest three general patterns in sex ratios at size, linked basically to 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 brought about the definition of the so-called "*biological regions*" for the Atlantic swordfish with a view to draw up data on stock assessment (Anonymous, 1999).

The data collected and presented in this paper comes exclusively from the activity of Spanish surface longline vessels in the East Pacific Ocean, which places a limit on how representative the samples are, as we do not have random data available collected from widespread areas and time periods. This adds yet another obstacle to the task of interpreting and attempting to generalise the results. A study of different sources of information from other fleets, in addition to a comparison with research from other areas is essential in order to draw general conclusions on the behaviour of this species.

This paper also aims to provide a preliminary analysis of the different gonad indices (GIs), traditionally defined in this species (Kume & Joseph, 1969; Hinton et al., 1997), based on standard length measurements (LJFL) recommended by ICCAT and to offer a better definition of the possible areas favoured by this species to carry out reproduction and to determine the reproductive condition of female swordfish.

2. MATERIAL AND METHODS.

The data used in this paper are based on information obtained through our on-board observer program on surface longliners in the Pacific. The program recorded data from 1990 to 2001 as well as information collected during Experimental Prospecting Expeditions that took place in zones and time periods when the activity of the Spanish surface longline fleet was sporadic or non-existent. The information was initially compiled in a 5ºx5º/month format.

A total of 9693 swordfish specimens were sampled to collect biological information from the North Pacific (between 0º-5º N and 95º-125º W) and the South Pacific (between 15º-35º S and 70º-80º W). These two broad geographic zones were the ones that were eventually used in the final data stratification, taking into account latitude and sea surface temperature (**Figure 1**).

The standard size lower jaw-fork length (LJFL) was measured on board to the lowest centimetre and then grouped into 5 cm size classes adjusted to the lowest cut-off point of each class (Miyake & Hayasi, 1978). Graphs of the size distributions of the fishes sampled were drawn up by geographic region. Also calculated was the cumulative percentage of the size classes sampled by area, zone and quarter to facilitate the comparison of the distributions. The eye-fork length (EFL) was calculated when required, from the LJFL value using the equation:

EFL=-8.259+0.930*LJFL (Taylor & Murphy, 1992).

During the processing of the fish on board, which consisted of emptying cavities and removing gills, fins, tails, head, etc., the scientific observers identified *"de visu"* the sex of the swordfish. Previously standardised identification criteria as established by the observers to sex swordfish were used to avoid biased identification, particularly in the smallest sizes, which are the most prone to error when the observer is not properly trained.

The overall sex ratio (SRo) for combined sizes by area and time period analysed as well as the sex ratio at size (SRs)/area/time period were obtained. Sex ratios were defined as : SR= Sample [females/(males + females)]*100, (Mejuto et al., 1995).

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

In the analysis of the sex ratios, however, we did, in fact, consider the variables area and quarter (Q1, Q2, Q3, Q4), defined as calendar quarters (January, February, March, etc.), despite the fact that the area factor would appear, in general, to have a greater impact on the variability of the SRs than the time factor (Mejuto et al., 1994; Mejuto et al., 1995; Turner et al., 1996). In the North Pacific, the only samples available were from Q1 and Q4, whereas in the South Pacific samples were collected in all of the defined quarters.

Female gonads were weighed on board with dynamometers having an accuracy of approximately 15 g. The purpose of this paper is not to provide an exact definition of the size at which the Pacific swordfish attains its first sexual maturity, but rather it aims to focus on the reproductive condition of the females sampled here. For this reason, we decided to analyse the different gonad indices (GIs) obtained for the called 'North' and 'South' Pacific zones, restricting this study to female swordfish specimens measuring 150 cm (LJFL) (or 130 cm EFL) or greater, as this is the minimum size at maturity observed in females in the Atlantic Ocean.

The size of 175 cm LJFL (154 cm EFL) would correspond to the size at first sexual maturity (Arocha & Lee, 1996) in the North Atlantic, while the size at first maturity based on 601 female swordfish sampled in the Pacific Ocean was estimated at 143 cm EFL (160 cm LJFL), (DeMartini, 1999).

The female gonad indices were defined :

KJ = (W gonad / LJFL ^3) * 10^4, based on Kume & Joseph (1969)
HEFL= ln Wg / ln EFL (Hinton et al., 1997)
HLJFL= ln Wg/ ln LJFL (modifying the equation above)

where:
Wgonad = weight of both female gonads in grams.
LJFL= lower jaw-fork length in cm.
EFL= eye-fork length in cm.

Previous works suggest values of GI >=3.0 (Kume and Joseph, 1969) or GI >= 1.375 (Hinton et al., 1997) as an indication of reproductively active female swordfish. Such GI values were defined from gonads weight and size (EFL). In order to know the value of KJ as the threshold to be equivalent to a threshold value of Kume and Joseph (1969), both indices were adjusted by a simple linear regression.

The maximum, minimum and average GI values were calculated for each geographic zone. The paired values KJ and HEFL were compared by preliminary linear regression analyses and finally by non-linear regression using Marquardt's algorithm (Statgraphics *plus ver.* 4.1), to obtain approximate equivalencies between the two values for the this set of samples.

It was not possible to consider the variables year or quarter to calculate the GIs, since the number of observations was too scarce to offer an acceptable coverage of the different areas-time periods defined and did not allow comparisons to be made between months, quarters or years. Moreover, owing to the extremely low levels of the GIs resulting from most of the observations, it would be difficult to be able to produce spatial-temporal comparisons of any interest.

3. RESULTS AND DISCUSSION.

During the 1990-2001 period a total of 9693 swordfish were sexed, with a size range of 75-300 cm (LJFL), or 60-270 cm (EFL). Nearly 11% of the observations pertained to the 'North' Pacific with a total of 1026 specimens sampled. Around 89% of the observations came from the 'South' Pacific with a total number of 8667 individuals sampled.

Figure 2 shows size distribution (LJFL cm) by sex and males and females combined, by geographic zone. Their distribution in cumulative percentage and in 5ºx5º quadrants was also calculated to facilitate the comparison of the distributions (**Figure 3**). As in the case of the Atlantic and Indian Ocean, there were considerable differences between the size distributions in the different areas, especially in the areas classified as North and South. On combining these areas into zones (North vs. South), the cumulative percentage accounting for 50% of the size distributions in the quadrants of the North Pacific were grouped into smaller size classes (approx. 125 cm) than those from the South Pacific (approx. 150 cm), (**Figure 4**).

Figure 5 presents the cumulative percentage of the size distribution found in each geographic zone and quarter. In general, regardless of the quarter examined, the size classes of the specimens sampled in the North Pacific were concentrated into size classes that were smaller than those in the quarters analysed for the South Pacific, with the exception of Q1 in the South Pacific, where there was only a small number of specimens sampled (361 fishes).

Table 1 summarises the data by 5ºx5º area, classified as North and South zones (all months and years combined), the number of fishes sampled by quadrant and overall sex ratio values (SRo). 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, prove to be useful in providing a preliminary diagnosis to detect possible differences between the geographic areas analysed (Mejuto et al, 1995). The values of SRo = 41 % in the North Pacific and SRo= 53 % in the South Pacific, along with the resulting size distributions, would, in principle, -for want of a broader sampling size and a later significance test- suggest the hypothesis that the two areas have populations with different distributions by sex, based on the specimens caught using this gear.

Table 2 presents the SRo values by area and quarter and the number of specimens sampled. In the North Pacific the SRo values were generally found to favour males regardless of the quarter sampled (Q1 or Q4). In the South Pacific, however, the SRo corresponding to all the quarters of the calendar year hovered consistently around 50% (Q3) or leaned towards the females.

The SRs values by size class (LJFL cm) that were calculated by quadrant and geographic area are given in **Tables 3** and **4**. The resulting SRs values for the entire Pacific ocean indicate that females are predominant as of 170 cm (**Figure 6**), similar to the findings recorded in other oceans. When the 5ºx5º areas are combined into North and South zones, the SRs values are an indication that there are changes between the two zones (**Figure 7**). The percentage of females in the North Pacific was less than 50% for sizes under 200 cm LJFL. The opposite was true in the South Pacific area, where females were more abundant in size classes of over 150 cm LJFL. The overall SRs for each zone and quarter is depicted in **Figure 8**, where the high variability can be seen. A comparison of the different SRs found by quarter and zone is also presented for descriptive purposes (**Figure 9**).

In the North Pacific we may highlight the different sex ratio at size between Q1 and Q4 (Fig. 9.a), especially in specimens measuring less than 130 cm LJFL. This difference, however, may be attributed to the small number of specimens sampled in Q1 (326), meaning that many size classes are not properly represented.

In the South Pacific, the SRs corresponding to each quarter would appear to be relatively similar, with a slight difference in Q1, which may also be due to the small number of individuals sampled (361) (**Figure 9.b**).

Quarters Q1 and Q4 from the respective zones are compared in **Figures 9c** and **9d**. In Q1 the SRs from the two zones might be similar, however it is necessary to consider that a scarce number of specimens were sampled in the two zones during this quarter (**Figure 9.c**). In Q4, the SRs from both zones differ substantially in size classes of less than 200 cm LJFL (**Figure 9.d**). This might be attributable to a moderate concentration of male individuals in the captures from the North Pacific.

This SRs pattern from the North zone could be interpreted as being similar to the SRs pattern defined as characteristic of the reproduction zones in other oceans (Mejuto et al., 1995; Arocha & Lee, 1996), however it does not quite fit the expected pattern in a typical ‘reproduction zone’, after studying surface longline data from other oceans. The sampling size available is not yet high enough to be able to allow us to draw reliable conclusions. On the other hand, the GI values in this North zone are not generally indicative of spawning, except in a low percentage of females. As we are dealing with zones located in the East Pacific, we would expect these areas to present, “a priori” conditions that would not be very favourable to the processes of maturation and spawning. Moreover, males and females may exhibit differential behaviour, either because the females are distributed in deeper waters and are not accessible to this type of longline fishery, or owing to other causes. In this sense, a comparison of the data obtained from this gear with those from other gears in the same zones (deep longline, driftnets) would be extremely helpful in clarifying some of these aspects.

By observing the SRs values in the areas of other oceans, we were able to detect patterns that are characteristic of the SRs in other reproduction areas (biological regions, “spawning”), with a greater relative presence of males in the catch. However, the cause of this characteristic pattern in the SRs favouring males at certain sizes is still not clear, since it could be due to 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 root of this characteristic SRs pattern. The SRs value that clearly favours males of specific sizes, as is the case in the so-called “spawning” grounds of the Atlantic or Indian Oceans, might be due, for instance, to the increase in 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 to be 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 –males were at least three time more abundant in the “reproduction” region than in the “feeding” region. If we compare the relative abundance in number of fishes by sex between the two regions, we find opposing values. While 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 zones respectively (from Mejuto et al., 1995).

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

The maximum and average GIs, confidence intervals (95%) and sampling size for each zone defined in the Pacific (North and South) were calculated for a total of 3150 female swordfish specimens. To arrive at these figures we used specimens ranging in size between 150 cm LJFL (130 cm EFL) and 300 cm LJFL (270 cm EFL). **Table 5** presents a summary of the results from each zone and for the different GIs defined.

The linear regression between the KJ index and the index previously defined (Kume and Joseph, 1969) suggests for KJ index a value 2.09 as equivalent to the threshold 3.0 defined by Kume and Joseph (1969).

For the zone defined as the North Pacific, the only data available pertained to 157 females measuring between 150-240 cm LJFL (130-215 cm EFL). The following values were obtained: KJmed= 1.207 and KJmáx= 12.749, HEFLmed= 1.200 and HEFLmáx= 1.777, HLJFLmed= 1.171 and HLJFLmáx= 1.737. Of these 157 females, only 18 (11.5%) had a KJ >= 2.09 (all found in Q4) . However, there were 20 females (12.7%) with a HEFL equal to or greater than 1.375 (all found in Q4 except for 3 females in Q1), presenting a size range of between 165 and 240 cm LJFL in both cases.

For the zone defined as the South Pacific, data were available for 2993 females measuring between 150-302 cm LJFL (130-272 cm EFL). The following values were obtained: KJmed= 0.653, KJmáx= 2.238; HEFLmed= 1.164 and HEFLmáx= 1.481; HLJFLmed= 1.138 and HLJFLmáx= 1.737. Only 3 (0.1%) of these females were found to have a KJ >= 2.09, nevertheless, there were 66 females (2.2%) with a HEFL >= 1.375 (8 in Q1, 29 in Q2, 12 in Q3, 17 in Q4), with a size range of between 165-300 cm LJFL.

The resulting data for the total samples examined revealed that only 24% of the specimens having a HEFL>=1.375 also had a value of KJ >=2.09. On the other hand, 100% of the females with a KJ>=2.09 exhibited a HEFL >= 1.375. This would suggest that the KJ index is more restrictive than the HEFL index, when attempting to distinguish females that are on the verge of spawning. **Table 6** presents the different maximum and average GIs and the sampling size by 5º x 5º quadrants .

The HEFL indices and their corresponding HLJFL were calculated using the 3150 female specimens. Both of these indices can be adjusted by a simple linear regression between the HEFL and HLJFL values (HEFL= -0.0203913+0.994052*HLJFL). Therefore a value of HEFL=1.375, defined by Hinton et al. (1997) as the threshold, would be equivalent to a threshold value of HLJFL=1.346.

The paired values of KJ versus HEFL were also fitted to this set of data. The preliminary fits of linear regression were, in general, satisfactory for specimens having low gonad indices (KJ <2.09 or HEFL<1.375). However, as was to be expected, the indices proved less satisfactory for individuals presenting GIs over these thresholds, which were generally quite variable. Final adjustments by means of non-linear regression (Marquardt's algorithm) resulted in the following relation: KJ= 0.173764 * HEFL ^ 6.9491 (R2= 0.8047), which shows the lack of equivalence between the thresholds values defined (**Figure 10**). These results and the empirical data from the "de visu" observation of the gonads would indicate that it is necessary to review the maturity thresholds defined by several authors based on GIs. In order to do this, it would be advisable to employ new sets of data covering broader spatial-temporal areas and maturity size ranges. A comparison between thresholds defined from set of samples obtained in different oceans and size ranges must be interpreted with cautions.

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Table 1. Number of swordfish sampled by sex (F:females, M:males) and overall sex ratio (SRo) by area (5ºx5º square) for all years-monhs combined and by defined geographic zone: 'North Pacific' and 'South Pacific'.

Tabla 1. Número de peces espada muestreado (F:hembras, M:machos) y valores de sex ratio global (SRo) por área (cuadrícula 5ºx5º) para todos los años-meses combinados y por zona geográfica definida: 'Pacífico Norte' y 'Pacifico Sur'.

Quadrant	Lat	long	# F	# M	# (F+M)	SRo
NW	00	095	106	119	225	**47**
		100	24	27	51	**47**
		105	102	158	260	**39**
		115	54	97	151	**36**
		120	104	160	264	**39**
		125	16	44	60	**27**
	05	095	10	5	15	**67**
Total NW			***416***	***614***	***1026***	***41***
SW	15	080	539	344	883	**61**
	20	075	2321	2092	4413	**53**
		080	74	59	133	**56**
	25	075	451	558	1009	**45**
		080	61	37	98	**62**
	35	080	1120	1009	2129	**53**
Total SW			***4567***	***4100***	***8667***	***53***

Table 2. Number of fishes sampled by sex (F:females , M:males) and overall sex ratio (SRo) values by geographic area and quarter.

Tabla 2. Número de peces espada muestreados (F:hembras, M:machos) y valores de sex-ratio global (SRo) por área geográfica y trimestre.

			QUARTER 1				QUARTER 2				QUARTER 3				QUARTER 4			
Quadrant.	**Lat.**	**lon.**	**# F**	**# M**	**# (F+M)**	**SRo**	**# F**	**# M**	**# (F+M)**	**SRo**	**# F**	**# M**	**# (F+M)**	**SRo**	**# F**	**# M**	**# (F+M)**	**SRo**
NW	00	095	70	82	152	46,1									36	37	73	49,3
		100	24	27	51	47,1												
		105	26	37	63	41,3									76	121	197	38,6
		115													54	97	151	35,8
		120													104	160	264	39,4
		125	16	44	60	26,7												
	05	095													10	5	15	66,7
Total NW			**136**	**190**	**326**	**41,7**									**280**	**420**	**700**	**40,0**
SW	15	080													539	344	883	61,0
	20	075					1585	1320	2905	54,6	724	767	1491	48,6	12	5	17	70,6
		080													74	59	133	55,6
	25	075					346	465	811	42,7					105	93	198	53,0
		080									61	37	98	62,2				
	35	080	212	149	361	58,7	908	860	1768	51,4								
Total SW			**212**	**149**	**361**	**58,7**	**2839**	**2645**	**5484**	**51,8**	**785**	**804**	**1589**	**49,4**	**730**	**501**	**1231**	**59,3**

Table 3. Values of overall sex ratio (SRo) and sex ratio at size (SRs) for the swordfish by 5ºx5º square in the zone defined as the 'North Pacific'.

Tabla 3. Valores de sex ratio global (SRo) y por clase de talla (SRs) del pez espada, por cuadrícula 5ºx5º en la zona definida como 'Pacífico Norte'.

PACIFICO NORTE

SRo / LJFL	00095 NW 47,111	00100 NW 47,059	00105 NW 39,231	00115 NW 35,762	00120 NW 39,394	00125 NW 26,667	05095 NW 66,667	P.NORTE 41
115	66,667	0,000	27,778	83,333	66,667	40,000	50,000	48,077
120	60,000	50,000	40,000	50,000	57,895	33,333		48,611
125	50,000	25,000	55,556	100,000	31,250	33,333	50,000	41,463
130	53,333	50,000	42,857	40,000	40,000	20,000		43,284
135	44,444	50,000	50,000	16,667	33,333	25,000	100,000	38,462
140	41,667	40,000	33,333	0,000	42,857	33,333	100,000	36,957
145	40,000	50,000	12,500	40,000	57,143	50,000	0,000	39,130
150	42,857	50,000	50,000	57,143	44,444	0,000		44,898
155	42,857	50,000	45,455	20,000	16,667	0,000	0,000	34,146
160	40,000	66,667	33,333	0,000	25,000		100,000	30,303
165	27,273	100,000	62,500	40,000	16,667	0,000	100,000	33,333
170	29,167	100,000	27,273	25,000	27,778	33,333		28,986
175	44,444	100,000	0,000	0,000	18,182	0,000		19,444
180	46,154	100,000	40,000	0,000	30,000	0,000	0,000	34,146
185	33,333	100,000	0,000	0,000	38,462	0,000		31,034
190	58,333		25,000	0,000	37,500	100,000		38,710
195	66,667		0,000	42,857	50,000			50,000
200	60,000		0,000	66,667	50,000	100,000	100,000	53,846

Table 4. Values of overall sex rati (SRo) and sex ratio at size (SRs) of the swordfish by 5ºxº5 square in the zone defined as the 'South Pacific'.

Tabla 4. Valores de sex ratio global (SRo) y por clase de talla (SRs) de pez espada obtenidos, por cuadrícula 5ºx5º, en la zona definida como 'Pacífico Sur'.

PACIFICO SUR

SRo / LJFL	15080 SW 61,042	20075 SW 52,618	20080 SW 55,639	25075 SW 44,653	25080 SW 62,245	35080 SW 52,607	P. SUR 53
115	27,273	33,125	100,000	35,294	100,000	0,000	34,286
120	46,429	33,929	62,500	42,623	50,000	30,769	36,802
125	41,667	41,876	47,059	30,864	66,667	20,833	40,096
130	46,491	46,429	57,143	27,160	28,571	50,980	44,638
135	57,407	49,361	42,105	32,927	25,000	33,929	46,970
140	62,963	49,407	50,000	39,130	100,000	38,636	48,971
145	62,963	41,200	66,667	26,786	33,333	46,154	43,460
150	70,455	46,352	100,000	36,986	33,333	33,750	43,629
155	60,606	51,394	62,500	46,032	60,000	39,264	47,901
160	79,487	55,510	50,000	49,180	75,000	46,875	54,070
165	66,667	63,033	33,333	51,515	66,667	51,799	58,411
170	73,171	68,617	50,000	67,647	55,556	58,480	64,719
175	75,000	62,937	100,000	41,176	44,444	56,818	59,819
180	61,538	67,290	100,000	48,148	80,000	63,699	63,898
185	54,545	61,290	0,000	38,462	40,000	68,807	60,000
190	60,714	76,531	50,000	31,818	100,000	67,769	67,279
195	64,000	80,769		50,000	0,000	63,953	68,750
200	66,667	75,342		53,571	66,667	63,529	66,667

Table 5. Gonad Index values calculated according to the different definitions expressed for females greater than 150 cm (LJFL) in the areas included within the two zones difined as the 'North Pacific' and the 'South Pacific. Gonad Index values (GIs): average (aver. GI), maximum (max. GI), standard deviation (St. dev.) and number of females sampled (#sa).

Tabla 5. Valores de índices gonadales obtenidos según las diferentes definiciones realizadas, para hembras mayores de 150 cm (LJFL), de las áreas incluidas dentro de ambas zonas definidas como 'Pacífico Norte' y 'Pacífico Sur'. Valores de índices gonadales (GIs) : medio (aver. GI), máximo (max. GI), desviación estándar (St.desv.) y número de hembras muestreadas (#sa.)

	NORTH PACIFIC				SOUTH PACIFIC			
	aver. GI	max. GI	St.desv.	# sa.	aver. GI	max. GI	St.desv.	# sa.
	00095 NW				15080 SW			
KJ	0,99	8,75	1,58	55	0,60	2,24	0,37	245
HEFL	1,18	1,75	0,15	55	1,12	1,48	0,14	245
HLJFL	1,15	1,71	0,14	55	1,09	1,45	0,13	245
	00100 NW				20075 SW			
KJ	0,61	1,35	0,29	11	0,63	1,72	0,22	1358
HEFL	1,11	1,33	0,10	11	1,15	1,46	0,11	1358
HLJFL	1,08	1,30	0,10	11	1,13	1,43	0,11	1358
	00105 NW				20080 SW			
KJ	1,56	11,37	2,24	29	0,62	1,96	0,38	63
HEFL	1,22	1,75	0,21	29	1,13	1,44	0,14	63
HLJFL	1,19	1,71	0,21	29	1,10	1,41	0,14	63
	00115 NW				25075 SW			
KJ	2,11	12,75	3,60	18	0,70	1,62	0,25	299
HEFL	1,24	1,78	0,24	18	1,19	1,46	0,12	299
HLJFL	1,21	1,74	0,23	18	1,16	1,43	0,12	299
	00120 NW				25080 SW			
KJ	0,85	2,31	0,45	37	0,77	1,36	0,25	44
HEFL	1,20	1,42	0,11	37	1,22	1,40	0,11	44
HLJFL	1,18	1,38	0,11	37	1,19	1,38	0,11	44
	00125 NW				35080 SW			
KJ	1,62	2,59	0,99	4	0,68	1,66	0,20	984
HEFL	1,34	1,48	0,17	4	1,18	1,45	0,09	984
HLJFL	1,31	1,45	0,17	4	1,15	1,42	0,09	984
	05095 NW							
KJ	2,75	6,05	2,89	3				
HEFL	1,34	1,62	0,25	3				
HLJFL	1,37	1,66	0,25	3				

Table 6. Gonad Index values for females greater than 150 cm (LJFL) for the two zones defined as the 'North Pacific' and the 'South Pacific'. Gonad Index values (GIs) : average (aver. GI), maximum (max. GI), confidence interval (95%), standard deviation (St. dev.) and number of females sampled (#samp.)

Tabla 6. Valores de índices gonadales obtenidos para hembras mayores de 150 cm (LJFL) para ambas zonas definidas como 'Pacífico Norte ' y 'Pacífico Sur'. Valores de índices gonadales (GIs): medio (aver. GI), máximo (máx. GI), intervalo de confianza (95%), desviación estándar (St. Dev.) y número de hembras muestreadas (#samp.)

	NORTH PACIFIC			SOUTH PACIFIC		
	KJ	HEFL	HLJFL	KJ	HEFL	HLJFL
ave. GI	1,208	1,200	1,171	0,653	1,164	1,137
max. GI	12,750	1,777	1,737	2,239	1,481	1,451
CI (95%)	0,295	0,026	0,001	0,009	0,004	0,000
St.desv.	1,884	0,168	0,166	0,241	0,108	0,108
# samp.	157	157	157	2993	2993	2993

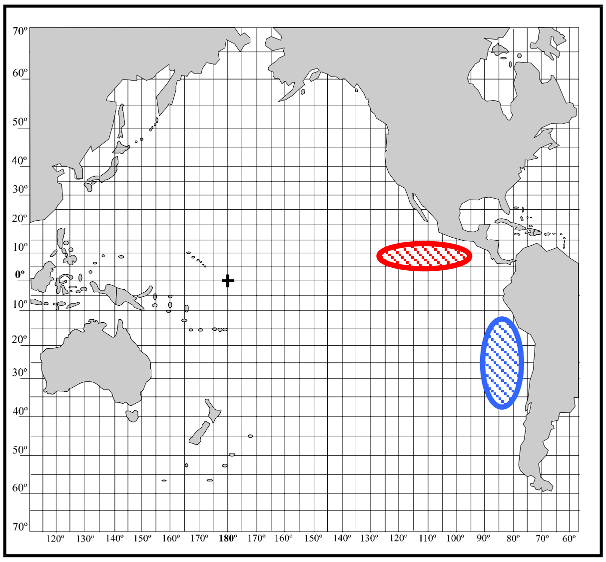


Figure 1. Geographic zones defined for the final stratification and analysis of data: 'North Pacific' (red) and 'South Pacific' (blue).

Figura 1. Zonas catalogadas para la estratificación final de datos y los análisis, agrupadas en las dos grandes áreas geográficas: 'Pacífico Norte' (rojo), 'Pacífico Sur' (azul).

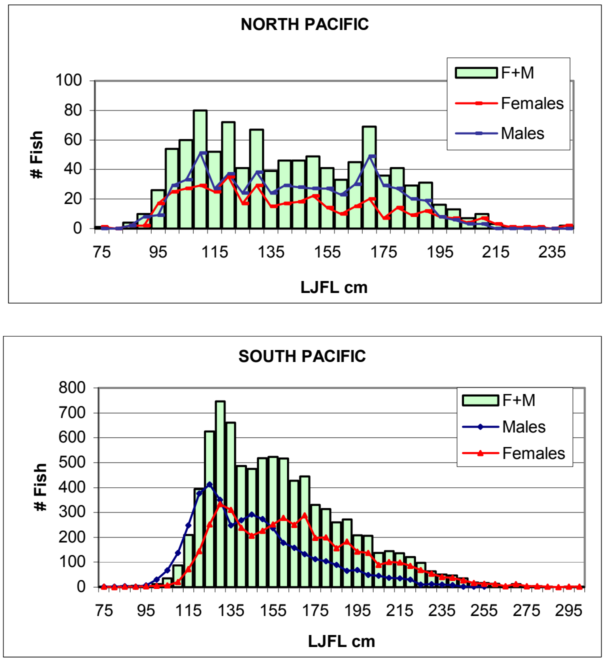


Figure 2. Swordfish size distribution (LJFL cm) by sex and combined sexes for each geographic zone, North and South Pacific.

Figura 2. Distribución de tallas (LJFL cm) de pez espada por sexos y sexos combinados para cada zona geográfica definida: Pacífico Norte y Pacífico Sur.

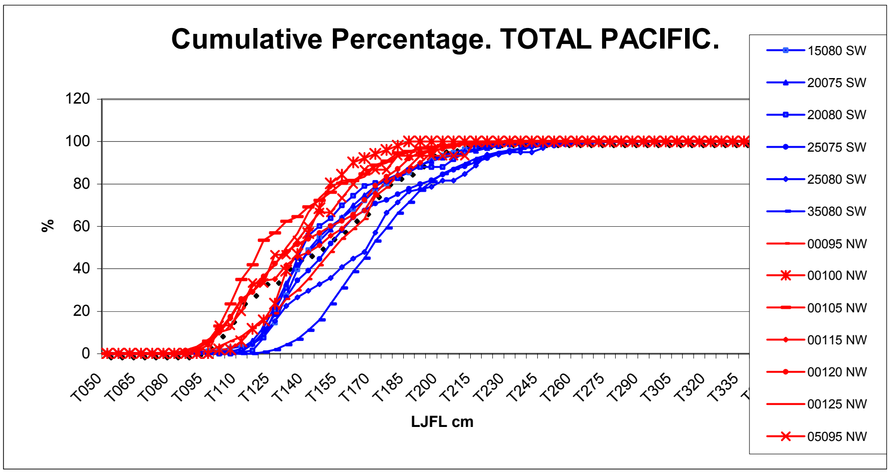


Figure 3. Swordfish size distribution (LJFL cm) expressed in cumulative percentage by 5º x 5º area in the Pacific Ocean.

Figura 3. Distribución de tallas (LJFL cm), en porcentaje acumulado, de pez espada por áreas de 5ºx5º en el Océano Pacifico.

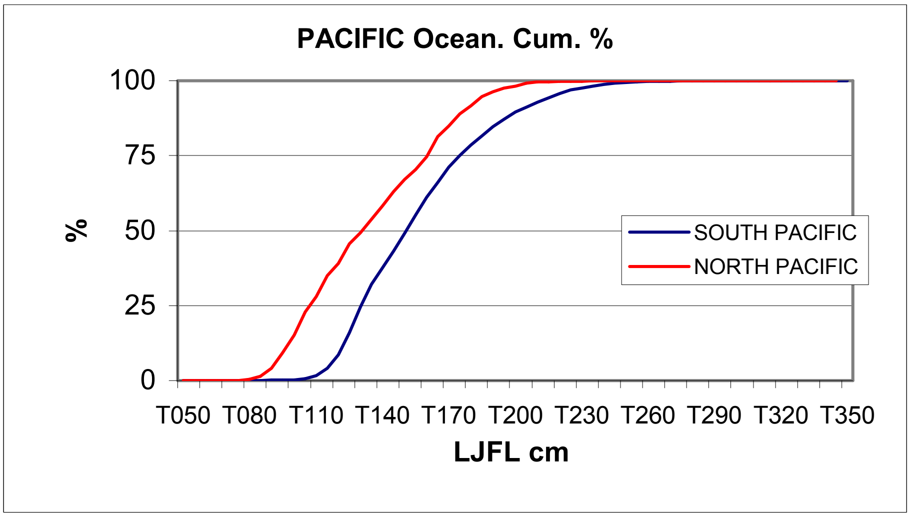


Figure 4. Cumulative percentage of swordfish size distribution (LJFL cm) in the geographic areas defined: 'North Pacific' vs 'South Pacific'.

Figura 4. Porcentaje acumulado de la distribución de tallas (LJFL cm) de pez espada de las dos zonas geográficas definidas: 'Pacífico Norte' vs 'Pacífico Sur'.

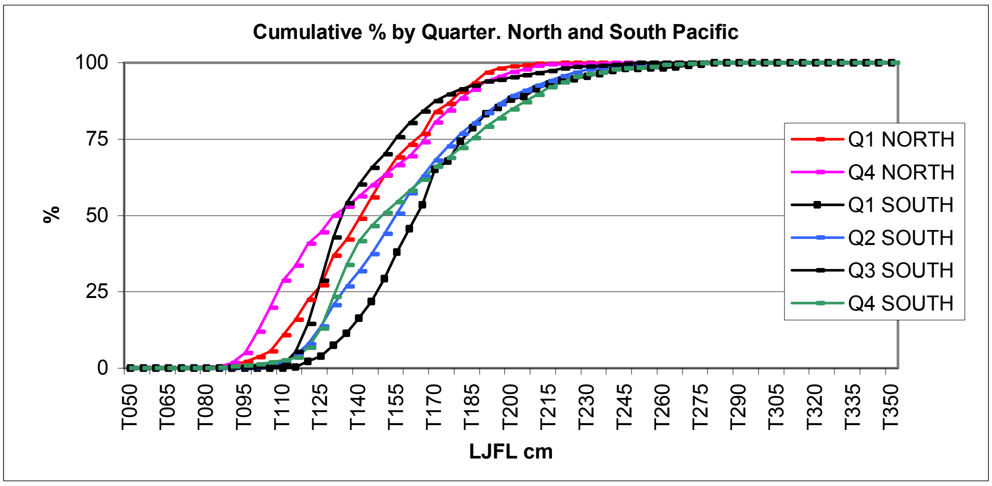


Figure 5. Cumulative percentage of swordfish size distribution (LJFL cm) by geographic zone and quarter.

Figura 5. Porcentaje acumulado de la distribución de tallas (LJFL cm) de pez espada por zona geográfica definida y trimestre.

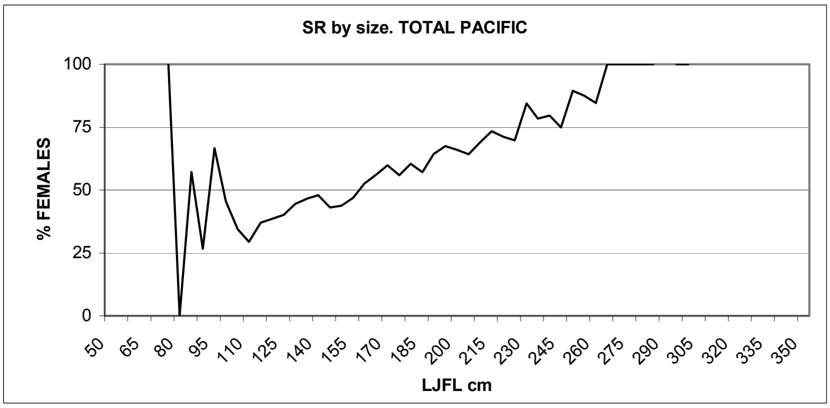
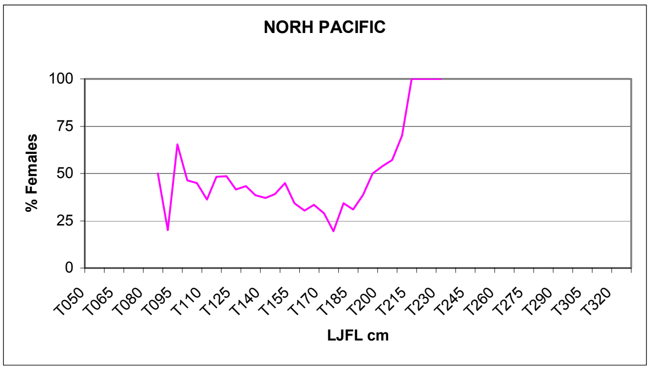


Figure 6. Overall pattern of sex ratio at size for the swordfish (percentage of females) in the areas of the Pacific examined (the zones defined as 'North Pacific' and 'South Pacific' have been combined).

Figura 6. Patrón general del sex ratio por clase de talla del pez espada (porcentaje de hembras) para las áreas observadas del Pacífico (las zonas definidas 'Pacífico Norte' y 'Pacífico Sur' han sido combinadas).



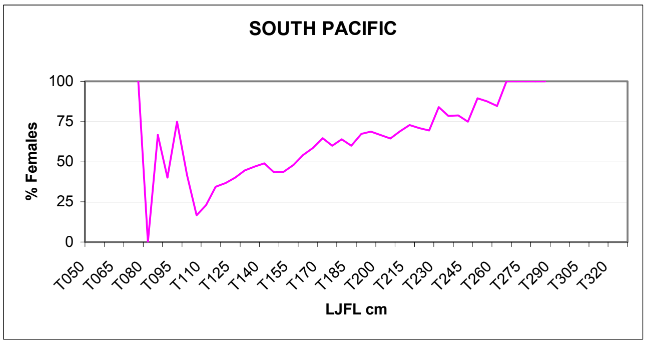


Figure 7. Overall pattern of sex ratio at size for the swordfish (percentage of females) in the zones defined as 'North Pacific' and 'South Pacific' respectively.

Figura 7. Patrón general del sex ratio por clase de talla del pez espada (porcentaje de hembras) para las zonas definidas como 'Pacifico Norte' y 'Pacífico Sur', respectivamente.

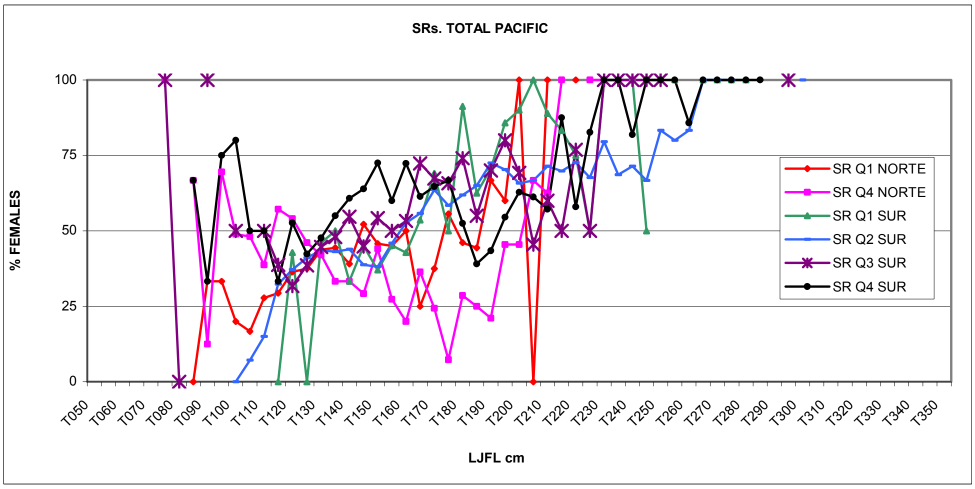


Figure 8. Pattern of sex ratio at size for the swordfish (percentage of females) calculated for each geographic zone defined ('North Pacific' and 'South Pacific') by quarter.

Figura 8. Patrón de sex-ratio de pez espada (porcentaje de hembras) por clase de talla, obtenido para cada zona geográfica definida ('Pacifico Norte' y 'Pacífico Sur'), por trimestre.

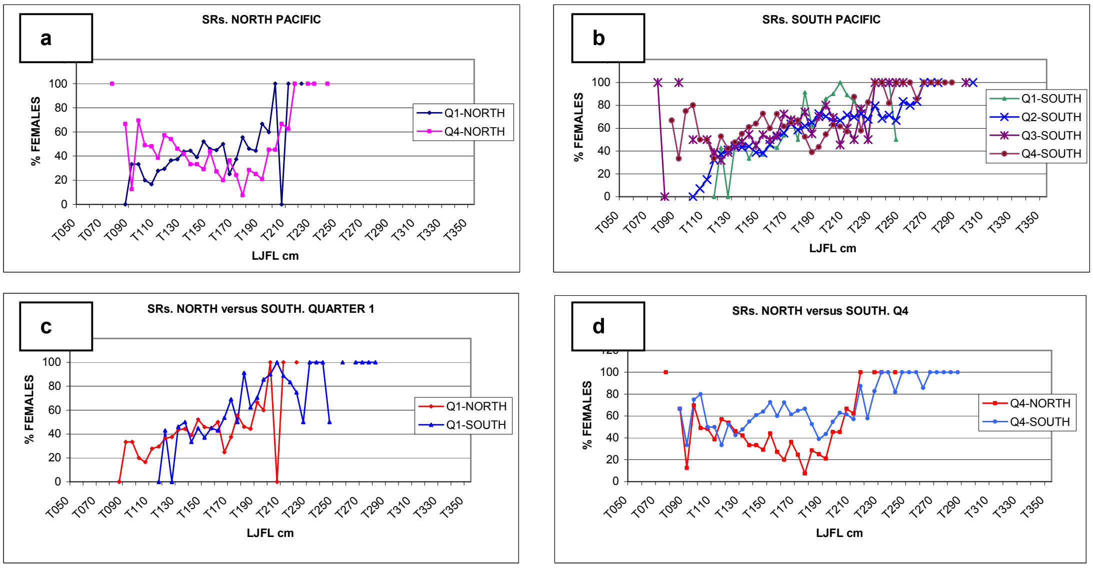


Figure 9. Compared values of sex ratio at size for the swordfish (percentage of females) by quarter and geographic zone. (a) Sex ratio at size for the swordfish in the North Pacific, quarters Q1 and Q4. (b) Sex ratio at size for the swordfish in the South Pacific for all quarters. (c) Sex ratio at size for the swordfish in the first quarter (Q1) for the North and South. (d) Sex ratio at size for the swordfish in the fourth quarter Q4 for the North and South.

Figura 9. Valores comparados de sex-ratio de pez espada (porcentaje de hembras) por clase de talla, por trimestre y zona geográfica. (a) Sex-ratio de pez espada por clase de talla para el Pacífico Norte, trimestres Q1 y Q4. (b) Sex-ratio de pez espada por clase de talla del Pacífico Sur para todos los trimestres. (c) Sex-ratio de pez espada por clase de talla obtenido en el primer trimestre (Q1) para el Norte y Sur. (d) Sex-ratio de pez espada por clase de talla obtenido en el trimestre Q4 para el Norte y Sur.

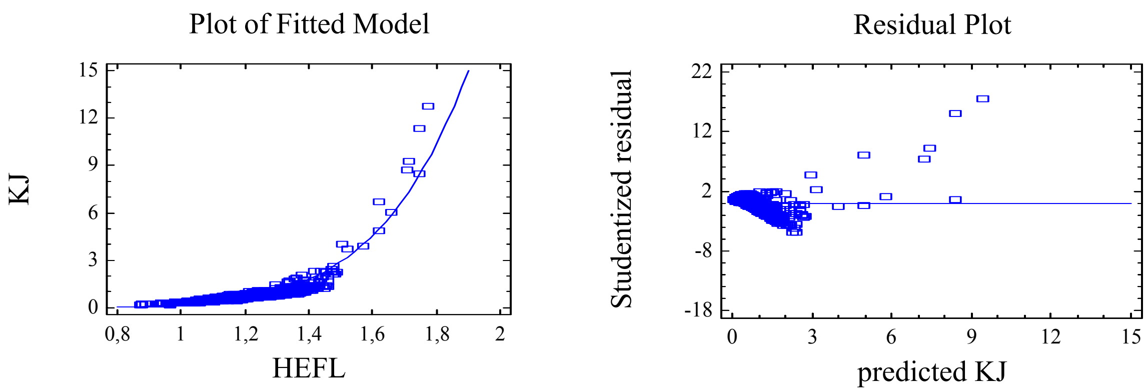


Figure 10. Fit of the Gonad Index values KJ and HEFL (Hinton et al., 1997) for the Pacific swordfish and the resulting residuals after applying a non-linear regression model.

Figura 10. Ajuste de los valores de índices gonadales KJ y HEFL (Hinton et al., 1997) para el pez espada del Pacífico y residuos obtenidos a partir de aplicar un modelo de regresión no-lineal.