A PRELIMINARY ANÁLISIS OF GONADAL INDICES OF THE SWORDFISH (XIPHIAS GLADIUS L.) IN THE ATLANTIC OCEAN

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SUMMARY

This paper describes the observations of gonadal indices carried out on a total of 13,739 fish, between the years 1986 and 1996 in the Atlantic Ocean. The results indicate that when attempting to define possible spawning areas based on the analysis of gonadal indices, it would be advisable to use adult individuals.

This paper concludes that females with ripe gonads or in spawning have a relatively wide distribution in the Atlantic, suggesting a possible continuity between the spawning areas reported for the Atlantic.

RÉSUMÉ


Le document permet de conclure que les femelles dont les gonades sont développées ou qui se trouvent en période de frai sont largement distribuées dans l’Atlantique, ce qui indique une éventuelle continuité entre les zones de frai observées dans l’Atlantique.

RESUMEN

Este documento hace una descripción de los valores de Índices Gonadales encontrados en una muestra de 13.739 peces, entre los años 1986 y 1996 en el océano Atlántico. Los resultados indican que, cuando se intenta definir las áreas de reproducción basándose en valores de Índices Gonadales, es recomendable el uso de individuos adultos.

El documento concluye indicando que las hembras con gónadas desarrolladas o en puesta presentan una distribución relativamente amplia en el Atlántico, sugiriendo una posible continuidad de las áreas de reproducción conocidas en el Atlántico.

INTRODUCTION

The definition of the spawning areas of the large pelagic fishes has been difficult to carry out in a short time period. The generally widespread geographical distribution of these species in addition to the limited geographical activity of the fleets has narrowed the possibility of collecting samples covering a broad spatial-temporal strata.

In the case of the swordfish (Xiphias gladius) reproduction studies have also been difficult to approach in an overall perspective. Several studies have been done with a restrictive spatial-temporal focus and they should be assessed as a whole. In this sense Rey (1988) offers an interesting bibliographic review and provides additional information on spawning areas of the swordfish in the Atlantic Ocean and Mediterranean Sea.

As regards the Atlantic Ocean, this author concludes that temperature appears to be the determining factor in the reproduction of the swordfish (between 23° and 26°C). However, it appears that the location of these reproduction zones could be closely linked to the research or sampling effort exerted.

Generally speaking, we could say that the reproduction areas of the swordfish have fulfilled this premise in that they are conditioned by the surface temperature. However, it is possible that this may not be the exclusive limiting factor.

With the introduction of new studies, the definition of spawning areas has broadened. A review of the available data up to the mid 1980’s indicated that the reproduction of the swordfish was carried out throughout the entire year at latitudes close to the Equator; that is between 10° N and 10° S, although these generally defined zones could be extended, which would coincide with the corresponding summer season in each hemisphere (Rey, 1988).

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Additional data recently provided by Mejuto & Hoey (1991), de la Serna et al. (1992), Arocha et al. (1994) Arocha & Lee (1995, 1996), de la Serna et al. (1996), to name a few, have served to supplement the available information and to give us a more overall view of this spawning behaviour.

The purpose of this paper is merely to provide a preliminary analysis by mapping the Gonadal Index values found in extensive zones of the Atlantic and to contribute to the improvement of some possible spawning areas of this species.

MATERIAL AND METHODS

This paper describes the observations carried out on a total of 13739 fishes between 1986 and 1996. The data pertaining to 1986 and 1987 were collected in commercial ports taking advantage of the landings of the traditional fleet. (Garcia & Mejuto, 1986). The rest of the observations were carried out during 21 trips by scientific observers on board the long distance surface longline vessels which dress the fish on board.

The combination of all the years made it possible for us to have samples during every month of the year, except February.

The areas observed are located between 45°N and 35°S latitude and 45°W and 5°E longitude. The data were first classified into sub-trips (a group of consecutive sets carried out during the same trip). Where a sub-trip was carried out in several 5°×5° squares, the data were assigned to the square having the greatest number of sets. If the number of sets was the same, the data were assigned to the 5°×5° square having the lowest latitude.

When the sub-trip was carried out in between two months, it was assigned to the month having the greatest number of sets. If the number of sets was the same, the data were assigned to the earlier month.

The temporal analyses by quarter were carried out by grouping the following months:
Quarter I : January-February-March
Quarter II : April-May-June
Quarter III : July-August-September
Quarter IV : October-November-December

The gonadal index have been defined as follows:

\[ GI = (Wg/LJ-FL)^{+3} \times 10^{-4} \times 10^{-4} \] (Kume & Joseph, 1969)

Where Wg is the weight in grams of both gonads and LJ-FL is the size of the fish in cm. Gonadal indices of over 3 have traditionally been considered to be spawning females or with ripe eggs.

Size was obtained using a gauge or metric tape measure to the nearest centimeter. Gonad weights were calculated in the landing ports using a precision scale. On board the vessel, however, the weights were determined with dynamometers. Individual data were later grouped together by size classes of 5 cm, using the lower limit in each size class (Miyaake & Hayasi, 1978).

The Gonadal Index values (GI-mean) and (GI-max) were obtained for each sub-trip and size class. The results obtained in each sub-trip were later considered in two size groups: fishes measuring less than 165 cm (small) and fishes measuring 165 cm or over (large).

For each of these size groups (small, large), the mean GI-mean and GI-max values were obtained based on the gonadal indices for each size class. Those mean values were considered to be representative of the gonadal indices found in each sub-trip and regarded as an observation in the 5°×5° square of the corresponding month.

When several observations were available in the same square-quarter, the mean values of all the available observations were calculated, weighting the GI-mean and GI-max values by the number of fishes sampled in each observation. These values, which we will call the overall GI-mean (Glo-mean) and overall GI-max (Glo-max) have been considered as representative of the total observations carried out in the same square-quarter or in the same square-year when it is a yearly analysis.

RESULTS

Table 1 provides a summary of the information pertaining to the ranges of gonadal index values found, as well as the number of fishes sampled per quarter and size group analyzed.

Several graphs have been drawn up to show the areas sampled and the zones where there were values of over 3 on the overall mean Gonadal Index and overall maximum Gonadal Index (Glo-mean, Glo-max).

The squares marked on the graphs indicate the zones that have been sampled. The numbers on the inside refer to the number of fishes sampled. The dotted squares refer to the zones having gonadal indexes of over 3.

Figures 1A and 1B show zones where a Gonadal Index of over 3 was attained for the size group called "small" (less than 165 cm). The data from all the years and quarters have been combined to offer an annual view.

Figures 1C and 1D provide the same information for the size group called "large" (165 cm or over). The individuals included in this "large" size group could be defined as potential spawners.

The mean gonadal index values (Glo-mean) of the "large" group (LJ-FL=165cm) (Fig 1C) can give us an idea of the areas where it is highly probable that swordfish will spawn. The maximum gonadal indices (Glo-max) may also provide information on the areas in which females in the reproduction process are likely to be found (Fig 1D).

The type of data processing used, based on the calculation of means, results in two similar figures with the potential spawning areas shown in Fig 1D being only slightly larger than in Fig 1C.

Figure 2 (A,B) provides quarterly information on the gonadal indices obtained (Glo-mean, Glo-max) for the "small" size group (LJ-FL=165). As was expected there are very few zones-quarters observed having values higher than three, for this size group.

Figure 3 (A,B) provides quarterly information on the gonadal indices (Glo-mean, Glo-max) obtained for the "large" size group (LJ-FL=165 cm). This group of individuals considered to be potential spawners have values of over 3 in broad areas of the Atlantic and during the four quarters of the year.

DISCUSSION

This paper presents a preliminary analysis of the two size groups, which, for practical purposes, have been called "small" and "large". As expected, data on the "small" group are relatively scarce so far as defining possible spawning areas, and only a few squares have gonadal indices of over 3 (Fig 1A, 1B).

Recent studies report that the minimum length at maturity observed in females was 150 cm (LJ-FL) and the proportion of mature females reaches 50% maturity at 175 cm (LJ-FL) (Arocha & Lee, 1996). Thus, earlier research suggests that the size of first maturity (50%) could be found around 165-200 cm (Garcia & Mejuto, 1988) or 182 cm (Taylor & Murphy, 1992).

The results confirm that when attempting to define possible spawning areas based on the analysis of gonadal indices, it would be advisable to use adult individuals at the size of the first maturity or over.

In this sense, the Gonadal Index data from the Madeira area (Gouveia, pers. com.), all of which belonged to females with primordial ova, fluctuate widely depending on the size (Fig 4). The data point to a size class of 155 cm as the smallest recommendable size to be used in the study of the gonadal indices.
The results from the yearly analysis of data (Fig. 1 C D) confirm a large part of the information reported by other authors, with reference to the fact that in the Atlantic spawning takes place in waters close to the Equator (Ueyanagi et al. 1970; Rey, 1988). These zones show a certain conformity to the West of 10° W longitude up to zones in the vicinity of Brazil. It should be pointed out that in this study there were very few mean Gonad indices higher than 3 in the innermost areas of the Gulf of Guinea. This is probably due to the lack of stability in the surface layers of the sea, caused by the cold Benguela current and the coastal upwelling processes. However, the presence of female spawners in this area has been described orally by several skippers of fishing vessels.

Rey (1988) reports that spawning in the swordfish is related to the sea water temperature (between 23° and 26°C). However, it is possible that the greater homogeneity of the surface water masses in areas to the west of the equatorial-tropical band, which have a thermocline at a greater depth (Mejuto et al., 1994), also play an important role, favouring the spawning processes in females.

Quarterly data from the "large" size group (LFL>165 cm) suggest that spawning is protracted throughout the year. However, the amount of data available makes it impossible to reach conclusions on the seasonality of the reproductive processes. Nonetheless, it is necessary to underline certain areas with high gonadal indices found in the SW Atlantic between 15°-35° S 20°-35° W, at least in the 1st and 2nd quarter, which may possibly be linked to warm water masses favoured by the Brazil current. In keeping with this, Amorim & Arfelli (1980) and Ueyanagi (1970) report females that spawn in nearby areas and in those closer to the coast.

Some authors have found very particular sex-ratio values in some swordfish spawning areas (Mejuto et al., 1995; Arocha & Lee, 1996). However, we must be careful with the interpretation of these sex-ratio values. It is possible that spawning females may have a different behaviour towards the surface longline either because they are distributed at deeper levels, or because of changes in the feeding behavior. Therefore, the fact that these females are not accessible to the longline should not necessarily imply that they are absent from these fishing areas. Thus, it would be of great interest, for the purpose of comparison, to carry out analyses on sex-ratios by size and gonadal indices of other fleets that use different gears.

Based on the overall data available, we can conclude that females that have ripe eggs or are spawning have a relatively wide distribution. This well-known distribution has broadened geographically with the increased availability of samples and data. We must not rule out the existence of a continuity between the spawning areas of the Caribbean-Antilles (Arocha & Lee, 1996; Rey, 1988) and the spawning areas reported in the equatorial zones and of these zones with the areas of the SW Atlantic. Figure 5 is a brief summary of the available information to date on the spawning areas of the swordfish in the Atlantic.

The spawning areas of the swordfish may possibly be linked to the distribution of the isotherms underneath the surface layers. The area included within the isotherm of 25 degrees, at a depth of 50 meters (Figure 5) could give us a better idea than surface isotherms about the areas where the swordfish is most likely to spawn.

LITERATURE CITED


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<th>Size group</th>
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Table 1. Range of values found in the Gonad indices, number of fishes sampled by quarter and size group analyzed.
Figure 1. Sampling areas (squares marked), areas with Gonadal Indices greater than 3 (dotted squares) and number of fishes sampled (within the square), for all years and months combined. (A) Glo-mean, LJFL<165 cm. (B) Glo-max, LJLF< 165 cm. (C) Glo-mean, LJLF>=165 cm. (D) Glo-max, LJLF>=165 cm.
Figure 2a. Sampling areas (squares marked), areas with Gonadal Indices greater than 3 (dotted squares) and number of fishes sampled (within the square), by quarter for all years combined. Glo-mean, LJLF<165 cm.
Figure 2b. Sampling areas (squares marked), areas with Gonadal Indices greater than 3 (dotted squares) and number of fishes sampled (within the square), by quarter for all years combined. Glo-max, LJLF<165 cm.
Figure 3a. Sampling areas (squares marked), areas with Gonadal Indices greater than 3 (dotted squares) and number of fishes sampled (within the square), by quarter for all years combined. Glo-mean, LJFL\textgreater=165 cm.
Figure 3b. Sampling areas (squares marked), areas with Gonadal Indices greater than 3 (dotted squares) and number of fishes sampled (within the square), by quarter for all years combined. Glo-max, LJFL>=165 cm.
Figure 4. Mean Gonadal Index values and corresponding confidence intervals (95%) by size class, for females with primordial ova. (from Gouveia pers. comm.).

Figure 5. Map of isotherms at 50 meter depth (above) and descriptive map of the known spawning areas of the swordfish (below) according to data provided by different authors and this paper.