IOTC 2006-WPB-11

AN OVERVIEW OF RESEARCH ACTIVITIES ON SWORDFISH (*XIPHIAS GLADIUS*) AND THE BY-CATCH SPECIES, CAUGHT BY THE SPANISH LONGLINE FLEET IN THE INDIAN OCEAN.

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ABSTRACT.

This paper presents some of the most pertinent results obtained over the last few years from the research carried out on the swordfish and bycath species in the Indian Ocean on the basis of data taken from the Spanish surface longline fleet. Information on the activity of this fleet updated for 2003 and 2004 is also given. New information on the reproduction of the swordfish based in large sampling coverage is provided. Reproduction areas of swordfish in the Indian Ocean are proposed, which seems to be restricted to western areas based on data for gonadal indices, sex-ratios at size and other available information taken from observers. Characteristic patterns of spawning-type sex-ratio at size are also identified in this Ocean. The spawning type is observed for the areas exhibiting high values on the gonadal index. A review of the available information on the tagging programs conducted on the swordfish and associated species is also done, with a comparison of the recapture rates obtained. Information on by-catch species, accidental by-catches, finning practices and the reproductive parameters of Prionace glauca are also summarized.

Key words: swordfish, surface longline, sex ratio, reproduction, bycatch, finning, blueshark.

1. INTRODUCTION.

The working groups to assess stocks usually consider only the fishery information in their databases and the most recent scientific papers presented. Oftentimes, however, there is a tendency to lose the retrospective perspective on the advancement of the knowledge of the biology of the species in different geographic zones. The loss of "historical memory", both in terms of databases –years that become excluded from the analyses- as well as the biological information available in the different zones is one of the identified problems. The advancement of the knowledge of these species is usually linked to the amount of resources invested in research, to the creation of voluntarily coordinated international research teams and to the constancy with which the scientists participate in these forums. This constancy in lines of research, research teams and budgets seen in some of the forums has led to great headway being made in the acquisition of biological knowledge of the swordfish on an international level in recent decades. The advancement of knowledge on a specific stock has been very useful in helping us to propose lines of research in other geographic areas or to recommend realistic methodological approaches and priorities that are in proportion to the resources and budgets for investigation.

This document aims to present a brief summary of some of the research activities carried out by these authors in recent years on the swordfish in the Indian Ocean, as well as on other species which are captured accidentally in surface longline fishery targeting swordfish. Also included is updated information and the cartography related to the activity of the Spanish surface longline fleet during the most recent years (2003 and 2004). New data are provided on the reproductive behavior of the swordfish on the basis of a major sampling effort conducted in this Ocean involving biological and reproductive parameters. In addition, on the basis of our experience in other Oceans, we offer our reflections on a number of different issues to contribute to the debate and the planning of research and assessment activities for the swordfish.

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2. BACKGROUND OF FISHING ACTIVITY.

The Spanish surface longline fleet targeting the swordfish in the Indian Ocean began its activity in September of 1993. A total of 5 ships under the Spanish flag began prospecting the fishery of this resource in the international waters of the Indian Ocean and the operation lasted until August, 1994 in a zone comprising 15ºN and 38º S and between 35º-60º E longitude (FAO 51). The fishing zone of the commercial Spanish flag vessels in subsequent years was approximately the same, although it did not generally include the Northern Indian areas. Only one of these boats continued in the commercial activity on a partial basis in 1995 (for approximately 1 month) and in 1996 (for approximately 2 months). In 1997 two vessels fished in this zone of the Indian Ocean for about 6 months. In 1998 a total of 8 vessels directed their fishing effort at the swordfish in the same area FAO 51 for a period lasting approximately 9 months. Two commercial vessels started a new fishery prospecting survey in international waters in October 1999 in southern areas 60º - 75º East longitude (FAO51), which lasted until January 2000. In addition, 7 vessels were fishing in 1999 throughout the year (GARCÍA-CORTÉS & MEJUTO 2000).

During the year 2000, the number of vessels that carried out fishing activity in the Indian Ocean increased to 11, although most of them alternated their activity between this ocean and others. Only two of these vessels have carried out continuous fishing activity in the Indian Ocean over the course of the years 1998-2000. In 2001 roughly 10 Spanish vessels continued their activity in waters of the Indian Ocean, but most of these vessels alternated between this and other oceans to carry out their fishery (GARCÍA-CORTÉS *et al.* 2003a). A total number of 16 Spanish longline vessels carried out fishing activity in the Indian Ocean during the year 2002 (GARCÍA-CORTÉS *et al.* 2004). During the year 2003 a total of 19 vessels had been fishing in the Indian ocean, 4 of these vessels participated in a prospecting survey from June to December, in southeastern areas from 80º East reaching 110º East longitude (FAO57). Finally a total of 24 Spanish vessels carried out most of their fishing activities throughout the South Indian Ocean in the year 2004.

The outcome of the surveys carried out by Spanish vessels in the Indian Ocean aimed at finding new fishing grounds has been positive. One of the objectives was to reduce the fishing effort in areas of the West Indian Ocean where the swordfish stock appeared to be subjected to increased fishing pressure by several international fleets, precisely in areas where we would expect to find a higher number of juveniles of swordfish. The results obtained prompted Spanish vessels to move gradually each year to this fishery in this ocean towards areas of the East Indian Ocean where the fishing effort carried out by all international fleets seemed to be less intense and where the fishing pattern was expected to be better in biological terms.

The basic data for the scientific monitoring of this fleet in this ocean since the beginning of the fishing activity in the Indian Ocean have been collected by an Information and Sampling Network (RIM) of the Spanish Oceanography Institute (IEO). At the same time, the observer program on board commercial vessels was extended from the Atlantic to the Indian Ocean for compiling information *in situ* on the activities of these periods-areas where fishing takes place and for getting biological information of the individuals of swordfish caught. Most of the basic scientific information is reported voluntarily by the fleet.

The fishing gear used by the Spanish surface longline vessels from the beginning of their activity in the Indian Ocean until the year 2001 was the "traditional longline", equipped with a plurifilament main line and clips. However, during the year 2001 the boats switched to the "American longline", a slightly modified version of the "Florida style" longline (HOEY *et al.* 1988), with a mean of 1,100 hooks per set, which are more hooks than reported in the standard Florida Style gear and considerably fewer than the number of hooks used in the "traditional" Spanish longline style.

The vessels operating in the Indian Ocean average 263 GRT, 39 meters in length and with a power of 812 HP. All species caught are dressed on board, frozen and stowed. The tunas are gutted processes in some cases.

3. MATERIAL AND METHODS.

The basic data used in the scientific monitoring of the Spanish fleet in the Indian Ocean were mostly taken from information provided voluntarily by the fleet. This information provides basic data (catch, effort, position, etc.). In addition, the individual weights of each swordfish caught is frequently reported. This information is combined with data taken from other sources, such as, landings, transfers, etc., and biological data provided by the on-board scientific observers for scientific purposes, based on a census of the catches taken. All of this information is computerized into related data bases. General information regarding the basic characteristics of the vessel, the trip, and the set is recorded along with biological data for the overall swordfish catch and each individual specimen, sometimes including species associated with this catch as well. This information is analyzed specifically and is included in the preparation of the basic tasks in 5ºx5º squares reported to the IOTC. The basic data provided by scientific observers on board the vessels that conducted the prospecting fishery and on commercial trips are biological information and size data (LJFL: lower jaw-fork length) of all the specimens of swordfish taken on board.

Fishing activity on Swordfish.

The information from the 1993-2004 period was processed using the standardized methodology recommended for these types of long distant longline fleets (MIYAKE 1990), in the same final format as reported within the ICCAT and the IATTC. The basic data were processed in a final format of 5ºx5º/month and sent to the IOTC, such us catches (number and round weight), catch-at-size by class (LJFL: 50-350 cm), nominal effort (thousands of hooks) and number of fish sampled. The overall annual nominal CPUE was calculated from the beginning of the fishery in the Indian Ocean using the overall catch and effort data, as well as the mean nominal CPUE from each stratum of 5ºx5º area and month. The nominal CPUE in number by size category (CAT) was plotted defining three size categories. Size CAT 1: sizes LJ-FL <= 120 cm., Size CAT 2: sizes 125 cm<= LJ-FL<=160 cm., Size CAT 3: sizes > 160 cm LJ-FL. Archview © software was used to prepare descriptive plots which include the nominal fishing effort, catch levels (in number and round weight), CPUEs by 5ºx5º squares. Additional information on methodological bases can be found in previous papers (GARCÍA-CORTÉS & MEJUTO 2000, GARCÍA-CORTÉS *et al*. 2003a, GARCÍA-CORTÉS *et al*. 2004)

Swordfish reproduction parameters.

The specimens sampled during the periods 1993-1994 and 1998-2002 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, 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 (figure **1**). The sex ratios were defined based on the samples obtained: SR = [females/(males+females)]*100, (MEJUTO *et al*. 1995). The overall sex ratio was obtained for all the sizes combined (SRo) by zone, as well as the sex ratio at size (SRs) for each zone because the area factor generally appears to have the main impact on the variability in the sex ratio at size (SRs) (MEJUTO *et al*. 1994, 1995; TURNER *et al*. 1996; ORTIZ *et al*., 2000). Methodological bases on the swordfish size, weight, size distributions, sex identification, gonadal state in females, gonadal indices (GIs) for females etc., are described in GARCIA-CORTES & MEJUTO 2003.

The values GI1 >= 2.09 (MEJUTO & GARCÍA-CORTÉS 2003a), equivalent to the 3.0 threshold defined by KUME & JOSEPH (1969) based on EFL and to the GI2 >= 1.375 (defined by HINTON *et al.* 1997), would be an *a priori* indication of females in active reproductive stages, according to the respective authors. For the purpose of comparing zones and the data set obtained from females equal to or greater than 150 cm LJFL (131 cm EFL), graphs are provided with average GIs by size class and their respective confidence intervals (95%) in the two periods (1993-1994 and 1998-2002), for those zones for which data were available. The prevalence of the different GI1 ranges for females LJFL>150 cm has also been plotted by 5ºx5º square for both periods and updated with information of new GI1 data obtained during 2003 and 2004 in eastern areas of the Indian Ocean. Three GI1 ranges have been defined for plotting: GI1=<2.09, 2.09=<GI1<5 and GI1>=5.

Fishing activity on Bycatch.

From 1993 to 2004, the breakdown into species of the most prevalent bycatch landed, such as the blue shark *Prionace glauca* (PGO) and the shorkfin mako *Isurus oxyrhinchus* (IOO) was mainly performed based on the information provided by the fleet itself in their voluntary reports, since their taxonomic identification is normally easy, reliable, commonly practiced and categorized for the market. However, the identification of species belonging to other groups such as sharks (SHK), billfish (BIL), others (OTH) and tunas (TUN) was fundamentally based on the information provided by on-board observers, who have a limited spatial-temporal coverage (GARCIA-CORTES & MEJUTO 2001, 2005). For descriptive purposes, the group of species of large pelagic sharks was grouped together under a generic label called SHK, comprised primarily of individuals from the family Carcharhinidae (mainly *Prionace glauca:*PGO) and from the family Lamnidae (basically *Isurus oxyrhinchus:*IOO). The TUN group includes a collection of tuna species. The group of billfish group (BIL) includes species from the Family Istiophoridae. The OTH collection groups several species, which, on some occasions, have not been identified (generally of very little commercial value) or identified at the species level, but caught very sporadically. More complete details of the methodology applied to compile these data are provided in GARCÍA-CORTÉS & MEJUTO 2001, 2005.

Finning.

The term 'finning' was frequently interpreted all over the world as the cutting off of shark fins and the non-retention of the rest of the body or trunks which are discarded. The Spanish surface longline fleet has not carried out this practice for many years now. In fact, the trunks (dressed weight) of virtually all the sharks caught, along with their respective fins, are stowed on board. Therefore the profitable use of the different parts of a shark is probably better than that of the teleosts in most international fisheries. Data by species, body weight (kg) and fin weight (gr), among other variables, were recorded mostly by observers during some of the commercial trips of the Spanish surface longline fishery across all the oceans, taking advantage of the commercial routine protocol on board which is common to all oceans. The ratios -conversion factor (FACTOR) and the percentage of fins (PCT_FIN)- were calculated by species for different types of body weights when available, where: Body weight = Fin weight * FACTOR, and the PCT_FIN = (Fins weight / (body weight *1000)) * 100. Preliminary ANOVA were done in order to evaluate the statistical significance of some of the factors which could affect the rates obtained. Around 8,500 raw records were available but only the results for some of the most important species were presented (MEJUTO & GARCÍA-CORTÉS 2004), in the event that they might be useful on a preliminary basis for all areas where the Spanish longline flag fleet is fishing.

Blue shark reproduction parameters

The wide geographic distribution of the Spanish surface longline fleet and its scientific monitoring with on board observers have provided us with sporadic and specific observations of 81,560 specimens of *Prionace glauca* (PGO) between 1993 and 2003, focusing on the reproductive parameters of PGO observed in different zones of the Atlantic, Indian and Pacific Oceans (MEJUTO & GARCÍA-CORTÉS 2005). The areas examined were located between 40ºN-35ºS: 55ºW-15ºE in the Atlantic, between 5ºS-30ºS : 35ºE-75ºE in the Indian Ocean and between 25ºN-40ºS : 85ºW-135ºW in the Pacific Ocean. The observations were initially grouped into 5ºx5º squares. Subsequently, to accommodate the different analyses, the data were tentatively classified into 22 zones and also into 5 regions: North Atlantic Region (ATLN): zones 01,02,03,04,06,91,92,93. Central Atlantic Region (ATLC): zones 07,08,09,10. South Atlantic Region (ATLS): zones 11,12,13,15. Indian Ocean Region (INDI): zones 52,53,54,55. Pacific Ocean Region (PACI): zones 40,44 (figure **2**). More information on methodological details can be found in the paper previously cited.

Incidental catch.

In order to estimate, in a preliminary manner, the potential impact of the longline activity of the Spanish fleet on turtles and sea birds, specific observations were carried out on 4 longliners during 5 long trips The fishing areas observed for this purpose were between 10º - 35ºS and between 35º-110ºE with a total of 626,400 hooks observed during 555 sets (GARCÍA-CORTÉS & MEJUTO 2005).

Tagging-recapture.

The tagging program (TP) carried out on swordfish by the IEO started in 1981 in the Atlantic ocean and includes both scientific tagging surveys and opportunistic tagging done by scientific observers on board commercial longliners and by crews, taking advantage of the live individuals caught (MEJUTO 1991, GARCÍA-CORTÉS *et al*. 2000, 2003b). This TP was extended in 1985 to other oceans and to the tagging of sharks and Istiophoridae, which are bycatch of this fishery. The purpose of these TP was to gain knowledge of these species and broaden the scope of the tagging activities started in the 1970s by several countries (CASEY 1985).

Also given is information on the number of individuals of swordfish and billfish marked by opportunistic tagging in the Indian Ocean by scientific observers on board commercial vessels and by the fleet itself, from the outset of the activity in this Ocean until 2004 inclusive.

A summarization of the information collected under the IEO TP for sharks (up until February, 2004) and information supplied on the total number of shark recaptures obtained were presented in MEJUTO *et al*. 2005. The shark recapture rates were estimated in percentage on the basis of the number of individuals tagged and their respective recapture levels in all fishing areas of the Spanish fleet (Indian Ocean and other areas). More specifically, the recapture rates were calculated with the two methods of tagging used by our TP, opportunistic tagging aboard commercial fishing vessels and the tagging cruises-surveys in the Atlantic ocean, the latter being interpreted as the recapture rate obtained in the scientific tagging surveys. The total recapture rate was obtained by summarizing the recaptures resulting from the two methods of tagging and compared among species.

4. RESULTS AND DISCUSSION.

Fishing activity on Swordfish

Although the activity of this fleet in the Indian Ocean until 2002 was restricted to areas west of 80º E, in subsequent years an expansion eastward reached the 95º E during the year 2002, 100º E during 2003 and 110º E during 2004. Figure **3** shows the new zones that the Spanish fleet has gradually started having access to grouped into four-year periods as well as the zones where the commercial vessels have carried out some pilot fishing operations. In 2004 a commercial surface longline vessel carried out some sets in northern areas of the Indian Ocean.

Table **1** presents a summary of the number of Spanish surface longline vessels per year which fished generally in the Indian Ocean from 1993 until 2004, the annual swordfish catch levels in number and round weight (kg) (figure **4**), nominal effort exerted (in thousands of hooks), number of individual fish sampled, estimation of mean round weight and sampling coverage in percentage.

Table **2** compiles the overall nominal CPUE per year in number of swordfish individuals (CPUE#) and in kg of round weight (CPUEw) obtained over the course of the 1993-2004 period (no processed information is available on the 1997 effort). Figure **5** shows the annual fluctuations observed during this 1993-2004 period. The highest CPUE observed since the year 2001 may be attributed to the fact that the fleet ceased to use the "traditional" style longline gear, replacing it with the new "American" style longline which offers greater catchability per hook (HOEY *et al.* 1988*;* WARD *et al.* 2000). A similar effect on the CPUE was also seen in other oceans when the CPUE is measured in relation to the number of hooks per set. These differences, however, seem to disappear or diminish substantially when the CPUE is measured per mille or per set (MEJUTO & GARCÍA-CORTÉS 2003b). All this information should be evaluate before standarization.

Some tables and figures presented in previous documents showed size distribution of swordfish by month and 5x5 degree format for the years 1988 and 1999 (GARCÍA-CORTÉS & MEJUTO 2000) and for the year 2001 (GARCÍA-CORTÉS *et al.* 2003).The size distribution of swordfish by month and 5x5 degree format from the start of this fishery until now has been sent to the IOTC. The high sampling rate obtained and the sampling system used resulted in good quality swordfish size information.

Previous documents also show plots of landings in number of fishes and in kg of round weight, as well as nominal effort in thousands of hooks set by the fleet during the years 1993-1999, 2001 (GARCÍA-CORTÉS *et al.* 2003) and the year 2002 (GARCÍA-CORTÉS *et al.* 2004) in 5x5 degree format (figure **6**). This paper also presents updated information in additional plots for swordfish landings and nominal effort for recent years, 2003 and 2004 (figure **7**). The greater fishing effort exerted by the Spanish surface longline fleet until 2002 appears to have taken place in western areas of the Indian Ocean. However, the geographic expansion of the Spanish fleet towards eastern areas of the Indian Ocean in 2003 and 2004 would imply that there was a spatial change in the strategy of this fleet.

Nominal CPUE in number of fishes and in kg of round weight have been previously plotted for the years 1993-2000 and 2001 (GARCÍA-CORTÉS & MEJUTO 2000, GARCÍA-CORTÉS *et al.* 2003) and for the year 2002 (GARCÍA-CORTÉS *et al.* 2004) (figure **8**). This paper also presents updated information in additional CPUE plots for recent years, 2003 and 2004 in 5x5 degree format (figure **9**). The low yields in round weight per thousand hooks found in the squares plotted from 1993-2000 correspond to the yields obtained using the 'traditional' longline gear which employed a large number of hooks (2000-2500 hooks per set) and contrast sharply with the high yields in round weight obtained in the 2001-2004 period, during which time the 'American' style gear was used (roughly 1100 hooks per set). Therefore it is wise to use caution when interpreting these graphs. Nevertheless, despite the change in gear, from the year 2001 onward, yields in weight obtained in the areas of the Indian Ocean have been relatively high. In fact, that year produced the highest yield observed by the Spanish fleet, in comparison with other oceans and years.

The catch rates (CPUE) in number of fishes per size category have been previously plotted for the year 2002 (GARCÍA-CORTÉS *et al.* 2004) (figure **10**). An update of the catch rates (CPUE) in number of fish per size category is presented for the years 2003 and 2004 (figure **11**). The values obtained by area for the three defined size categories show low CPUE values for CAT1 and higher values for CAT2 and CAT3, for the years plotted. The CAT3 CPUE seems to increase towards the eastern areas, which would explain the high CPUE in weight also observed (figure **9**). These differences between catch rates obtained for the different size categories could indicate that the thermal conditions of the surface sea layers of the new Spanish fleet fishing areas are not very suitable for small fish (LJFL<125) abundance or availability.

Swordfish reproduction parameters.

Previous paper have presented different reproductive parameters for swordfish from a total of 23,648 swordfish sexed during the 1993-2002 period in the Indian Ocean, within a size range of 50-300 cm (LJFL) (GARCIA-CORTES & MEJUTO 2003). The main conclusions drawn in those papers were as follows:

-The cumulative percentage of the size distribution by geographic zone suggested considerable differences in size distributions among the different zones defined (figure **1**). 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 (figure **12**).

-The overall sex ratio values (SRo) and sex ratio at size were summarized (for all the years combined and for the defined zones). Table **3** presents the overall sex ratio (SRo) values for each zone defined. The overall sex ratio can be useful in providing a preliminary visual diagnosis to detect differences between the zones analyzed. The SRo values were found to favour males by 29.5% in zone IND51, they were around 50% in zones IND52 and IND55 and between 65-75% in zones IND53 and IND54.

-The sex ratio at size cm LJFL values (SRs) for the Indian Ocean also showed different patterns between zones (table **3**, figure **13**). The SRs results obtained in zone IND51(spawning type) was corroborated by the high GI values found (average GI1=5.14, average GI2=1.46), which would suggest that this zone may be a possible reproductive and spawning region.

-From 6,870 females sampled in the two periods (1993-1994 and 1998-2002), equal to or greater than 150 cm LJFL (131 cm EFL), graphs were provided with the average GI1 shown by size class and their respective confidence intervals (95%) for the zones for which data were available (figure **14**). The graph representing zone IND51 stands out because of the high average GI1 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 observations but not in the general GI averages. 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.

-It was not possible to tabulate the qualitative '*de visu'* information from the different gonadal stages of the females analyzed for the data set from the 1993-94 period; therefore we could not calculate the prevalence of the different maturity stages. After reviewing the reports drawn up by the scientific observers (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). However, we were 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 **4**). 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 confirm that in these zones and during the time period analyzed, females are often sexually inactive or in the post-spawning stage. It has not yet been 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.

All this information provided in previously papers hypothesized that there were differences in distribution by sex of the population between the geographic zones, based on the SRo values along with the size distributions obtained and with the high variability of the SRo also detected in individuals caught by other fleets in the Indian Ocean (ANONYMOUS 2001). However, the information compiled in GARCIA-CORTES & MEJUTO 2003 came exclusively from the activity of the Spanish surface longline vessels, which limits the representativeness of the samples, as the data were not collected from wide areas/time periods where the swordfish are available. This presented an additional drawback when interpreting the results and attempting to make generalisations.

By observing the SRs values by areas in other oceans, we were also able to detect the so-called 'spoon shape' SRs patterns in the Indian Ocean (zone IND51 of figure **13**) which are characteristic of the reproduction areas ("spawning" type biological region) (MEJUTO *et al.* 1998), and clearly show a greater relative presence of males in the catches taken by surface longliners. However, the cause of this characteristic pattern in the SRs favouring males at certain sizes was not clear, since it could stem from changes in the local relative abundance (or catchability) between both 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. Data from some spawning Atlantic and Mediterranean areas have suggested higher catch rates of males but similar catch rates of females than in feeding areas, which would imply concentrations-more abundance (or availability)- of males in the catches taken in spawning zones.

The spatial and temporal variability of sex ratio at size (SRs) has been reported for decades by several authors in different oceans (BECKET 1974; HOEY 1986, 1991; GARCÍA & MEJUTO 1988; LEE 1992). The overall 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 among regions 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 NW Atlantic called "*size-temperature mediated sexual segregation*", which was later confirmed for all Atlantic areas in works by other authors using thousands of sex samples. 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 ICCAT definition of the so-called "*biological regions*" for the Atlantic swordfish for the purpose of preparing data for stock assessment (ANONYMOUS 1999) which were later corroborated via GAM models using the same set of data (ORTIZ *et al.*, 2000). 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 similar 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, in some areas of the NW Indian Ocean (MEJUTO *et al*. 1995), and also detected in some Mediterranean spawning grounds. Additional information from the Indian Ocean also found feeding patterns in the SW areas of Madagascar (ARIZ *et al.*, in press), as expected linked to the Agulhas current, flowing south within the southwest corner of the Indian Ocean and producing feeding concentrations of swordfish already known since decades a go from fishing data (FARBER 1988).

Figure **15** shows the levels of female swordfish sampled and the prevalence of the different GI1 ranges defined, by 5x5 square, obtained since 1993, including updated information for the years 2003 and 2004. Once again, this graph confirms the preliminary conclusions obtained previously in the sense that the zone between 5ºN-10ºS to the West of 60ºE exhibits a large quantity of females with gonads in an advanced or very advanced stage of maturation, where the high prevalence of individuals with GI1>= 5 would indicate that these females are extremely close to carrying out reproduction in a zone that is probably a swordfish spawning area. This high prevalence of GI1 is consistent with the mean GI1 values previously obtained for zone IND51 and with the '*de visu'* observations carried out to determine the presence of hydrated and transparent oocytes. Moreover, the SRs patterns obtained for this zone (spoon shape) are in keeping with the lower prevalence of females in catches and coincide with the size ranges of reproductive males. It can also be observed that there is a moderate number of females with GI1 ranges of over 2.09 in zones located to the West of 45ºE, between 60ºE – 80ºE, and to the South of 10ºS, which is consistent with the results obtained previously (these zones correspond to IND52, IND54 and IND55, where the previous results from the '*de visu'* observation exhibited a mixture of females in an advanced stage of maturation (5%), but not yet mature enough to spawn, and females in the post-spawning stage (roughly 4%)). Therefore, these zones to the East and West of the probable spawning area would indicate the movement of the swordfish immediately before and/or after spawning. Swordfish females sampled in areas to the South of these zones (South of 25º S) and in the areas located to the East of 75ºE, have GI1 levels of less than 2.09, which would suggest that these are areas in which reproduction will not take place soon. More samples are needed for us to be able to include the time variable in future analyses.

The definition of the zones located between 5ºN-10º S and to the West of 60ºE as probable swordfish reproduction areas is also supported by the preference of swordfish for reproductive areas in tropical or subtropical zones located in the western zones of oceans. 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 2003a, 2003c, AROCHA & LEE 1996) and specifically during the period from October to April around Reunion Island (POISSON & TAQUET 2000; POISSON *et al.* 2001).

It is essential to have access to other information sources from other fleets and to make comparisons with papers and experiences from other areas to be able to draw some general conclusions on the reproduction behaviour of this species.

Fishing activity on Bycatch

From the outset of its activity in the Indian Ocean, in addition to the target species *Xiphias gladius* (SWO), the Spanish surface longline fleet has been catching other species such as billfish, tuna and pelagic sharks, the latter being of great importance, both because of their abundance as well as their increasing economic worth (MEJUTO & GONZÁLEZ-GARCÉS 1984; MEJUTO 1985).

The relative prevalence of the by-catch species observed from 1993 to 2003 has been previously described for this fishery in the Indian Ocean (GARCÍA-CORTES & MEJUTO 2001, 2005). The information of 2004 updated in this paper confirms the conclusions previously obtained. The main conclusions drawn can be summarized as follows:

-The group including the three most prevalent species in the catch of the Spanish longline fishery, which are also those of highest commercial interest for human consumption (SWO+PGO+IOO), represented, on average, 90% of the total landings made in the Indian Ocean from 1993 to 2004. This level was very similar to that observed in the regions of SE Pacific, where the rate is estimated to be around 91%.

-The group of species considered as bycatch of the swordfish (*Xiphias gladius*) surface longline fishery in the Indian Ocean between 2001 and 2004 accounted for 49% of the total catch landed in weight (table **5**). This percentage turned out to be slightly lower than that observed for the Atlantic Ocean (CASTRO *et al.* 2000, MEJUTO *et al.* 2002a, 2002b). This was to be expected in view of some activities targeting PGO carried out in certain areas of the Atlantic.

-During the1993-2004 period the bycatch consisted mainly of large pelagic sharks (SHK) which accounted for an average of roughly 47% in weight of the total catch landed for all the species combined. The average landing of the tuna group (TUN) accounted for 4.0%. The group of species with the lowest economic value (OTH) represented around 1% as did the billfish group (BIL).

-The volume of landings in weight per group of species in relation to the bycatch as a whole (excluding the target species) amounted to an average of 86% for the SHK group, 11% for the TUN group, 2.0% for the OTH group and 1% for the BIL group. The bycatch analyzed during the above mentioned period was made up fundamentally of PGO, with an average landing of 63% of the total bycatch and 71% within the SHK group.

As expected, all of these conclusions suggest that the amount of SHK was much more prevalent as compared to the other groups. However, it was lower than what was observed in the landings of the Atlantic as a whole, where the SHK group represented between 95% and 99% of the bycatch, depending on the year of observation (CASTRO *et al.* 2000, MEJUTO *et al* 2002a).

On some occasions, it was impossible to calculate the breakdown of the catch into species, due to the rapid expansion of the fleet to new fishing areas in this Ocean and to the limited geographical areas covered by the observers. In 2003 the observed areas were mainly aimed at the new experimental fishing areas in the Eastern Indian Ocean (between 85º-110º E and 20º-35º S), where only 4 vessels were fishing and the information obtained from these trips in eastern areas was not applicable to the entire fleet operating in other areas of the Indian Ocean.

The amount of landed pelagic sharks has become increasingly important over the past few years for many fleets in all oceans. This is due to their higher relative abundance in number and biomass in most oceans and fishing areas; the loss of discards of these species in many fleets which used to be numerous in the past (MEJUTO & GONZÁLEZ-GARCÉS 1984, MEJUTO 1985), the improvements in the conservation systems and the upward trend of the price of these species and its derivative products in international markets (MEJUTO & GARCÍA-CORTÉS 2004). Therefore, these species, which have been caught intensively for many decades, are now present in international markets in the form of their bodies and fins.

In distant longline fleets all over the world, it is difficult to correctly identify all the bycatch species, especially when they present a certain taxonomic difficulty and / or have a low price at the markets. For this reason, we must be cautious when considering data related to low-prevalence or low-priced bycatch species. The breakdown by species in some cases could be based on biased information from the fleet and/or on data provided by scientific observers covering a narrow spatial-temporal range and it is quite likely that in such cases there may be considerable errors in the redistribution of the by-catch landings by species.

Finning

A long explanation of finning in the different fleets has been provided in several papers (MEJUTO & GARCÍA-CORTÉS 2004, SANTOS & GARCIA 2005, ANONYMOUS 2005). Some specific relationships between the wet fin weight and the body weight of some pelagic sharks caught by the Spanish surface longline fleet have been indicated previously (MEJUTO & GARCÍA-CORTÉS 2004). The main conclusions were as follows:

-The largest mean percentage (PCT_FIN), was obtained for the long fin *Carcharhinus longimanus* with around 16 % of the body dressed weight when the largest sample size of 529 fish is used, and around 10% for its body round weight. The mean percentage of fins for *Prionace glauca* was around 14% for body dressed weight and 6.5% for body round weight. This high percentage is due to the slender body and larger fins of this species in relation to other *Carcharhinidae* or *Lamnidae* species. Fin ratios for another 8 sharks species are also provided in the above paper.

-A preliminary ANOVA for *Prionace glauca* points to a statistically significant relationship between the ratios obtained (fin / body weights) and the boat variable. The relationship between the body weight of the fish and the weight of its fins has been seen to be quite consistent for a wide spectrum of sizes, both in *Prionace glauca* and in *Isurus oxyrhinchus*. For this reason, the resulting ratios are generally compatible for these wide size ranges, which would suggest that it is appropriate to use mean overall ratios by species for all the sizes combined (figure **16**) or to use threshold values by species or groups of species defined by means of their respective upper confidence intervals for compliance purposes. The ratios, conversion factor (FACTOR) and the percentage of fins (PCT_FIN), when representing a mixture of species would, by necessity, be very close to the values obtained for the blue shark (*Prionace glauca*) because this species is clearly one of the most prevalent species in the large pelagic system -taking advantage of the mean value of 37 embryos per female (CASTRO & MEJUTO, 1995)- and represents the most important amount of the so-called by-catch species (CASTRO *et al*., 2000; MEJUTO *et al*., 2002a; ROSE & McLOUGHLIN, 2001) and one of the most prevalent species in the international fin markets from long distance pelagic fleets (ANONYMOUS, 1999).

An international discussion on the range of fin ratios has been going on recently in different fora. The apparent inconsistencies among authors was mainly based on the different criteria for dressing the fish, cutting fins, drying the fins onboard, etc. This make difficult to apply simple numerical comparisons of the results without having an in-depth knowledge of their respective methodological aspects, particularly when these ratios are defined in terms of weights that have already been processed (dressed, gutted, etc.), or fins in varying stages of drying, or only part of fins are included in some calculations. This lack of precaution in making these comparisons has, on occasion, led to incorrect conclusions or inferred apparent numerical discrepancies among authors that might not exist. It seems that the weight of shark fins has generally been defined as only accounting for 1 to 5 percent of the total body weight (ANONYMOUS, 1999), but this range would probably not fit some of the most prevalent species in the epipelagic system. Nevertheless, this 1-5% range might be a realistic reflection of some other fisheries or other shark species commonly captured in bottom fisheries or for some national large pelagic fisheries with specific dressing criteria or different fins (or parts) used in the calculations. In this sense, recent papers have pointed out this problem and suggest that the percentage of fins obtained from *Prionace glauca* would represent around 6.0% of its round weight (GORDIEVSKAYA, 1973, cited in ROSE & McLOUGHLIN, 2001, SANTOS & GARCIA 2005). However, the same study also indicates a value of 2.06 % from the same species and type of body weight (ANON., 1993, cited in ROSE & McLOUGHLIN, 2001). The latter authors also report a value of 3.74% between fins and carcass or dressed weight. Apart from the possible different methodologies used among authors, these apparent numerical inconsistencies among results, such as the % of fins related to dressed weight being lower than the % fins related to round weight for the same species, are probably an indication that the different authors-fleets are not using the same fins -or the same parts of the fins- or the same dressing criteria, etc.

Nowadays the catches of the large shark species are employed more profitably (CUNNINGHAM-DAY, 2001), with less (or null) waste-discards than in the previous decades, and new ways being found to make profitable use of the different parts of the body (GRUBER, 1990, cited by CUNNINGHAM-DAY, 2001), leading to a more productive result than in most of the teleost species caught traditionally in a wide range of fisheries all over the world. This full utilization of the catch is to be encouraged and is consistent with FAO recommendations. Yet, the undesirable practice of finning still seems to linger on in some fleets of both developed and developing nations, particularly affecting fleets that are limited in terms of operational ability, or with space problems onboard, those having inadequate means of conservation, aimed at specific markets such as those only dealing in fins, etc. Accurate conversion factors between fins weight and body weight, or equivalent factors such as the percentage of fins related to the landed body weights, could be very useful to estimate the levels of catches of some of these species from fin landings and fin markets. So the accuracy of such factors could be vital to eliciting a scientific point of view to be able to estimate international catches made by the international fleets, including the catches obtained by national or multinational fleets, which should be accurately reported to the International Fisheries Bodies, or to estimate catches landed by important foreign fleets at national ports and markets which are normally transfer places to their final destination in Asian markets. More information on this issue can be found on the ICCAT web page (ANONYMOUS 2005).

Blue shark reproduction parameters

We have reported in previous works some reproductive parameters with a total of 81,560 blue shark (*Prionace glauca*) observed, averaging 178 cm FL in size during the 1993-2003 period in all the oceans-areas (figure 2) (MEJUTO & GARCÍA-CORTÉS 2005). The main conclusions were:

-35.23% of the total blue shark sampled in all the areas were females.

-7,779 specimens, of the total sampled in all the areas, pertained to the Indian Ocean where 21.29% were females (1,656 individuals), of which 70.14% presented signs of fecundation (where 28.60% were pregnant and 41.54% presented mating injuries).

-The lowest SRo values were found in regions ATLS and INDI (figure **17**) with a predominance of males. In the Indian Ocean the lowest SRo value was found in IND53 (table **6**), evidencing spatial-temporal segregation by size and sex.

-The SRs values, by both region and zone, are highly variable in pattern (figure **18**). These SRs patterns by zone are influenced by the spatial definition used, and are also very likely affected by the temporal variability -which has not been taken into account in that analysis-. Moreover, the different SRs by zone may also be affected by the depth-dependent segregation of males and females, since this effect may have a greater or lesser consequence, depending on the seawater temperature in the zone (NAKANO & SEKI, 2003). The different SRs patterns observed would also be explained by the nominal CPUE data collected in each zone. The CPUEs (combined sizes) by zone, sex, or sexes combined, generally suggest a greater prevalence of males versus females in this surface longline catch, particularly if we consider the CPUEw of most of the zones (figure **19**). The CPUE data by size class and sex would point to a complex geographic distribution of specimens by size and sex, with a surprisingly greater prevalence of males in some zones, which could be related to mating processes. Furthermore, the data suggest that there is widespread cohabitation among the different size groups in most zones, with an alternating predominance of some of the size groups depending on the zone. Nevertheless, the comparison of the CPUEs among zones must be interpreted with caution, since the targeting intensity of the fleet may not be the same in all the zones. In this sense, in some zones-seasons, the fishery may target the prevalent species -swordfish and blue shark-, or it may even focus preferentially on only the latter species. Therefore, a comparison of the CPUEs by sex within each zone would appear, a priori, to be more appropriate than the comparison of nominal CPUEs among zones.

-Pregnant females were large in size, exceeding the mean sizes of females with mating injuries, which might imply that many of the females close to adulthood had already mated, but had not yet produced embryos. Although there have been occasional records of extremely small-sized pregnant females (some records of around 110 cm), small females with embryos begin to appear in significant numbers when they reach roughly 150 cm. Fifty percent of the size distributions of these females generally fall within the 180 to 215 cm size class, depending on the zone. The largest gravid females measured were between 265 and 290 cm, depending on the region. Table **7** gives the mean sizes of females identified as gravid and their respective confidence intervals (95%), by zone and region.

-In region INDI 70% of the females analyzed exhibited signs of fecundation (internal or external) (figure **20)** (with a greater presence of gravid females in April – November in most of the zones), 41% of which had mating injures and only 29% of the females examined were found to have embryos (mean litter size =38) (table **8**) with a relatively high mean embryo size (mean FL= 26.2 cm) (figure **21**). These results confirm the findings of previous studies for the same fleet (CASTRO & MEJUTO 1995) and fall within the ranges reported previously by several authors (NAKANO & SEKI o.c.). The mean embryo sizes were overall relatively high from July to November, attaining values of around 30 cm FL. Minimum values were recorded between March and June, also suggesting a possible seasonal cycle (figure **22).**

-To assess the significance of the predictive factors month and zone relative to the mean embryo size, GLM procedures indicate a statistically significant relationship between the size of the embryos and both predictor variables at the 99% confidence level in almost all regions, except ATLS where the effect of the zone was not statistically significant at the 90% or higher limit. The R-squared statistic indicates that the models fitted explain 51.7%, 22.2%, 64.4%, 31.4%, 71.7% and 61.3 % of the variability of the embryo size, for regions ATLN, ATLC, ATLS, ATL (all), PACI and INDI, respectively (figure **23**).

-The embryo sex ratio for all the regions was 0.4966, very close to the theoretical value of 0.50 as indicated for this species by several authors (CASTRO & MEJUTO o.c., NAKANO & SEKI o.c). This result does not explain the higher prevalence of males in the catch in most of the zones. The possibility of a differential natural mortality by sex might be able to partially explain these differences observed in the catches by sex. However, other more plausible causes must not be ruled out, namely the reduced catchability of females in the surface longline gear, owing, among other causes, to the different depth distribution of the specimens depending on the size, sex, temperature and area (NAKANO & SEKI o.c.). However, diametrically opposed phenomena have also been reported. Females appear to be distributed somewhat closer to the surface than males in some tropical zones (HAZIN *et al*. 1994), which would make them, *a priori*, more vulnerable to being caught with this surface gear. Moreover, local abundances of a seasonal nature in temperate waters have been reported with females dominating the regions in the vicinity of the British Isles (STEVENS 1974, VAS 1990).

-The period of time expected to elapse between the mean sized females FL_pregnant *vs.* FL_mating would be estimated at between 0.8 and 1.1 years for all the observations combined, based on growth equations defined for different size types for the Atlantic (sex combined) and for the Pacific (females) (NAKANO & SEKI o.c.), transforming them into FL by means of the appropriate conversions (NAKANO *et al*. 1985, CASTRO & MEJUTO o.c.) However, the total number of gravid females observed did not contain embryos in a predominantly advanced developmental stage in all zones, so an additional brief period of gestation must be estimated until the embryos reach a viable birth size. The longest data series from the ATLS region points to a monthly growth increase explained by the linear equation FL embryos (cm) = 3.7393 + 3.394 * months (R^2 = 0.769). This equation would allow us to estimate that birth size could be attained after 10 or 11 months of embryonic development. However, the estimated growth rates based on these monthly mean values may be underestimated in slope because no cohorts or individually tagged embryos were tracked. The possible entry into the area-month under observation of new pregnant females carrying small embryos could produce a systematic underestimation of the growth rates obtained. In such a case, the real growth rates of the embryos could be higher and the time needed to reach the viable birth size shorter than previously calculated.

-The zones-seasons involved in the reproduction processes of this species appear to be broad and much less restrictive that the ones first considered on the basis of other data sources of a more limited scope.

Incidental catch.

A total of 626,400 hooks were observed during 555 sets in order to make a preliminary evaluation of the incidence of this fishery in the Indian Ocean on seabird and turtle bycatch. The species of turtles and seabirds identified by the observers were *Caretta caretta*, *Dermochelys coriacea, Lepidochelys kempii, Lepidochelys olivaeca* and *Diomedea exulans,* respectively. The incidence obtained through these observations was one sea bird (dead) and 22 turtles, 21 of which were released alive and in good condition. The last one was found dead, tangled up in the main line. This would suggest global incidence rates per hook of around 3.52903E-05 for turtles (dead and alive) and 1.60411E-06 for dead turtles in areas between 18º - 32ºS and between 37º-106ºE. Only one incidence of a seabird (dead) was reported near 26º South latitude, suggesting an incidence rate of 1.60411E-06 for dead seabirds. Nonetheless, further observations are needed in order to obtain more consistent and representative estimations (GARCIA-CORTES & MEJUTO 2005).

Tagging-recapture.

The number of fish tagged in the Indian Ocean by scientific observers on board commercial vessels and by the vessels' crews, from 1993 until 2004 inclusive, amounted to 355 swordfish and 44 billfish. There have been no recaptures reported in the Indian Ocean on swordfish and billfish.

A total of 5580 sharks were tagged by Spain until February 2004 in all oceans and years combined, 444 of which were tagged in the Indian Ocean (table **8**). A total of 227 sharks were recaptured, 6 of which were in the Indian Ocean (table **9**). The recapture rate for sharks varied depending on the species and tagging method used (table **10**). From a total of 2435 shark recaptures carried out by the Spanish fleet between 1984 and February 2004, 2208 pertained to fishes tagged by other labs-countries (table **11**). The data of movements assumed to be rectilinear of several sharks species, were plotted in MEJUTO *et al.* 2005.

The joint work carried out by scientists to interpret the available data from the different tagging programs on sharks may present an exceptional opportunity to attain greater insight into the behaviour of these species, their spatial-temporal segregation and stock structure. The greatest possible diversification of the tagging areas and seasons would be highly recommendable. A combination of traditional tagging techniques with electronic tagging and genetic studies, among other techniques, could improve the interpretation of the behaviour of the species.

The recapture rate obtained for swordfish tagged by the Spanish surface longline fleet in all of its areas of operation was 0.49% (GARIA-CORTES *et al.* 2003), which is a very poor outcome, especially if we compare it to the overall recapture rate obtained for all of the shark tagged by this same fleet, which amounted to 4.07% (MEJUTO *et al.* 2005). This discrepancy between the recapture rates of swordfish and shark may be attributed to the fact that the swordfish is a more fragile species, and therefore has a lower survival after tagging. The recapture rate of the swordfish after conducting scientific tagging surveys was 6.11%. This clearly confirms that the handling of the swordfish during tagging procedures is a critical factor to the success of this technique. For this reason, when evaluating the tagging rates obtained, it is essential to consider the different tagging protocols used, the size selection made for tagging, the areas and seasons when the tagging was carried out, as well as the activity of the fleets and the recapture information provided by the different fleets.

The tagging level we were able to achieve under our TP was greater in scope than that of the activity of the traditional North Atlantic fleet, since this sector of fleet began collaborating decades ago and the contacts maintained are more frequent and open. In the Indian and Pacific Oceans, this long distance activity is more reduced since the fisheries were started more recently.

Moreover, it would be advisable to standardise the protocols among countries to be able to obtain and report tagging-recapture data, establish standardized units of size and weight, etc. through the scientific recommendations by the different regional fisheries bodies.

5. OTHER TOPICS FOR DICUSSION.

Studies on stock structure:

The WPB, Group of SWO, have considered that swordfish tagging is one of the keys that will facilitate the study of the structure of the swordfish stock/s in the Indian Ocean. Previous experience acquired in other oceans over the course of decades could help focus these research efforts. Experiences in the Atlantic Ocean indicates that the study of swordfish stock structure is the fruit of decades of multi-focussed research work and scientific cooperation on the basis of a battery of data ranging from the activity of the fleets (fishing zones, CPUE and CPUE by age etc.,), to many different biological studies – size and sex distributions, reproduction- the use of long-term conventional tagging –with the specific problems entailed-, electronic tagging –with enormous technical difficulties and budget issues-, genetic studies of a broad spatial range –very promising in some geographic areas-, etc. All of the above are some of the most useful tools that will help us to achieve this objective.

In light of the progress made on this species in other oceans it would seem that the base hypotheses for these studies are more easily introduced into the different experimental designs by the identification of the different biological regions formed by the stock/s. Once again, biological data on this species seem to be one of the keys to the correct definition of the respective stocks, making it possible to give biological coherence to the interpretation of the results obtained from each one of the different techniques used.

Tagging is a useful technique, although hard to apply in the case of the swordfish. In this sense, there is a long history of experience –since the middle of the last century- in the Atlantic with conventional tagging (scientific or voluntary tagging by the fleets) as well as conventional tagging carried out by specific scientific surveys (with varying degrees of success). The advantages and drawbacks of these different approaches have been discussed previously (MEJUTO *et al*, 2005).

The electronic tagging of swordfish with pop-up tags is still in the early stages –"archival implantable" tags do not appear to be feasible in this species-. While electronic tagging projects have been planned since years, they are not easy to execute, owing to budget problems.

However, in view of the fragility of this species, we would expect that a substantial number of individuals that have had these tags inserted would not have a successful response in the end, as has been suggested by the difference in recapture rates between the swordfish and shark species, which are able to endure handling during conventional tagging procedures. It is fundamental to exercise the appropriate handling of swordfish for these experiments to be viable. In this case, this percentage of expected losses must be added to the already high percentage of failure that these tags seems to be having on tuna species which are much more resistant to handling. These two drawbacks must be taken into account in the experimental costs, which has already skyrocketed. Regardless of whether conventional or electronic tagging is used, the spatial-temporal design of the experiment has proven to be one of the long-term key factors determining the correct interpretation and generalization of the results obtained.

Genetic tools used on swordfish have improved considerably over the last 10 years and specific tasks should also be undertaken in the Indian Ocean. In keeping with this the *ICCAT Working Group on swordfish stock structure (Crete, March 2006)* may be able to help discern the most suitable genetic technique for this species and make an assessment of what might be expected of this tool if used on the swordfish of the Indian Ocean, which has specific oceanographic conditions that would make it more difficult, a priori, to differentiate the stocks genetically, even from Pacific. Nevertheless, the reproductive behaviour of this species based on *spawning site fidelity or phylopatry,* as suggested by recent genetic studies (ALVARADO *et al.*, 2005), gives us an incentive to undertake this structure in the Indian Ocean, as well. The results and progress of these ICCAT working Group should be followed closely in order to be able to plan future genetic tasks coordinated in this ocean and among oceans.

Since the 1980s, a number of CPUE analysed by 5ºx5º squares and time periods have been carried out on the basis of data from the longline fleets operating in the Atlantic Ocean, with a broad spatial-temporal range in terms of fishery activity (FARBER 1988, MEJUTO *et al*., 2003a, 2003b, 2004, 2005, in press). Although these analyses have been –and continue to be- of great practical use, it is true that none of them have led to the clear identification of discontinuities that would help define the borders between the stocks, that were assumed to exist a priori. However, the possible lack discontinuities does not necessarily mean panmixia. Data from the Atlantic Ocean have generally pointed to a general continuity in the swordfish resource between the northern and southern areas of this ocean (when fishing effort provides observations) which is especially striking across the tropical zones of both hemispheres, between which some separation would have been expected. This information, along with other available sources and the most recent genetic analyses, highlight the complex behaviour of the swordfish, with their respective spawning areas pertaining to each respective stock, and, at the same time, the existence of probable areas that overlap between stocks at certain geographic levels. The way the stocks are structured emphasizes the practical difficult of differentiating the origin of the captures (between the stocks), at least in the broad overlapping zones, which means that, in terms of stock assessment and regulation, practical criteria may have to be adopted to define borders and mixing rates.

The most recent data available from the Spanish fleet operating in the Indian Ocean, on a yearly basis, would also suggest that there appears to be a continuity of the resource from 35º E to 110º East (GARCÍA *et al*. 2005). The results from experiments carried out in other oceans are in keeping with this.

Swordfish growth:

Growth studies based on the hard parts (generally consisting of spiny rays the dorsal fin because of their easy extraction, preparation and reading) are very helpful in understanding the biology of the swordfish. These studies expect to obtain the growth differential by sex starting at a specific size. As recommended by the WPB, these studies must be corroborated. But not only in terms of the estimation of the size-age correlation, but also regarding how their pattern of marginal increments is formed, on the basis of a plausible biological hypothesis that can explain the formation of ¿annual? rings in a species that is highly migratory, especially in certain stages of its life.

In the Atlantic Ocean, growth studies have been very useful in the estimation of the demographic structure of the catches of the population; in the estimation of the size-age at the onset of maturity and in designing abundance indices "by age class" (or proxis) in some fleets having the necessary data. The early analyses based on VPA were later used in VPA analyses by sex, which required the previous preparation of data of enormous technical complexity and field work for the previous definition of biological regions, with some other additional difficulties (size-sex substitutions between fleets) owing to the limited biological data available from some fleets. The most recent stock assessments for the North Atlantic suggest that the diagnoses obtained were very similar, regardless of whether VPA type models (requiring high volumes of data entries) or production models (less demanding than the former in terms of data entries) were used. Again, the key would seem to be the reliability of the CPUE indices assumed to be indicators of abundance or the abundance indices by age which could be affected by additional sources of error.

In the case of stocks whose assessment depends on inconsistent or unreliable data, or those having a high level of size substitution between fleets-areas, it is necessary to consider the possibility of determining the priority of growth and CPUE-age tasks to be used in stock assessment by means of models that are structured by age, as opposed to other alternatives.

Size data analysis:

Oftentimes, scientific debates on swordfish revolve around the variability in the size distributions observed within and between the fleets and their consistency over the years. All of these exercises are of interest in terms of having a sharper focus on stock assessment without losing sight of the fact that the size and sex of the swordfish are dependant upon environmental conditions related to spatial-temporal variables.

However, among these differences that are often detected, there are other, underlying elements whose importance is usually underestimated: the different sampling ranges covered by the fleets, the different procedures used to compile size data and the different methods used nationwide to estimate the CAS affected by the substitution levels as well as the criteria employed to process this information. All of the above comprise some of the elements that play a key role in the CAS obtained and make it difficult to carry out a comparison within and between fleets. The sampling protocol pertaining to size is not the same in all the fleets. Some fleets carry out size samplings on the basis of the random selection of only one or several individuals per set chosen at random by the crew. Other fleets use protocols based on taking a census of each and every fish caught in the sample set or on data from observers. The group must evaluate the different size estimations and protocols established for the sampling according to the fleet, before drawing conclusions on the different CAS obtained.

An additional problem is the different type of longline activity carried out by the different fleets – those clearly targeting the swordfish (nocturnal activity), opportunistic or undefined activity, a clearly non-targeted activity (daytime longline), etc.-. Each of these activities has specific characteristics, from both a spatial-temporal standpoint as well as the configuration of the fishing gear and fishing practices.

On the other hand, the size / mean weight of the swordfish caught is usually linked to oceanographic variables –mainly water surface layer temperatures- with a substantial spatial-temporal element. Variations over time in the spatial-temporal behavior of the fleets, changes in the configuration of the gear or changes in the target species, to name a few, may cause considerable changes in the mean weights of the catch obtained, which must not be mechanically interpreted as a change in the mean weight of the population. For this reason, the SCRS of the ICCAT has not been amenable to using trends in the mean weight of the catches as an indicator of stock status, taking into account both the history of this fishery and the type of data available in the time series available.

Stock status indicators:

The decreasing trend of the parent stock of the North Atlantic swordfish (generally considered to be ages 5+) has been put forth as one of the main indicators of the overfishing suffered by this stock over the last few decades of the past century. Recent studies simulating a population over the course of almost a century highlight the tendency of this adult fraction to be highly influenced by decadal or multidecadal cycles or phases in stock recruitment levels, which could be related to environmental cycles. Under this assumed scenario, a negative recruitment stage, linked to unfavorable environmental factors, would be enough to explain a declining numbers in the adult fraction, even in a scenario without fishery activity (MEJUTO 2000). It is essential to have data of CPUE by age of the different components of the stock, or at the very least, of the different size classes assumed to be ages. As an exceptional case, when possible, it would be advisable to compile reliable recruitment indicators on the basis of reliable data of the juvenile age classes, preferably ages 1 and 2 covering broad areas of their distribution.

Also related to this subject with some of the aspects discussed earlier, the identification of reliable indicators of abundance by age, particularly of the adult fraction, is no easy task. The standardized CPUE data for the adult fraction of a fleet (or pooled ages) should not necessarily be assumed as an indicator of the abundance of the adult fraction of the stock. The CPUEs by age class could be affected at least by the same doubts and biases as the CAS data.

CPUE standardization: This aspect is of utmost importance if we assume, in general, that CPUE trends are indicators of stock abundance. The diversity of fishery activities among the different fleets is an element that complicates the interpretation and comparison of the CPUEs obtained. Without going into problems related to methodology that can affect CPUE estimations (GOODYEAR & ORTIZ *in press*), the processing of the CPUE data should be done on a case-by-case basis, taking into account the type of activity of each fleet and the availability and consistency of their respective data. The target issue is being debated worldwide, especially where the fleet's activity has changed over the years or is opportunistic, or in cases where it is difficult to identify a clear fishing pattern. Information on the configuration of the fishing gear sometimes helps to determine the type of fishing activity carried out by the vessel-skipper (e.g., hooks per basket). At other times, however, this information is non-existent, unclear or less important in mixed or opportunistic fisheries. In other fleets it is not possible to clearly identify characteristic elements in the configuration of the gear that would allow us to identify the type of species that the skipper intends to fish. In the latter cases, the ratio between the species captured (by set or trip) might be able to help interpret the skipper's intention to direct the activity towards a particular species, with this ratio oftentimes being a good proxy of the "target intensity". This ratio between species has been identified in some cases as the most important factor explaining the variability of the CPUE in swordfish, - even more important than factors such as year, area or time period- particularly when the distribution and fishing area overlaps between the different target species and when there is a negative correlation between their respective local abundances.

In most fleets the compilation of CPUE data in number or weight (depending on the reports of each fleet), would probably be, a priori, less affected by estimation errors than the CPUEs by age, especially when the latter case excludes age substitution procedures (e.g., assuming the same mean weights or mean size distributions between areas-time periods, trips or vessels). In this case it would seem logical to give priority to obtaining the standardized CPUE in weight or number versus other CPUE types.

ACKNOWLEDGEMENTS.

We would like to express our gratitude to the crews of the Spanish surface longliners for their collaboration and voluntarily allowing scientific observers on board their vessels for scientific purposes. We are especially grateful to the many scientific observers who contributed to the processing of the data used in this paper. Special thanks go to the I.E.O staff involved on this task under the projects SWOATL, SHKLL and SHKLL03, between 1993 and 2004, in alphabetic order, Isabel González, Ángel Fernández and Manuel Quintans.

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