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SCIENTIFIC ESTIMATES OF BYCATCH LANDED BY THE SPANISH SURFACE LONGLINE FLEET TARGETING SWORDFISH (*Xiphias gladius*) IN THE INDIAN OCEAN WITH SPECIAL REFERENCE TO THE 2004 – 2006 PERIOD.

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ABSTRACT

This paper presents scientific estimates of the bycatch species landed by the Spanish surface longline fleet targeting swordfish (Xiphias gladius) in the Indian Ocean since the beginning of this fishery in 1993, as well as an update for the recent period 2004- 2006. The species classified as bycatch amounted to 46.2% of the total weight landed. The three most prevalent species in the catch, Xiphias gladius, Prionace glauca and Isurus oxyrhinchus, represented 85.2% of the total weight landed during this last period. As far as bycatch species are concerned, large pelagic sharks were the most prevalent group with 76.5% of the bycatch in weight, whereas tunas amounted to 15.0%, billfish to 2.2% and other species to 6.3%. Prionace glauca and Isurus oxyrhinchus are the two most prevalent bycatch species in the group of large pelagic sharks, reaching 84.4% and 12.0% of the landings of this group, respectively.

Key words: bycatch, surface longline, statistics.

INTRODUCTION

Historically, the Spanish surface longline fleet has targeted swordfish *Xiphias gladius* (SWO) in the Atlantic, Pacific and Indian areas, although other species are also caught simultaneously for human consumption, mostly large pelagic sharks and, to a lesser extent, tunas, billfish, etc. (GARCÍA-CORTÉS & MEJUTO 2000a, 2000b, 2001, 2002, 2005; MEJUTO *et al*. 2000, 2002a, 2002b, 2003, 2006). The fishing gear used by the Spanish surface longline vessels since the beginning of their activity in the Indian Ocean until 2000 was chiefly the 'traditional Spanish longline', equipped with a multifilament main line and clips. Since then, however, the monofilament 'American style' –Florida style modified– longline gear has been introduced in most of the vessels of the Spanish fleet, with a mean deployment of 1,100-1,500 hooks per set.

Although the catch of large pelagic sharks has always been very significant for many fisheries in the world, the landings of these species have gained an increasing importance in recent years for many fleets in all oceans, owing to several different factors, such as their high relative abundance in number and biomass in most oceans and fishing areas, the reduced discards of these species in many fleets, which used to be common practice in the past decades (MEJUTO & GONZÁLEZ-GARCÉS 1984; MEJUTO 1985), the improvements in the conservation systems onboard and the increasing economic worth of these species and their derivative products on the international markets (MEJUTO & GARCÍA-CORTÉS 2004). Therefore, these species, which had been intensively caught for many decades and frequently discarded by many fleets, are now landed and taken to international markets for their bodies and derivative products. Since the important development of the oceanic longline fisheries in the middle of the last century, it is well known that the blue shark is highly prevalent in the oceanic epipelagic layers of almost all the oceans in the world. This species is generally found at least between 50ºN and 50ºS. The prevalence of the blue shark over other pelagic species of elasmobranchs and teleosts is probably due to its advantageous reproductive strategy, with an elevated renewal rate and around 37 embryos per litter on average (CASTRO & MEJUTO 1995; MEJUTO & GARCÍA-CORTÉS 2005a). As a result, this species is much more prevalent than other pelagic elasmobranchs and even than many species of teleosts (CASTRO *et al* 2000; MEJUTO *et al* 2002b, 2007).

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It is known that the correct identification of all bycatch species is sometimes difficult in distant longline fleets all over the world, especially when they present a certain taxonomic complexity and / or have a low price at the markets. For this reason, we must be precautious when considering data related to low-prevalence or low-priced bycatch species. The same applies to other fishing gears targeting tuna, which provide confusing or underestimated specific identifications in logbooks and landing records.

The objective of this paper is to analyse and update the historical series of scientific estimates of bycatch data from the Spanish surface longline fishery operating in the Indian Ocean. Previous reports already included data from 1993 to 2000 (GARCÍA-CORTÉS & MEJUTO 2001) and the 2001-2003 period (GARCÍA-CORTÉS & MEJUTO 2005). In this paper, the bycatch landings are updated for the most recent period 2004-2006. Moreover, this paper aims to provide knowledge on the annual bycatch landings associated with this fishery to the most detailed taxonomic level possible and to define the relative global prevalence of the species. This information could help us determine the consistency of the estimates over the years and provide an idea of the complexity of the epipelagic ecosystem.

MATERIAL AND METHODS

The data contained in this paper are based on declarations on landing, interviews with skippers at the ports and other information filled out voluntarily by the fleet, as well as the information provided by the scientific observers on board commercial vessels, carrying out regular or experimental fisheries on swordfish. For descriptive purposes, the species related to large pelagic sharks were included in the SHK group, which is made up mainly of specimens of family Carcharhinidae (fundamentally *Prionace glauca*), family Lamnidae (mainly *Isurus oxyrhinchus*), Sphyrnidae and finally, Alopiidae. The TUN group includes different tuna species among which *Thunnus obesus*, *Thunnus alalunga* and *Thunnus albacares* are the most important. The group of billfish was labelled as BIL and includes species belonging to the family Istiophoridae. The group OTH includes several species which have not been identified in certain cases (generally with low commercial value) or which were identified at species level but whose catch is sporadic or very rare.

The breakdown into species of the most prevalent bycatch landed, such as *Prionace glauca* and *Isurus oxyrhinchus*, was based on the information provided by the fleet in their voluntary scientific reports, since their taxonomic identification is generally easy, reliable and common practice. However, the identification of other bycatch species belonging to different groups such as SHK, BIL, OTH and TUN was fundamentally based on the information provided by on-board observers, who have a limited spatial-temporal coverage. Due to the historical geographic expansion of Spanish vessels to new fishing areas in the Indian Ocean, it was impossible to achieve a satisfactory breakdown into species of the landings in certain cases. This has an impact on the reliability of the estimates by species and, as a result, the reported landings are in some cases assigned to a single species. The data were geographically compiled and set down in 5ºx5º squares-month and raised by spatial-temporal strata, according to the methodology described for distant longline fleets (MIYAKE 1990).

When originally based on dressed weight, the records were converted, where necessary, to units of round weight (RW) by applying different conversion factors according to the species or group of species, depending on the handling process applied to the fish on board (MEJUTO *et al.* in press a). Conversion factors were defined for different species and presentations: *Prionace glauca:* Round weight (RW)= Dressed weight (DW) * 2.4074. *Isurus oxyrhinchus:* Round weight (RW)= Dressed weight (DW) * 1.4541. The other pelagic sharks (SHK) Round weight (RW)= Dressed weight (DW) * 1.4 (except for the genus Carcharinus, where the factor 2.0 was used). All species included in the group of billfish (BIL): Round weight (RW)= Dressed weight (DW) * 1.2. The conversion factors applied to each species within the group of tuna (TUN) were Round weight (RW)= Gutted weight (GW) * 1.1 and Round weight (RW)= Dressed weight (DW) * 1.25.

In order to complete the historical series of the bycatch obtained by the Spanish fleet in the Indian Ocean, the information published in previous reports (since the beginning of this fishery in the Indian Ocean in 1993 until 2003) has also been included (GARCÍA-CORTÉS & MEJUTO 2001, 2005). Besides, the information concerning the 3 most recent years (2004-2006) has been updated.

RESULTS AND DISCUSSION

The group including the three most prevalent species in the catch, which are also those of highest commercial interest for human consumption (*Xiphias gladius* + *Prionace glauca* + *Isurus oxyrhinchus*) represented 85.2% of the total landings in the Indian Ocean during the period 2004-2006. This level is very similar to that observed in the regions of SE Pacific and the Atlantic, estimated to be around 91% (MEJUTO & GARCÍA-CORTÉS 2005b; MEJUTO *et al.* 2007) and 90% (MEJUTO *et al.* in press b), respectively.

The group of species considered to be bycatch of the swordfish (*Xiphias gladius*) surface longline fishery in the Indian Ocean between 2004 and 2006 accounted for 53.8.% of the total catch landed in weight (table **1**, figure **1**), which is similar to the bycatch caught in the Pacific during 2006 (50.8%) (MEJUTO *et al.* 2007) . This percentage turned out to be lower than that observed for the Atlantic Ocean (CASTRO *et al.* 2000; MEJUTO *et al.* 2002b), which reached 71.7% for the years 2005-2006 (MEJUTO *et al.* in press b). This was to be expected in view of the fact that the fishing patterns have changed in the Atlantic fisheries because management actions and changes in targeting swordfish and blue shark.

Between 2004 and 2006, the bycatch consisted chiefly of large pelagic sharks (SHK), reaching 4,436 t/yr on average. This accounts for 41.2% of the total landings in weight for all species combined. The average landing of the tuna group (TUN) was 868 t/yr, which accounted for 8.1% in weight of the total catch landed. The group of species with the lowest economic value (OTH) represented around 3.4% of the total annual landings, reaching 363 t /yr on average. Finally, the volume of billfish (BIL) amounted to 1.2% of the total landings, reaching 129 t/yr on average (table **2**, figure **2**). The landings in weight per group of species in relation to the bycatch species only (excluding the target species) amounted to 76.5% for the SHK group, 15.0% for the TUN group, 6.3% for the OTH group and 2.2% for the BIL group over the 2004-2006 period. As expected, the amount of SHK was much more prevalent as compared to the other groups. However, it was lower than that observed in the landings of the Atlantic as a whole, where the SHK group represented between 94% and 99% of the total bycatch, depending on the year of observation (CASTRO *et al.* 2000; MEJUTO *et al.* 2002b; MEJUTO *et al.* in press b).

In certain occasions, it was impossible to calculate the breakdown of the catch at a species level, due to the rapid expansion of the fleet to new fishing areas in this ocean and to the limited areas covered by the observers. Figure **3** represents a summary of the recent geographic expansion of this fleet between 1993 and 2004 in the Indian Ocean.

Between the years 2004-2006, the overall observer coverage was around 4% of the catch in weight but in 2005 and 2006, nearly half of the Spanish longliners with observers targeted the new experimental fishing areas, mostly in northern and southwestern areas of the Indian Ocean (5º N-10º S / 60º-95º E and 28ºS-42º S / 85º E- 115º E) (GARCÍA-CORTÉS *et al.* in press). As a result, the information obtained from these trips in eastern areas is not mechanically applicable to the whole of the fleet operating in other areas of the Indian Ocean.

The bycatch analyzed during the said period was basically made up of *Prionace glauca*, with an average landing of 64.6%, followed by the *Isurus oxyrinchus* with 9.2% and the other SHK with 2.7%. As for the TUN group, *Thunnus obesus* and *Thunnus alalunga* stand out, accounting for 6.8% of the total landings, as well as *Thunnus albacares*, accounting for 1.1%. The landed species belonging to the the BIL group were always below 1.7% of the total landed. It must be noted that the species *Lepidocibium*

flavobrunneum into the OTH group represented 4.9% of the total landed bycatch weight.

During the same period the *Prionace glauca* species accounted for 84.4% within the SHK group, followed by *Isurus oxyrinchus*, reaching 12.0%. These figures are very similar to those observed for the Spanish surface longliners in different oceans, where the prevalence of *Prionace glauca* is clearly predominant and remarkably higher as compared to the group of other bycatch species. Within the TUN group, the species *Thunnus alalunga* and *Thunnus obesus* represented 57.3% and 34.1%, respectively. Within the BIL group, 74.8% was identified as *Istiophorus platypterus* and 9.1% as *Tetrapturus audax.* Within the group of OTH, 77.7% was represented by the species *Lepidocibium flavobrunneun.*

Thunnus alalunga and *Istiophorus platypterus* are more easily identified by the skippers than other tuna or billfish species, and as a result, both are frequently well recorded specifically. This could result in greater catch estimates within its respective group after the raising and substitution procedures.

Table **3** summarizes the total bycatch landings for the complete historical series in the Indian Ocean, from the beginning of the fishing activity of the Spanish surface longline fleet in 1993 until 2006.

The possible statistical improvement may be related with an increase in the landing in weight for the overall bycatch of some species, as compared to previous periods. Nonetheless, the increased number of vessels fishing in this ocean must be also taken into account, as it rose from 19 to 28 units. However, the relative prevalence observed for the period 2004-2006 are generally similar to those previously obtained for the Spanish fleet in the Indian Ocean (GARCÍA-CORTES & MEJUTO 2001, 2005).

An accurate estimation of the bycatch levels entails many difficulties in most of the world's fisheries, especially when the aim of the taxonomic levels are very demanding. The classification of the catch on board is usually based on commercial criteria rather than on scientific norms. Consequently, this is a common problem in many coastal and oceanic fisheries. In tuna fishing fleets, this problem could affect not only the bycatch, but even to the target species that have a similar appearance and price and are included in the same commercial category. Therefore, in order to obtain annual catch estimates at the species level, it is essential to use scientific procedures or a proxy taxonomic level that in some cases provides more reliable estimations than the commercial records.

The information on bycatch species from most of the distant-water fleets operating all over the world could also be affected by a similar problem. Moreover, the taxonomic identification of some of these bycatch species is not always easy and continuous efforts for training are required in order to carry out information campaigns to crew members, as well as to establish more detailed routine for skippers to improve record of their bycatch. Thus, the taxonomic identifications could be inaccurately recorded in some commercial catch records, especially in the case of the least prevalent species. The problem is aggravated as the number of taxonomic levels to be recorded increases. Therefore, this issue must be approached realistically from a technical stance, taking into consideration the possibilities of obtaining quality information and trying to adopt routine procedures that allow us to gradually reduce these limitations. In this document we have estimated the annual landings of as many as 38 different taxonomic levels, although only the prevalence of three species combined exceeds 85% of the landings.

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Table 1. Scientific estimation of landings (kg of round weight –RW-) of the target species (SWO: *Xiphias gladius*) *vs.* combined by-catch species of the Spanish surface longline fishery in the Indian Ocean during the 2004-2006 period.

YEAR	2004	2005	2006
SWO	4713320	5078650	5155419
BY-CATCH	5469359	5980437	5939316
TOTAL	10182679	11059087	11094735

Table 2. Scientific estimation of by-catch landings by group (kg of round weight –RW-) of the Spanish surface longline fishery in the Indian Ocean during the 2004-2006 period.

YEAR	2004	2005	2006
BIL	107175	132908	148001
OTH	267756	400857	419170
SHK	4423035	4562317	4322464
TUN	671393	884355	1049681
TOTAL ByC	5469359	5980437	5939316

Table 3. Scientific estimation of landings by species (kg of round weight –RW-) considered to be bycatch of the Spanish surface longline fishery, during 1993-2006 period.

Group	SPECIES	1993	1994	1995	1996	1997	1998	1999
BIL	*Makaira indica / M. Nigricans*	0	14321	1296	372	no inf.	0	602
BIL	*Makaira mazara*	0	0	0	0	no inf.	0	16172
BIL	*Tetrapturus audax*	0	0	0	0	no inf.	0	814
BIL	*Istiphorus platypterus*	0	2208	0	0	no inf.	8517	7427
BIL	*Tetrapturus angustirostris*	0	0	0	0	no inf.	0	1951
BIL	*Tetrapturus pfluegeri*	0	0	0	0	no inf.	1822	0
OTH	*Acantocibium solandri*	0	0	0	0	no inf.	0	3974
OTH	*Brama spp.*	0	0	0	0	no inf.	0	0
OTH	*Coriphaena spp.*	0	0	0	0	no inf.	0	65
OTH	*Gempilidae*	0	0	0	0	no inf.	0	12
OTH	*Lepidocibium flavobunneum*	0	0	0	0	no inf.	0	0
OTH	*Lampris guttatus*	0	0	0	0	no inf.	0	0
OTH	*Oth*	0	1448	0	0	no inf.	0	0
OTH	*Rubetus pretiosus*	0	0	0	0	no inf.	0	0
OTH	*Sphyraena spp.*	0	0	0	0	no inf.	0	71
OTH	*Seriola dumerili*	0	0	0	0	no inf.	0	0
SHK	*Alopias spp.*	0	308	0	0	no inf.	0	0
SHK	*Alopias superciliosus*	0	0	0	0	no inf.	0	0
SHK	*Carcharhinus spp.*	7088	165165	4120	6170	no inf.	0	57521
SHK	*Carcharhinus limbatus*	0	0	0	0	no inf.	0	0
SHK	*Carcharhinus falciformis*	0	0	0	0	no inf.	10689	13968
SHK	*Carcharinus galapagensis*	0	0	0	0	no inf.	0	0
SHK	*Carcharhinus longimanus*	0	0	0	0	no inf.	11629	31777
SHK	*Carcharhinus plumbeus*	0	0	0	0	no inf.	0	0
SHK	*Galeocerdo cuvieri*	0	1417	0	0	no inf.	221	0
SHK	*Isurus oxyrinchus*	10182	80899	3374	6356	no inf.	320625	543911
SHK	*Isurus paucus*	1721	2672	0	0	no inf.	858	30423
SHK	*Lamna nasus*	0	0	0	0	no inf.	0	4542
SHK	*Prionace glauca*	0	179315	30645	36327	no inf.	908999	2879468
SHK	*Pseudocarcharias kamoharai*	0	0	0	0	no inf.	0	0
SHK	*Sphyrna lewini*	0	0	0	0	no inf.	0	0
SHK	*Sphyrna spp.*	733	11786	854	1358	no inf.	1085	893
SHK	*Sphyrna zygaena*	0	0	0	0	no inf.	15932	11431
TUN	*Thunnus alalunga*	0	0	0	0	no inf.	5130	42589
TUN	*Thunnus obesus*	6791	25693	100	235	no inf.	34517	58502
TUN	*Gasterochisma melampus*	0	0	0	0	no inf.	0	0
TUN	*Thunnus maccoyii*	0	0	0	0	no inf.	0	0
TUN	*Katsuwonus pelamis*	0	0	0	0	no inf.	0	0
TUN	*Thunnus albacares*	9896	21254	83	195	no inf.	23350	43740

Note: the data for the 1993-2003 period have been taken from previous papers.

Table 3.(cont).

Group	SPECIES	2000	2001	2002	2003	2004	2005	2006
BIL	*Makaira indica / M. Nigricans*	54	0	0	697	663	772	2202
BIL	*Makaira mazara*	1440	20389	0	1662	4656	2435	20688
BIL	*Tetrapturus audax*	73	0	16164	11434	15827	2157	17462
BIL	*Istiphorus platypterus*	661	0	8900	42235	72557	117041	100560
BIL	*Tetrapturus angustirostris*	174	12364	22711	375	13473	10340	6994
BIL	*Tetrapturus pfluegeri*	0	0	0	363	0	163	95
OTH	*Acantocibium solandri*	0	0	127	82	0	392	2066
OTH	*Brama spp.*	0	0	10	0	0	7	27
OTH	*Coriphaena spp.*	25	0	1833	10317	9011	22430	37934
OTH	*Gempilidae*	0	0	0	0	0	0	0
OTH	*Lepidocibium flavobunneum*	0	28591	200039	134686	211519	320765	312929
OTH	*Lampris guttatus*	0	0	222	140	641	687	770
OTH	*Oth*	0	4195	19489	13701	35646	16320	34993
OTH	*Rubetus pretiosus*	0	0	7307	461	2532	19622	15984
OTH	*Sphyraena spp.*	0	35	420	503	8407	20634	14467
OTH	*Seriola dumerili*	0	0	0	30	0	0	0
SHK	*Alopias spp.*	0	0	21	0	0	0	31
SHK	*Alopias superciliosus*	0	0	0	0	0	717	2419
SHK	*Carcharhinus spp.*	14313	22714	55814	19053	25987	0	0
SHK	*Carcharhinus limbatus*	0	0	0	0	681	37164	0
SHK	*Carcharhinus falciformis*	0	0	6	0	0	104	120542
SHK	*Carcharinus galapagensis*	0	0	0	968	0	0	0
SHK	*Carcharhinus longimanus*	62	0	660	456	0	39792	74695
SHK	*Carcharhinus plumbeus*	0	0	0	0	0	4	7797
SHK	*Galeocerdo cuvieri*	0	196	81	**0**	1022	2773	3103
SHK	*Isurus oxyrinchus*	324264	146067	308252	411826	405730	696105	498165
SHK	*Isurus paucus*	5102	240	214	932	3410	9977	14207
SHK	*Lamna nasus*	0	494	2581	1277	6049	10314	2706
SHK	*Prionace glauca*	3031075	1203991	2549703	3904120	3950370	3716077	3568483
SHK	*Pseudocarcharias kamoharai*	0	0	0	19	0	0	1112
SHK	*Sphyrna lewini*	0	0	0	147	119	965	1184
SHK	*Sphyrna spp.*	0	9448	11511	4939	29667	46686	25991
SHK	*Sphyrna zygaena*	0	0	1219	659	0	1639	2029
TUN	*Thunnus alalunga*	122291	165451	241384	48153	71477	821441	600878
TUN	*Thunnus obesus*	47065	75764	109296	382140	590323	26804	271592
TUN	*Gasterochisma melampus*	0	0	27089	0	0	580	679
TUN	*Thunnus maccoyii*	0	0	0	3365	0	2618	15494
TUN	*Katsuwonus pelamis*	0	233	0	3402	0	6605	8945
TUN	*Thunnus albacares*	108403	44876	106693	0	9593	26306	152092

Note: the data for the 1993-2003 period have been taken from previous papers.

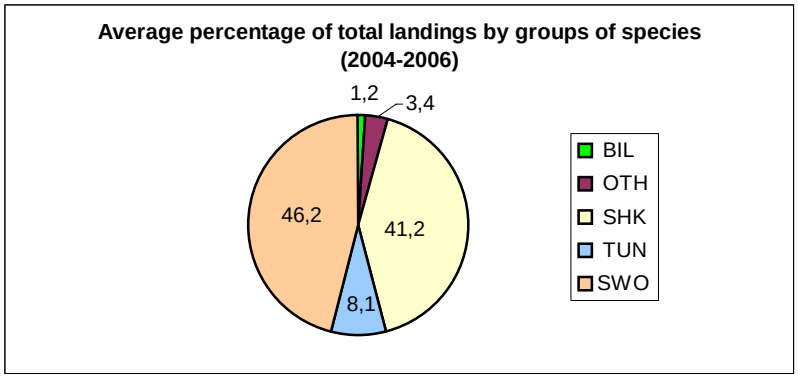

Figure 1. Scientific estimation of the percentage of the total landings (relative prevalence) by group (target and by-catch species) of the Spanish surface longline fishery in the Indian ocean during the 2004-2006 period. Note: decimal numbers in Spanish (, = .)

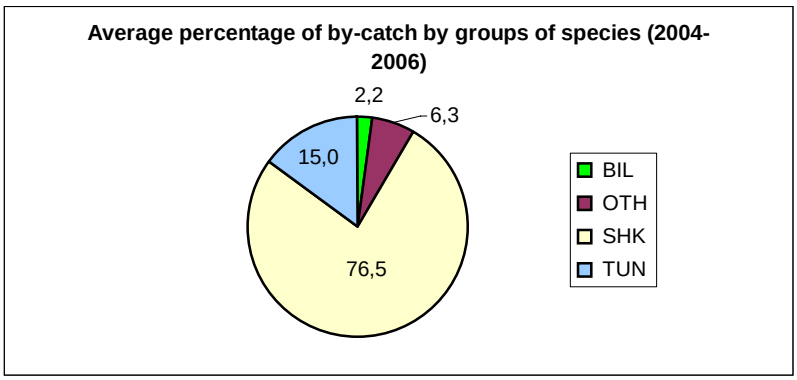

Figure 2. Scientific estimation of the percentage of landings by group (by-catch species) of the Spanish surface longline fishery in the Indian Ocean, during the 2004-2006 period. Note: decimal numbers in Spanish (, = .)

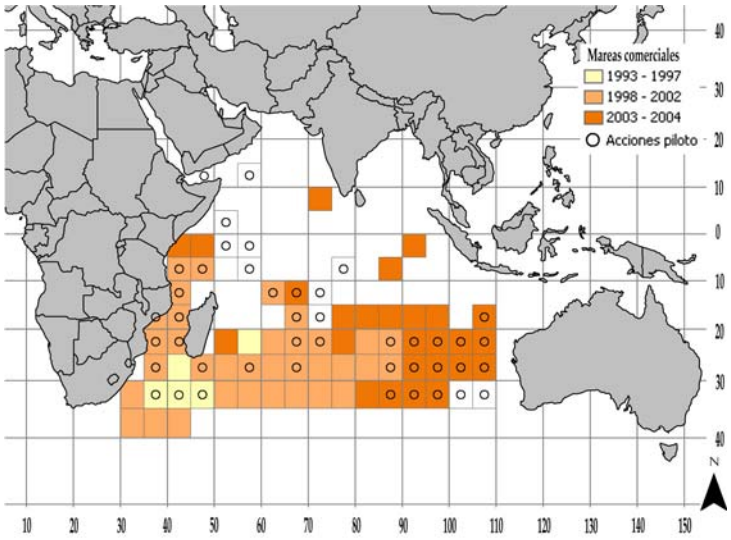

Figure 3. Summary of the areas accessed by the Spanish surface longline fleet from 1993 to 2004, grouped by four-year periods. The circles indicate the areas where vessels of the commercial surface longline fleet carried out experimental or pilot activities (from Mejuto *et al*. 2006).