RETROSPECTIVE AND GEOGRAPHICAL OVERVIEW OF THE INTERACTION BETWEEN SEABIRDS AND THE SPANISH SURFACE LONGLINE FISHERY TARGETING SWORDFISH IN THE INDIAN OCEAN DURING THE 1993-2017 PERIOD INFERRED FROM DATA PROVIDED BY SCIENTIFIC OBSERVERS AT SEA

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Abstract

A total of 5.8 million hooks were scientifically observed at sea for seabird interactions in broad areas of the Indian Ocean between 1993 and 2017. Two types of information were obtained in the surface longline fleet targeting swordfish: (a) during regular commercial fishing and (b) during experimental surveys. 59.54% and 40.46% of the total effort was observed in each case, respectively. The geographical coverage of the study goes beyond the areas in which this commercial fleet has historically fished, because the information includes experimental surveys. Twenty years of regular commercial fishing data are included in the analysis and in thirteen of these years the interactions occurring were nil. Positive interaction occurred in twenty four of the one hundred and twelve 5ºx5º areas observed during regular commercial fishing and experimental surveys combined.

A total of 165 seabird interactions were recorded for both types of information in all areas and years combined, 77.58% of which occurred during experimental surveys and 22.42% during regular commercial fishing. 49.7% of the total interactions observed occurred in a single boat-survey in 2005-2006 in areas further east than 85ºE, where other boats involved in the same experimental survey at the same time recorded nil or very few interactions. No interaction occurred North of 20ºS and only a few sporadic interactions North of 30ºS. 70.3% of interactions occurred in areas well to the south and east, between 30º-45ºS/85º-115ºE, most of then related to experimental surveys in areas where commercial fishing by this fleet did not regularly take place. Procellariiformes was the order of seabird observed in encounters. Observations from commercial fishing alone generally suggest nil or low rates of interaction in most areas observed, while observations from surveys done in southern and eastern areas suggest relatively higher rates of interaction. The data provide a useful geographical overview of different areas of the Indian Ocean and suggest a possible latitudinal-longitudinal gradient related to higher interaction rates the further to the south and east fishing activity occurs, an aspect that should be verified by data from other fleets regularly fishing in those areas. The authors also include some comments on caution which should be exercised by readers when interpreting these results.

Key words: seabirds, surface longline, interaction, Indian Ocean

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1. Introduction

International and National Plans of Action[2] and scientific guidelines on seabirds recommend the study of interactions between fisheries and seabird populations in order to promote effective measures to mitigate the possible impacts in each fishing ground where this occurs. The regulatory framework of the Common Fisheries Policy of the European Union establishes technical measures, some of which are aimed at protecting sensitive species including seabirds. These technical instruments aim to minimize incidental catch of these species and are reflected in international agreements, plans, regulations, recommendations and resolutions, which should be supported by reliable scientific information.

Since the mid-1990s the Regional Fisheries Management Organizations responsible for the management of tuna and tuna-like species (tRFMOs) have undertaken action to assess the potential interaction between their fisheries and the seabird species in their respective areas of authority. Action by tRFMOs has included resolutions and recommendations to incorporate precautionary mitigation measures and also to assess their potential impact on their respective tuna and tuna-like fisheries (Anon. 2016, Jimenez *et al.* 2017, Lewison *et al*. 2005). Action implemented at domestic level has in some cases been more precautionary than tRFMO recommendations, mandatory mechanisms having been established for information to be compiled and annual reports produced by the respective contracting parties (CPCs), including information regarding interaction with seabirds and domestic action implemented. The rate of interaction, together with other sources of mortality, should be taken into account in any assessment of seabird populations (Croxall *et al.* 2012).

Additionally, tRFMO scientific groups have suggested guidelines to carry out studies with a view to assessing the levels of interaction in the respective areas-fisheries targeting tuna and tuna-like species and recommending effective and practical measures to minimize or avoid undesirable impacts where these may occur. In this respect, the ICCAT and IOTC ecosystem and by-catch scientific working groups have recently requested some specific studies of the interactions observed, focusing on restricted areas considered to be of special interest (Lat.≥25ºS) and certain periods in specific years. The information about different fleets analyzed according to these restrictive scientific guidelines may be considered very useful, complementing other information available from studies according to the areas of fishing activity of each fleet-gear-style or via the mandatory mechanisms established annually. Recently some studies of scientific observations made in the Spanish surface longline fishery targeting swordfish in Atlantic and Indian Ocean areas have been produced in response to these specific scientific guidelines (Fernández-Costa *et al.* 2016, Ramos-Cartelle *et al.* 2017). Additionally, a broader spatial and temporal overview has recently been provided for all Atlantic fishing areas based on twenty-five years of scientific observations at sea (Fernández-Costa *et al.* 2018).

Large numbers of studies have described a variety of anthropogenic effects other than fishing on the mortality of seabirds. Macro- and micro-plastic materials are nowadays recognized as one of the main causes of international concern (Lebreton *et al.* 2018). The pollution of the ocean by plastic is increasing dramatically, causing problems for humans but also impacting ecosystems, health and economies. It leads to morbidity and mortality in seabirds and in many other marine species such as fish, marine mammals, sea turtles, etc., through the direct intake of plastic materials or by intake through the trophic chain when ingesting their natural prey. Chemical pollution and spills of oil and derivatives have also been identified as one of the most visible causes of mortality among seabirds. Relatively little attention has been paid in recent years to these latter impacts, except those that have occurred as a consequence of huge, very visible ecological catastrophes produced by the "black tides" of oil spills. Some other negative impacts, such as the introduction of predators in the areas where seabirds nest and the effect of other human activities on their natural habitats, such as urban development or increasing tourism in some ecologically sensitive areas, have also been pointed out. However, global warming and climate change have been identified as major factors contributing to mortality, the decline in some seabird populations, changes in migration pathways and nesting periods, the geographical distribution of these species and also shifts in the geographical abundance and distribution of their natural prey.

Some fishing operations, such as those carried out using trawling, driftnets, purse seine, longlines and many other gear types may have unwanted interactions with seabirds but the problem has been generalized and it has been assumed that the overlap between the areas of distribution of the different seabird populations and the distribution of fishing activity using different types of gear necessarily implies an interaction between the two, leading to the death of seabirds. Fishing practices can produce greater, lesser or nil impact on the seabird

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[2] **FAO:** *International plan of action for reducing incidental catch of seabirds in longline fisheries, Rome, 1999, pp 1-10***. COM/2012/0665 final.** *Action Plan for reducing incidental catches of seabirds in fishing gears. Brussels, 16.11.2012.* **IOTC** *Resolution 12/06 On reducing incidental bycatch of seabirds in longline fisheries.*

populations present in a fishery area (Brothers *et al.* 1999), the level of interaction depending on a variety of factors primarily linked to the behavior and distribution of the seabird species, but also to the areas, times, methods and equipment used to catch each target fish species and the fishing pattern followed, among other factors. In some cases, fishing may consolidate or increase the number of seabirds present in particular fishing areas (Furness 2003) their presence being linked to the discards and waste produced in the course of regular fishing activity (Santos *et al.* 2011, Valeiras 2003, Valeiras *et al.* 2009).

It has often been pointed out that the greatest interaction with seabirds is regularly associated with high latitudes, open seas and the more productive cold water areas where much international fishing activity is assumed to take place. Although these generalizations are in some cases useful for certain species considered more vulnerable, the information available (e.g. Cortés *et al.* 2018, García-Barcelona *et al.* 2010[a,b,c], 2013; Báez *et al*. 2014, BirdLife International 2004, Valeiras and Camiñas 2003) suggests that these criteria must be qualified in the case of certain regions, coastal fishing areas and some seabird populations in particular, because substantial numbers of individuals might be bycaught annually in some coastal areas-fisheries (e.g. Oliveira *et al.* 2015). Moreover, information about interactions with seabirds within coastal, artisanal or recreational fisheries is usually very scarce in most sources.

There is a wide variety of oceanic longlines (such as surface, mid-water, deep, demersal), of target fish species (from epipelagic to demersal) and of fishing practices (ranging from cold to tropical regions, coastal to open seas), etc. These factors, among others, can determine the likelihood of interaction with some of the species of seabirds to be found in a fishing ground. Areas and fishing periods have been described as significant factors in some cases to explain the interaction with some species of seabirds (BirdLife International 2004, Baker *et al*. 2007, Jiménez *et al*. 2010, Tuck *et al.* 2011, Yeh *et al*. 2012). However, the fish species targeted, and thus the distribution of the species and the selection of fishing areas and times, and the fishing strategy applied in each case could also have a significant influence on the probability of interaction.

In the particular case of oceanic longlines targeting tuna and tuna-like species, the different gears are often mistakenly assumed to be similar, all being classified as *pelagic or drifting longlines* in most literature. It has been reported that the size and type of bait used on the hooks can sometimes lead to interaction, but it also depends on other variables, such as time and location, related to the fish species targeted. Even within the general category of longlines there is a wide range of styles with different potential impacts depending on each style, target species and fishing ground (e.g. Anderson *et al*. 2011, García-Barcelona *et al.* 2010[a,b,c], 2013; Inoue *et al*. 2012[a,b], Jiménez *et al.* 2011, Mejuto *et al*. 2008, Yeh *et al*. 2012). The choice of prey of the seabirds present in the fishing area and the specific mitigation measures applied by the fleet, or those already implicit in each fishing technique, are elements to be taken into account in the wide range of situations described in the abundant literature available. So, preventive measures should be adapted to each situation if they are to be effective (Gilman *et al.* 2005). The type/style of longline, the target species, the distance from the coast of fishing activity or the proximity of ocean islands in areas of possible overlap with these fish species and the seabird populations present in each area can play a significant role in determining a greater or lesser presence of seabirds in the selected fishing areas and the potential interaction of fishing operations with them (Brothers *et al.* 1999). The longlines used for tuna and tuna-like species may be of different styles (e.g. surface, deep, mixed) with different technologies (mechanical spool-set or manual) with different main lines (e.g. monofilament, multifilament) and different configurations (hooks, baits, leaders, weights, etc.) depending on the fleet, target species and fishing areas. However, from the point of view of their potential impact on seabirds, irrespective of the technique used and other factors for each type of longline, at least two major categories should be considered: those set mostly at night and those set during the day.

This document summarizes the information scientifically recorded at sea on the interaction with seabirds during regular commercial fishing activity and also during surveys of the Spanish surface longline fishery targeting swordfish in the Indian Ocean using night setting. The information recorded at sea during regular commercial fishing was thus complemented with observations obtained in surveys generally carried out in areas where fishing operations were infrequent to provide a broader geographical overview including useful information on northern, southern and eastern areas where other fleets could target swordfish and/or other fish species. This paper could be considered as a retrospective and complementary overview of information previously provided in annual reports or via other scientific papers, according to the guidelines of the scientific working group or mandatory requests of IOTC after the implementation of specific recommendations on these species, or domestic or international plans of action[2] regarding these species. However this study also provides information from periods long before the implementation of such action or specific guidelines on seabirds. The objectives of this study coincide with the objective set by this regulatory framework of "*reducing the bycatch of seabirds to the lowest levels in practice*" as indicated in the International and EU Plans of Action[2] on seabirds, which are directed towards the "management of ecosystems that encompass all their components, as the purpose of the current EU Common Fisheries Policy" and more specifically of IOTC Resolutions in the framework of fisheries targeting tuna and tuna-like species in the Indian Ocean.

2. Material and methods

The data analyzed were recorded between 1993 and 2017 by scientific observers on board surface longline fishing vessels targeting swordfish using night setting. However, observations from the years 1995, 1996 and 1997 are not available. Historically, the practices and fishing areas of the Spanish fleet targeting swordfish in the Indian and other oceans have been adapted to the areas of greatest abundance-distribution of this species (Palko *et al.* 1981) and also their vertical migrations (Abascal *et al.* 2010, 2015; Neilson *et al.* 2009), the swordfish regularly being more abundant in areas with SSTs above 17ºC and showing a clear diel pattern in vertical behavior staying in surface waters or around the mixed layer at night.

The vessels observed were engaged in regular commercial fishing operations (referred to hereafter as commercial fishing) and generally did not change their fleet's standard practices during the trips observed. Some additional trips were engaged in experimental-scientific surveys (referred to hereafter as surveys) carried out between 1993-1994 and 2003-2008, some of them further south and/or east of the regular commercial fishing areas of this fleet targeting swordfish, and in one case a trip was used to test modifications to gear. In those particular surveys the fishing sets took place in previously defined and restricted areas where commercial fishing activity targeting swordfish is not regularly carried out by this fleet. The observations obtained during these surveys were analyzed, validated and combined with information obtained during regular commercial fishing operations targeting swordfish.

All effort (hooks set) and haulback during the commercial and survey trips targeting swordfish were observed and interactions (positive or null) recorded. The information recorded was compiled by year, month and area (5ºx5º squares), named following the criteria of four quadrants (1,2,3 and 4), latitude (2 digits) + longitude (3 digits). The name of each 5ºx5º area represents the nearest point to 0º Lat./0º Lon. Information by area and years combined was used to obtain an overall picture for the whole period observed and analyzed. Rates of interaction were defined for each area based on the nominal effort observed (thousands of hooks) and the number of seabird interactions recorded (positive or null) for the respective number of hooks. Average-annual 5ºx5º Task II-effort of the Spanish fleet during the period 1993-2017 was used for comparison with the areas observed at sea and the interaction with seabirds recorded. Combined 5ºx5º effort data for the surveys were also used for specific descriptions of rates of interaction by area occurring during surveys.

3. Results and discussion

During the period 1993-2017 a total of 5,796,074 hooks in 112 areas (5ºx5º squares) covering broad regions of the Indian Ocean were scientifically observed for seabirds and analyzed. 59.54% (3,450,915 hooks) of the total fishing effort was observed during surveys carried out between 1993-1994 and 2003-2008. 40.46% (2,345,159 hooks) of the total fishing effort was observed during commercial fishing operations between 1998 and 2017.

Figure 1 shows a comparison between the nominal effort (thousands of hooks) scientifically observed by area during the combined period and the number of positive interactions with seabirds recorded in each area during commercial fishing and survey trips combined. Zeros are omitted in this figure for those areas with effort observed and null interactions. **Table 1** summarizes the number of hooks observed during surveys and commercial fishing, respectively, where positive interaction occurred, as well as the number of interactions and rates of interaction with seabirds per thousand hooks, for 5ºx5º areas. Areas which were observed but where there was no positive interaction are also omitted from this table.

Only in 24 of the 112 5ºx5º areas observed did positive interactions occur. **Figures 2, 3 and 4** provide information about the total fishing effort (thousands of hooks) scientifically observed for 5ºx5º areas during the whole period, as indicated in Figure 1 (color scale), combined with layers of the nominal fishing effort of the total fleet during the respective surveys/commercial fishing/all data combined (circle scales), as well as the respective rates of interaction with seabirds by area during surveys/commercial fishing/all data combined (triangle scale).

A total of 165 seabirds were recorded in all areas in surveys and commercial fishing during the whole period observed. However, 128 of them (77.58%) were observed during surveys and only 37 of them (22.42%) during commercial fishing. No interaction with seabirds was recorded North of 20ºS in either type of trip and only a few sporadic interactions occurred North of 30ºS (**Figure 1**). The largest number of interactions (70.3%) occurred in areas further south and east between 30º-45ºS/85º-115ºE, most of then related to surveys in areas where commercial fishing was not regularly carried out by this fleet (**Figures 2, 3 and 4).** However, the highest rate recorded was in a single set in the area 35070 SE during a commercial trip (**Figures 3 and 4**).

Table 2 provides information about numbers of interactions observed during surveys and commercial fishing, respectively. Procellariiformes was the order of seabird encountered for both types of fishing. **Table 3** summarizes the number of interactions observed by year and each type of fishing. Data for twenty years of commercial fishing were used in this analysis and in thirteen of these years the interactions occurring were nil.

A significant finding was that 82 (49.7%) of the total interactions observed for both types of trip during the whole period analyzed occurred during a single boat-survey conducted between 2005 and 2006 in areas further east than 85ºE, while at the same time other boats involved in the same survey in the same areas recorded nil or very few interactions. The reason for this unusually high rate of interaction in this particular survey-boat was not elucidated from the observer's notes. However, a similar event was described in relation to observations obtained for the South Atlantic Ocean, where 74% of the total interactions observed during a period of twenty-five years occurred during a single trip-boat, being related to unusual circumstances during that trip (Fernández-Costa *et al.* 2018). The geographical coverage of the study exceeds the areas in which the Spanish commercial fleet has traditionally fished for swordfish because of the addition of some areas only observed during surveys.

An analysis of the information broken down by type of observation (surveys or commercial trips) in the respective areas indicates that the highest rates of interaction have generally occurred during surveys conducted south of 35ºS and east of 85ºE (**Figures 2 and 3**), mostly outside the commercial fishing areas historically visited by the Spanish fleet, with the exception of a single commercial set observed in area 35070, during which the highest rates of interaction among all the areas observed were recorded **(Figure 4**).

The data obtained during commercial trips in general suggest null or very scarce interaction with seabirds in most of the 5ºx5º areas observed. A similar situation was described for the Spanish fleet targeting swordfish in the Atlantic (Fernández-Costa *et al.* 2018). Some areas to the SW of Madagascar show positive interaction rates, although they are relatively low compared with areas further to the east, information for which comes mainly from surveys **(Figures 3, 4 and 5)**. However, it should be borne in mind that the historical information analyzed here includes data since 1993, i.e. before the introduction of action plans and mitigation measures (both domestic and by tRFMOs) to minimize interaction with seabirds. In this regard, data from the commercial fleet in the period 2009-2017 indicate that a total of only 19 interactions was recorded (**Table 3**), 13 of which occurred in a single trip by one vessel in 2013, and that in 6 of the 9 years observed interaction was null. However, despite the null or scarce interaction associated with this fleet, the dissemination and training already undertaken should be continued to minimize the sporadic interaction that may occur during a particular trip, with the efficient application in all cases of the measures already implemented, which seem to have been generally effective in the Spanish fleet targeting swordfish.

One possible explanation of the regularly null or low rates of interaction observed in this Spanish fleet may be related to its regular fishing practices and to the limited overlap between the temperate areas preferred by swordfish and/or the Spanish fleet in the south-western and south-central Indian Ocean and those areas preferred by certain seabirds such as Procellariiformes. The highest rates of interaction with these species of seabirds may well occur further to the South and/or East than the areas where swordfish are predominantly distributed and/or fished by this fleet.

The results obtained allow for different interpretations and the reader must exercise some caution before drawing conclusions. Information from commercial fishing gives figures for interaction in line with what might be expected historically for the Spanish fleet in those areas where commercial fishing took place in the last two decades. However, information from surveys gives us an idea of the rates of interaction that one might expect in other areas outside those habitually fished by the fleet. In particular they provide information for certain areas situated further to the south and east, where there might be a greater likelihood of interaction with seabirds if fishing activity took place there.

The rates of interaction obtained by combining the two types of data should not be interpreted as representative of the interaction one could historically expect for this commercial fishing fleet. Neither should they be taken as representative of other fleets fishing in the Indian Ocean using similar or different gear or styles, whether these target swordfish or other species. However, the combined results do give a spatial view which could be useful to some extent in establishing the possible existence of a latitudinal and longitudinal gradient indicating higher rates of interaction the further south and east fishing takes place, a trend that should be verified with data from other fleets that fish these areas regularly.

Sightings were also considered during some trips and in some cases these were very abundant (see details in e.g. Fernández-Costa *et al.* 2016). Most sightings took place in the middle of the day or during navigation, but on some occasions when setting or hauling were taking place, although no interactions occurred during most sightings. The sightings varied greatly from one area to another. Most scientific observers attributed the general lack or scarcity of positive interactions in commercial data to various main factors and the routine regularly followed: (a) The lack or low occurrence of some seabird species in the most important ocean areas where this commercial fleet regularly fishes swordfish in the Indian Ocean. (b) Setting is generally started with very little light, mainly at dusk or when night has fallen. (c) In general, there is no waste during the setting operations that might attract seabirds and deck lighting is limited to what is strictly necessary for the safety of the vessel and the crew. (d) The speed of setting procedures with the spool and line setter designed to pull monofilament longlines from the spool at a rate greater than or equal to the speed of the vessel, allowing the main and weighted branch lines carrying the hooks and bait to sink more rapidly, plus the bait types regularly used.

As indicated above, oceanic longlines used to target different tuna and tuna-like species are very often all mistakenly assumed to be similar. However, fishing areas (e.g. ranges of lat-long) and target species, gear characteristics and styles, fishing protocols and many other factors differ greatly among different longline types and fisheries. For this reason, the results obtained in a fleet should not be assumed as representative of other longline fleets or styles. Records from different fleets should not be combined in a simple way without considering the peculiarities of each fleet-gear-style and the source of information. When information from several different fleets is combined, the analyses should at least consider fleet specific factors and details about each fleet and the circumstances associated with its data.

The night setting style was historically used by this and most longline fleets targeting swordfish. Before the first IOTC Resolution 06/04 on reducing incidental bycatch of seabirds in longline fisheries came into force, the Spanish National Fishing Authority (NFA) had already been implementing some precautionary measures to reduce the likelihood of such interactions since 2002. Since that year, in response to domestic Order APA/1127/2002, precautionary mitigation measures had been implemented, applicable to all surface longline fishing vessels flying the Spanish flag and targeting swordfish in waters South of 30º S, irrespective of the ocean and area in which they carried out their activity. Later, in the case of IOTC, some measures based on Resolution 06/04, Resolution 08/03, Resolution 10/06 and Resolution 12/06 were put in place and also incorporated by the NFA in Domestic Orders and other mandatory mechanisms. However, more recently, via Domestic Order AAA/658/2014[3], the NFA has established more precautionary measures which are stricter than those specified in IOTC and other tRFMO resolutions and recommendations, and they are applicable to all Spanish surface longline vessels irrespective of the fishing area or ocean in which they are authorized to fish.

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Table 1. Fishing effort observed (thousands of hooks), number of seabird interactions and rates of interaction (number per thousand hooks) for those 5ºx5º areas (Quad.+Area) where positive interaction was observed (at least one seabird interacted in the area during the whole 1993-2017 period observed). Information by area is provided for experimental survey trips, regular commercial trips and both types of fishing combined. Those areas with fishing effort observed but null interaction occurring are omitted from this table.

		Observed in surveys			Observed in commercial			Observed total		
Quad.	Area	Effort	Seabirds	Rate	Effort	Seabirds	Rate	Effort	Seabirds	Rate
2	20085	23.301	1	$4.292E^{-02}$	9.508	0	0	32.809	1	$3.048E^{-02}$
2	25035	50.476	1	$1.981E^{-02}$	292.750	0	0	343.226	1	$2.914E^{-03}$
2	25060				49.953	1	$2.002E^{-02}$	49.953	1	$2.002E^{-02}$
2	30035	47.125	5	$1.061E^{-01}$	193.368	12	$6.206E^{-02}$	240.493	17	$7.069E^{-02}$
2	30040	8.876	0	0	152.468	8	$5.247E^{-02}$	161.344	8	$4.958E^{-02}$
2	30045	32.500	4	$1.231E^{-01}$	59.394	3	$5.051E^{-02}$	91.894	7	$7.617E^{-02}$
2	30050				43.635	3	$6.875E^{-02}$	43.635	3	$6.875E^{-02}$
2	30055				37.552	2	$5.326E^{-02}$	37.552	2	$5.326E^{-02}$
2	30070				42.117	1	$2.374E^{-02}$	42.117	1	$2.374E^{-02}$
2	30085	82.420	19	$2.305E^{-01}$	16.661	0	0	99.081	19	$1.918E^{-01}$
2	30090	58.310	4	$6.860E^{-02}$	18.130	0	0	76.440	4	$5.233E^{-02}$
2	35035	11.763	0	0	6.315	1	$1.584E^{-01}$	18.078	1	$5.532E^{-02}$
2	35040	4.329	0	0	5.039	1	$1.985E^{-01}$	9.368	1	$1.067E^{-01}$
2	35070				1.235	5	$4.049E^{+00}$	1.235	5	$4.049E^{+00}$
2	35085	25.251	36	$1.426E^{+00}$				25.251	36	$1.426E^{+00}$
2	35090	27.551	6	$2.178E^{-01}$				27.551	6	$2.178E^{-01}$
2	35105	27.721	1	$3.607E^{-02}$				27.721	1	$3.607E^{-02}$
2	40035	2.464	1	$4.058E^{-01}$				2.464	1	$4.058E^{-01}$
2	40085	11.671	11	$9.425E^{-01}$				11.671	11	$9.425E^{-01}$
2	40090	10.930	20	$1.830E^{+00}$				10.930	20	$1.830E^{+00}$
2	40095	10.007	11	$1.099E^{+00}$				10.007	11	$1.099E^{+00}$
2	40100	9.641	2	$2.074E^{-01}$				9.641	2	$2.074E^{-01}$
2	40105	10.207	4	$3.919E^{-01}$				10.207	4	$3.919E^{-01}$
2	40110	10.198	2	$1.961E^{-01}$				10.198	2	$1.961E^{-01}$

Table 2. Number of interactions reported by scientific observers in each type of fishing (experimental surveys or regular commercial fishing) during the 1993-2017 period combined.

	Observed in surveys		Observed in commercial		Observed Total	
Genus/Family/Order	Number	Percent	Number	Percent	Number	Percent
Thalassarche	24	18.75	17	45.95	41	24.85
Procellaria	17	13.28	5	13.51	22	13.33
Diomedea/Diomedeidae	85	66.41	5	13.51	90	54.55
Phoebetria	2	1.56	10	27.03	12	7.27
Total # interactions	**128**		**37**		**165**	

Table 3. Number of seabird interactions reported by scientific observers by year and type of fishing (experimental surveys or regular commercial fishing) during the 1993-2017 period (data is not available for the years 1995, 1996 and 1997).

Year	Observed in surveys	Observed in commercial	Observed Total
1993	0		0
1994	10		10
1995			
1996			
1997			
1998		0	0
1999		0	0
2000		0	0
2001		0	0
2002		1	1
2003	1	0	1
2004		0	0
2005	97	0	97
2006	19	10	29
2007	1	2	3
2008	0	5	5
2009		0	0
2010		0	0
2011		0	0
2012		0	0
2013		13	13
2014		2	2
2015		4	4
2016		0	0
2017		0	0
Total	**128**	**37**	**165**

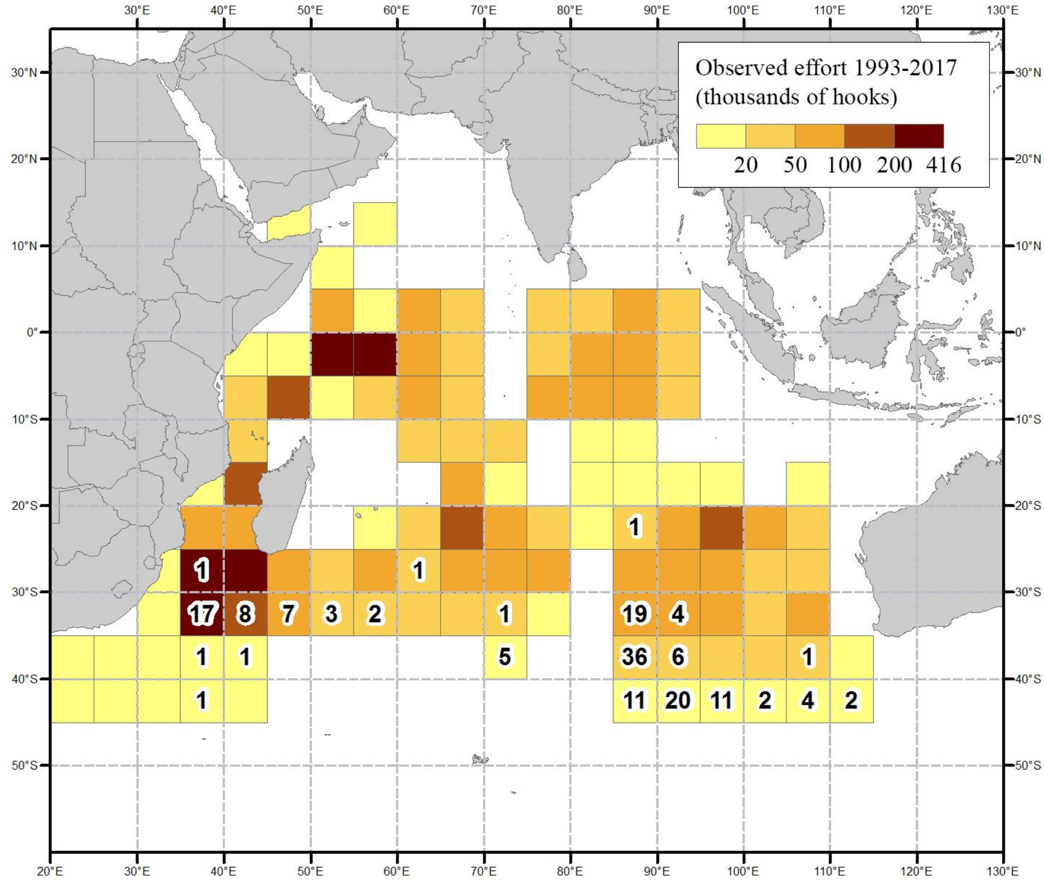

Figure 1. Total fishing effort (thousands of hooks) scientifically observed (scale yellow-brown) by 5ºx5º area of the Indian Ocean for the combined 1993-2017 period, including surveys and regular commercial fishing. Numbers in each square identify the number of seabird interactions occurring during both types of fishing combined. The number is omitted for those areas with fishing effort observed and null interaction reported.

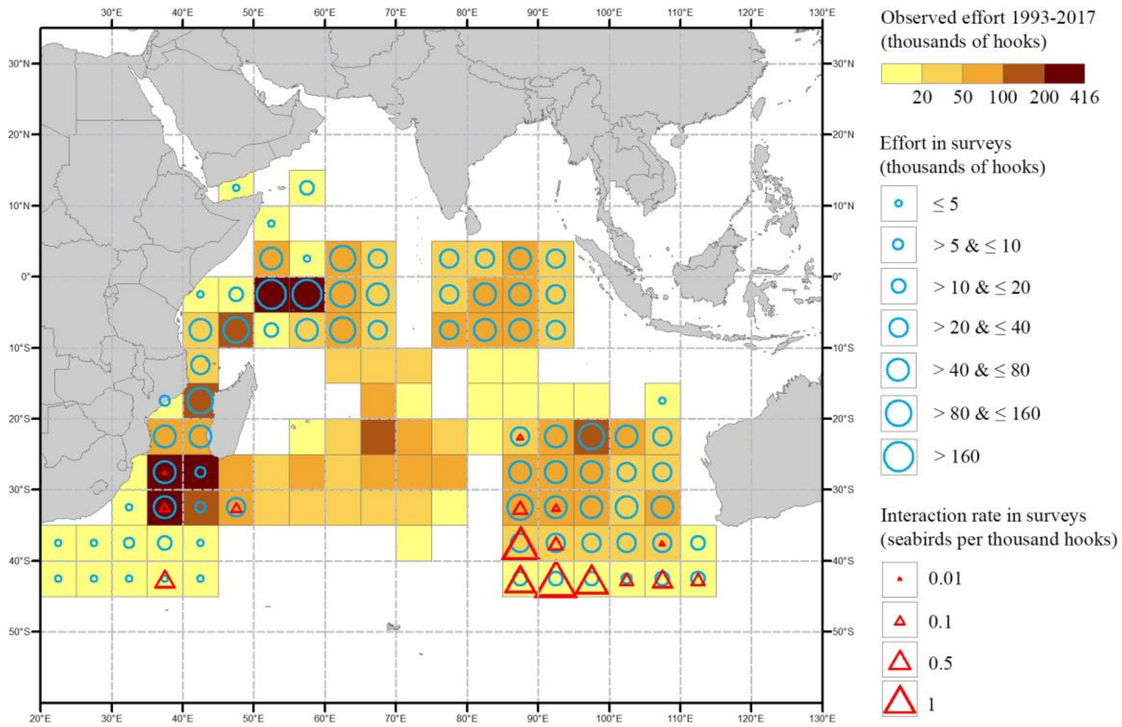

Figure 2. Total fishing effort (thousands of hooks) scientifically observed for 5ºx5º areas during the 1993-2017 period as indicated in Figure 1 (color scale). Total nominal fishing effort (thousands of hooks) by area during experimental surveys for the whole period observed (circles) and interaction rates with seabirds (number per thousand hooks) observed by area during experimental surveys (triangles).

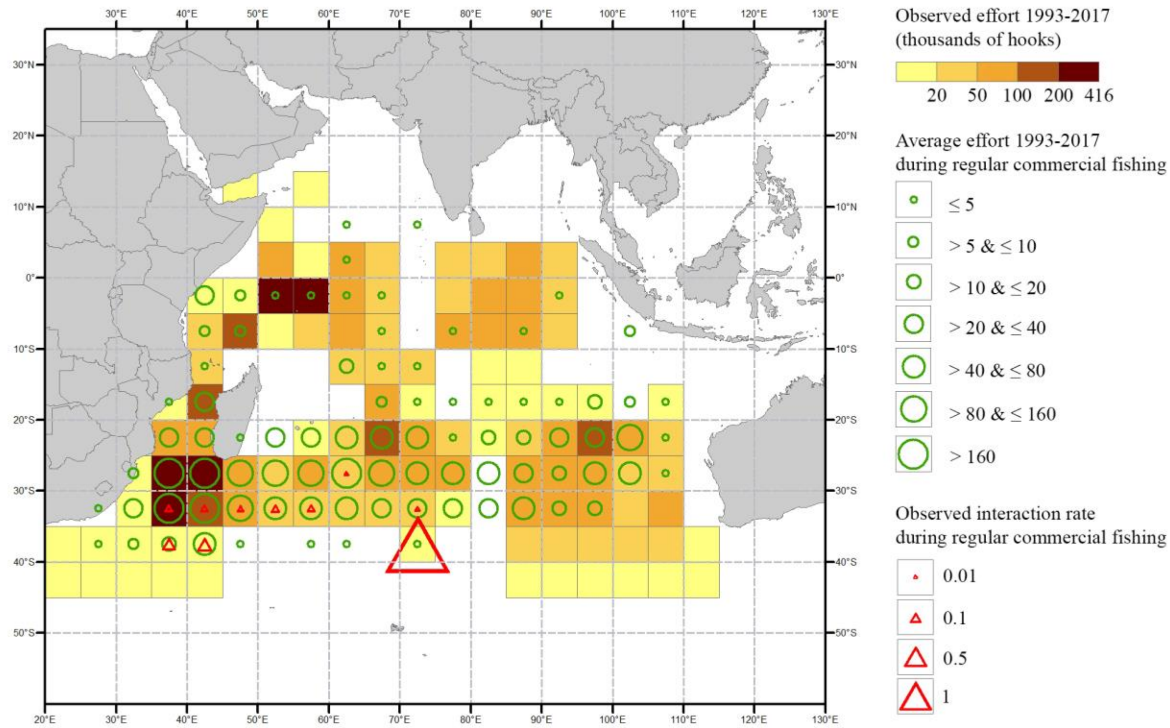

Figure 3. Total fishing effort (thousands of hooks) scientifically observed for 5ºx5º areas during the 1993-2017 period as indicated in Figure 1 (color scale). Mean annual fishing effort (task II-effort in thousands of hooks) of the whole Spanish fleet during regular commercial fishing operations between 1993-2017 (circles) and interaction rates with seabirds (number per thousand hooks) observed by area during regular commercial fishing operations (triangles).

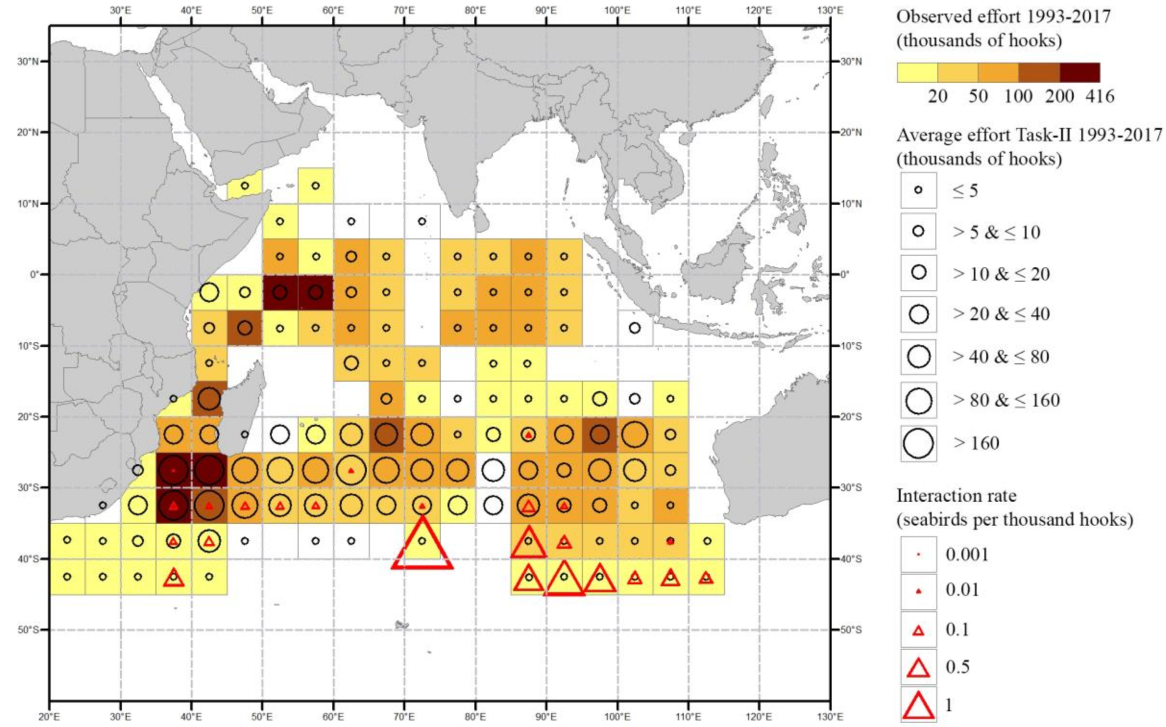

Figure 4. Total fishing effort (thousands of hooks) scientifically observed for 5ºx5º areas during the 1993-2017 period as indicated in Figure 1 (color scale). Mean annual fishing effort (task II-effort in thousands of hooks) of the whole Spanish fleet during regular commercial fishing and experimental surveys combined (circles) and interaction rates with seabirds (number per thousand hooks) observed by area during regular commercial fishing and experimental surveys combined (triangles).

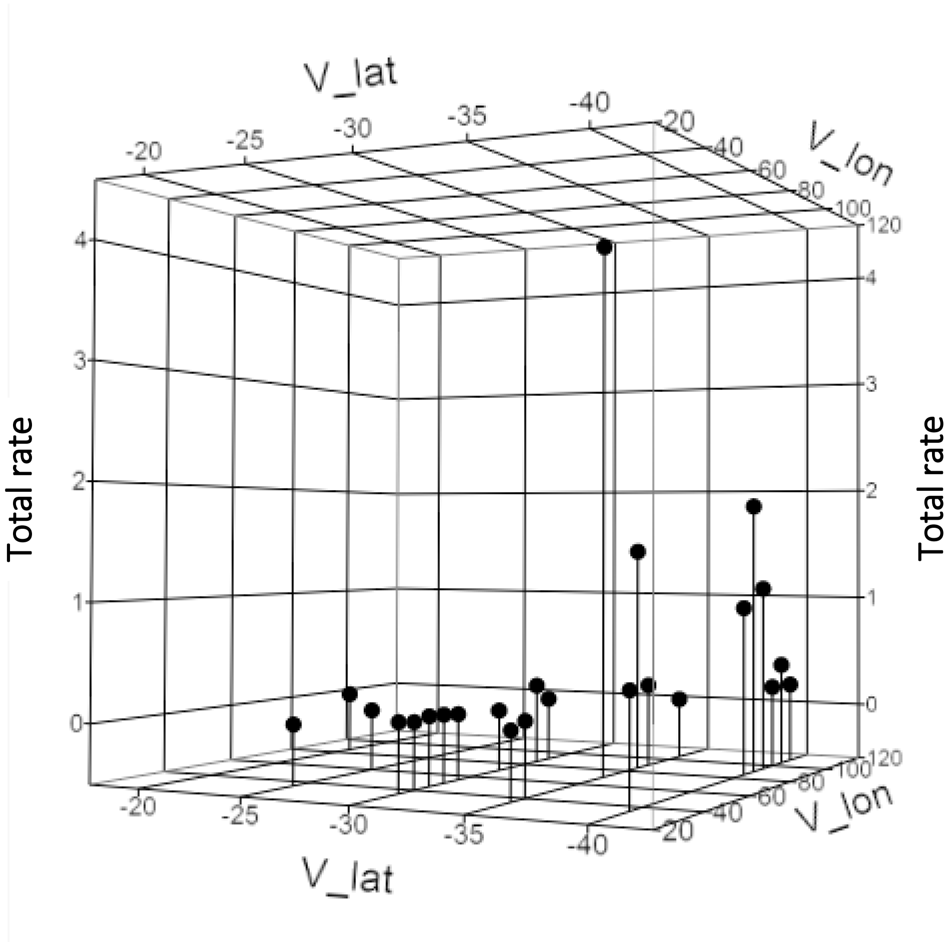

Figure 5. 3-D summary of the positive rates of interaction (number of seabirds per thousand hooks) observed in the Indian Ocean for latitude and longitude squares (only those 5ºx5º areas with positive interactions included) in data from commercial fishing and experimental surveys combined, during the period 1993-2017. Those areas with effort observed but null interaction occurred are omitted from this chart (see Table 1 and previous figures for details).