CopeMed II - MedSudMed Workshop on Fisheries and appraisal of *Coryphaena hippurus*

05-06 July 2011

Palermo, Italy

Dolphinfish bycatch in Spanish Mediterranean large pelagic longline fisheries, 2000-2010*

David Macías[1,a], José C. Báez, Salvador García Barcelona[1], and José M. Ortiz de Urbina[1].

[1]Centro Oceanográfico de Málaga, Instituto Español de Oceanografía, Puerto pesquero, s/n 29640, Fuengirola, Spain.

Abstract - Incidental catch or bycatch represents a significant threat for the conservation of fish populations. The western Mediterranean is an important fishing area where the Spanish pelagic and semi-pelagic longline fleet targeting swordfish (*Xiphias gladius*), bluefin tuna (*Thunnus thynnus*) and albacore (*Thunnus alalunga*) operates. Bycatch of these fisheries includes several fish species. Given the importance of conservation of the bycatch species (fish, marine mammals, turtles, sharks and seabirds), an on-board observer program was implemented by the Spanish Oceanographic Institute (IEO); this included collecting data on effort and catch, as well as weight and number of individuals of the main bycatch species. The aim of the present study is to report data on Coryphaena bycatch collected by the on-board observer program of the IEO in the Western Mediterranean.

Data on dolphinfish bycatch were collected for the period 2000-2010, throughout the year. Six longline gears targeting large pelagic fish were identified operating in the area of study, but only three had an important effect on dolphinfish. Differences in catch per unit effort (CPUE, fish per 1000 hooks) for each gear, fishing grounds and year, are reported in this study. A total of 6 151 508 hooks were monitored, which yielded 6 663 dolphinfish. The average CPUE for the studied period was 1.08 fish per 1000 hooks.

The main aim of this paper was modelling the abundance and distribution of dolphinfish bycatch from Spanish Mediterranean longline fishery as a function of technical, geographical and seasonality factors. We built a favourability function from a logistic model, where the dependent variable was the dolphinfish by-catch and the independent variables were related to technical characteristics of the fishery, geographical location and seasonality.

Our results suggest that dolphinfish is mainly affected by the gear type, day setting and geographical variables.

Keywords - **Bycatch, dolphinfish, CPUE, Western Mediterranean Sea, pelagic longline**

[1,a] Corresponding author: david.macias@ma.ieo.es. IEO. Pto. Pesquero s/n, 29640 Fuengirola. Spain. Tlfno 0034952197124; fax 0034952463808

[*] This document was prepared as part of the CopeMed II contribution to the Coryphaena Workshop held in Palermo, 5-6 July 2010.

1 Introduction

Incidental catch or bycatch represents 8 % of global fisheries production (Kelleher 2005). Bycatch is defined as any unwanted species caught during normal fishing operations and may include non-target fish species, marine mammals, turtles, sharks and seabird (Hall 1996; Alverson 1999).

Dolphinfishes (C*oryphaena hippurus* and *Coryphaena equiselis*) are highly migratory pelagic species inhabits tropical, Subtropical and temperate waters. They constitute a valuable seasonal resource for small scale fleets. Traditionally, dolphinfish has been an important food resource for the Mediterranean people. The Mediterranean landings of these species have increased regularly in the last decade (Massuti and Morales, 1999). Nevertheless, the assessment and management of dolphinfish is difficult mainly due to the scarcity of data on biology, migratory patterns and exploitation of these species in the Mediterranean.

Dolphinfishes in the Mediterranean support both commercial (small-scale fishing) and recreational fisheries (Lleonart et al., 1999; Potoschi et al., 2009). In Malta, Tunisia, Sicily and Balearic Island from the end of summer to autumn, dolphinfish juvenile are caught using Fish Attracting Devices (FADs) (Bono et al., 1998; Morales-Ninet al., 1995; Potoschi and Sturiale, 1996). But these species are also caught as bycatch of commercial longline fisheries (De Metrio et al., 1997; Macías and de la Serna, 2000). The Western Mediterranean Sea is an important fishing ground where the Spanish drifting longline fishery operates targeting mainly swordfish *Xiphias gladius*, bluefin tuna *Thunnus thynnus* and albacore *T. alalunga*. In this context, identification of the principal factors that determine this by-catch is basic to improve the assessment and management of the Mediterranean dolphinfish stocks.

The aim of this paper is to describe the dolphinfish bycatch rates in the longline fisheries of the Western Mediterranean and modelling the bycatch abundance and distribution of dolphinfish from the Spanish Mediterranean as a function of technical, geographical and seasonality factors.

2 Materials and methods

2.1 Data collection

Catch and effort data for longline fisheries were collected by the Spanish Oceanographic Institute (IEO) on-board observer training program, planned according to ICCAT recommendations. Observers were assigned based on strata. The positions of the fishing grounds and spatial distribution of gear effort are shown in **figure 1**.

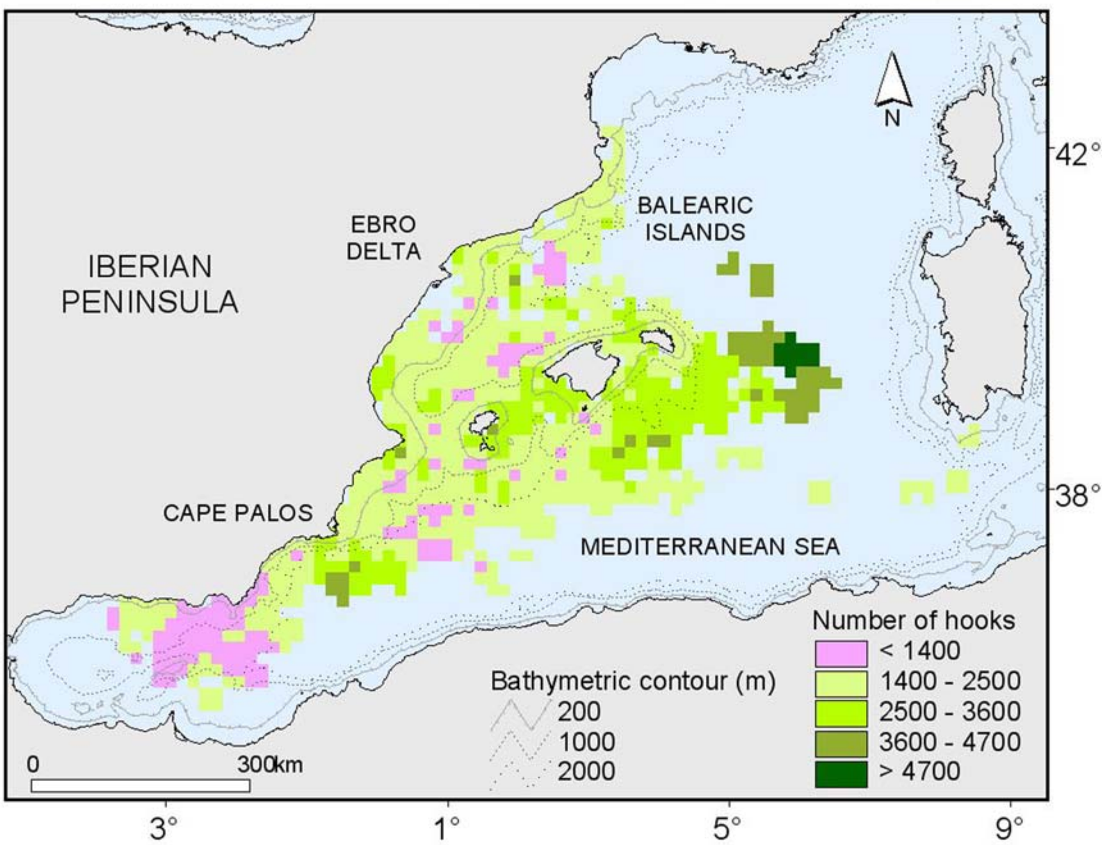

Figure 1. Spatial distribution of observed fishing effort and known fishing grounds.

The IEO on-board observer Program (IEO-OP) provided commercial fish catch and bycatch data collected on longline vessels from 1997 to 2010. Dolphinfish bycatch data were collected from 2000 to the present day, so we only included the 2000-2010 period in the present study. For each fishing set observed, data were recorded on fishing set location, time of setting and hauling; environmental data (sea surface temperature, distance to the coast, depth and weather conditions, moon phase), soaking duration; gear characteristics (total length, mean depth, number of hooks, etc.); type and size of bait; species composition; and corresponding biological information (size/weight). Within each sampled set, observers monitored 100 % of the total hooks retrieved and recorded information on species composition, number and estimated weight of both target species and bycatch including dolphinfish. In addition, the environmental variables listed above were also recorded.

With regards to dolphinfish, the objectives of observers were to record captures and identify specimens to the lowest taxonomic level possible. However, at the beginning of the temporal series, as the observers had little experience with dolphinfish, many specimens could not be identified and /or recorded at species level. The accuracy of the data improved gradually reaching and now has a high degree of precision.

2.2. Explanatory factors and variables

Like Báez et al. (2010c) and García-Barcelona et al. (2010b), who followed a hypothetical-deductive method, we define previously three explanatory factors (as a set of variables with a similar explanation): technical characteristics of the fishery, geographical location and seasonality. Each explanatory factor was represented by a set of variables (**table 1**), and is linked with a hypothesis:

Table 1. Factors and explanatory variables used in the general logistic regression model.

Factors	Variables	Variables type	Abbreviation
Dependent variable	Absence/ presence Coryphaena by-catches per set	Binary	CO
Technical characteristics of the fishery	Number of hooks	Quantitative	NH
	Distance between both extremes of the longline	Quantitative	DL
	Diurnal or nocturnal setting	Binary	DN
	Setting hours	Categorical	
	Drifting surface longliners targeting bluefin tuna	Binary	LLJAP
	Traditional longliners targeting swordfish	Binary	LLHB
	American longliners targeting swordfish	Binary	LLAM
	Drifting surface longliners targeting albacore	Binary	LLALB
	Drifting semi-pelagic longliners targeting swordfish	Binary	LLSP
	Demersal longliners targeting swordfish	Binary	LLPB
Geographical location.	Latitude where the setting started	Quantitative	LATSS
	Longitude where the setting started	Quantitative	LONGSS
	Latitude where the setting finished	Quantitative	LATFS
	Longitude where the setting finished	Quantitative	LONGFS
	Sets over continental shelf	Binary	SCS
Seasonality (phenology)	January	Binary	JA
	February	Binary	F
	March	Binary	MR
	April	Binary	AP
	May	Binary	MY
	June	Binary	JN
	July	Binary	JL
	August	Binary	AU
	September	Binary	S
	October	Binary	O
	November	Binary	N
	December	Binary	D

Technical characteristics of the fishery (TCF). Indicators of the influence of this factor include the positive relation with the number of hooks; we directly controlled 5,398,297 hooks. We expected an inverse relationship of the by-catch with the distance between both extremes of the longline. Moreover, we considered the categorical variables: diurnal or nocturnal setting, and setting hours (06:00-12:00, 12:00-18:00, 18:00-24:00, and 24:00-06:00), and *strata* type. García-Barcelona et al. (2010a) divided the Spanish longline fleet from the Mediterranean Sea in six *strata* types in function of boat strata and gear type: drifting surface longliners targeting bluefin tuna (LLJAP), traditional longliners targeting swordfish (LLHB), American longliners targeting swordfish (LLAM), drifting surface longliners targeting albacore (LLALB), drifting semi-pelagic longliners targeting swordfish (LLSP), and demersal longliners targeting swordfish (LLPB) Valeiras & Camiñas (2003), Camiñas et al. (2006), Báez et al. (2007a, b), Báez et al. (2009), Báez et al. (2010a, b), García-Barcelona et al. (2010a) showed in a detailed description of fleet strata and technical characteristics of the fishery.

Geographical location (GL). We used as geographical variables the latitude and longitude where the line setting started (LATSS, LONGSS respectively) and where the setting finished (LATFS, LONGFS respectively); and the categorical variable fishery operation over continental shelf or not (sets over continental shelf, SCS).

Seasonality (SE). Like García-Barcelona et al. (2010 b), we expected a positive relationship between season and seabird by-catch. Thus, the breeding season of Cory's shearwater ends in October and both adults and juveniles gather to leave the Mediterranean Sea in the first two weeks of November. The effect of different seasons was tested using the different months as explicative variables. Thus, we used a categorical variable (yes or no) for each observed month. We used months as temporal units, bearing in mind their possible utility for management purposes.

Environment **(EF)**. We tested the Moon phase and sea surface temperatute as explanatory environmental variables. The Moon effect was estimated as a binary variable, where from half full moon to full moon was considered 1 and the rest of the phases as 0. Regarding Sea Surface Temperature (SST) we considered the following variables: SST where the setting started (SSTSS), SST where the setting finished (SSTFS), mean SST between SSTSS and SSTFS (MR), and absolute variation between SSTSS and SSTFS (AP = SSTFS – SSTSS).

2.3 Data analysis

We calculated annual dolphinfish bycatch rates as the total number of individual dolphinfish caught in a year divided by the number of hooks deployed (CPUE). In addition, we calculated the average annual CPUE as the mean of CPUE per set (all sets in a year) and standard errors for dolphinfish, to explore patterns in the data. A chi-square test (Sokal and Rohlf 1995) was used to test for statistically significant differences in number of dolphinfish caught between gear strata and between levels of fishing effort by year.

To estimate the average annual dolphinfish bycatch, we calculated the observed annual CPUE (average annual CPUE per set). After that, we calculated the average number of fish caught each year, extrapolating the observed annual catch rates (CPUE) to the total annual effort. Finally, we calculated the mean number of dolphinfish and standard errors in the period studied. The average annual number of dolphinfish was calculated using the same methodology.

To adjust Length-weight relationships, power curve regressions were performed. We used pair length-weight data from 155 individuals of Coryphaena by-caught in longline from different boat strata during the study period. We selected the best fit among several significant regressions, in accordance with the highest F-value.

In a first step, we performed a binary logistic regression of the presence and absence of dolphinfish bycatch to test whether the probability of incidentally catching a dolphinfish (1 or more) may be forecast by some of these explanatory variables listed in table 1. With this first step we standardized the most optimal capture conditions of Coryphaena sp. bycatch. It allows us to delete those sets with structural absences. Many authors recommend the use of logistic regressions for evaluating the effects of environmental conditions and fishing practices on the probability of interactions with by-catches (Ward et al., 2004; Gandini and Frere 2006; Garrison, 2007; Báez et al., 2007b, García-Barcelona et al., 2010b), and it could relate the probability of an event (for example, the risk of catching a specimen of Coryphaena) with a series of variables and explanatory factors.

By performing a logistic regression of the by-catch presence/absence on each variable separately, we selected a subset of variables significantly related to the distribution of the by-catch. To control for the increase in type I error due to multiple tests (Benjamini and Hochberg, 1995; García, 2003), we only accepted those variables that were significant under a False Discovery Rate (FDR) of $q<0.05$, using the Benjamini and Hochberg procedure (1995). We then performed forward stepwise logistic regression on the subset of significant predictor variables to obtain a multivariate logistic model.

Model coefficients were assessed by means of an omnibus test and the goodness-of-fit between expected and observed proportions of by-catch events along ten classes of probability values was evaluated using the Hosmer and Lemeshow test (which also follows a Chi-square distribution; low p-0.05 would indicate lack of fit of the model). On the one hand, the Omnibus test examines whether there are significant differences between the -2LL (less than twice the natural logarithm of the likelihood) of the initial step, and the-2LL of the model, using a Chi-squared test with one degree of freedom. On the other hand, the Hosmer & Lemeshow test compares the observed and expected frequencies of each value of the binomial variable according to their probability. In this case we expected that there are no significant differences for a good model fit.

In addition, the discrimination capacity of the model (trade-off between sensitivity and specificity) was evaluated with the receiving operating characteristic (ROC) curve. Furthermore, the area under the ROC curve (AUC) provides a scalar value representing the expected discrimination capacity of the model (according to Lobo et al., 2008, models with an AUC value higher than 0.9 are considered as outstanding discrimination; no realistic classifier should have an AUC less than 0.5). The relative importance of each variable within the model was assessed using the Wald test.

In a second step, we modelled for boat strata (LLALB, LLAM, LLHB) between May and November during the study period, the probability of a fishing operation present a CPUE value higher than the average CPUE for this boat stratum, using binary logistic regression and the variables of the **table 2** as explanatory factors. Consequently, we assigned the value 1 when the CPUE of a particular set was higher than the mean CPUE for that boat strata pooled together, while we assigned the value 0 when the CPUE was lower than that mean CPUE value.

Table 2. Factors and explanatory variables used in the partial logistic regression models.

Factors	Variables	Variables types	Abbreviation
Dependent variable	the probability of a fishing operation present a CPUE value higher than the average CPUE for this boat stratum	Binary	COcpue
Technical characteristics of the fishery	Distance between both extremes of the longline	Quantitative	DL
	Diurnal or nocturnal setting	Binary	DN
Geographical location.	Latitude where the setting started	Quantitative	LATSS
	Longitude where the setting started	Quantitative	LONGSS
	Latitude where the setting finished	Quantitative	LATFS
	Longitude where the setting finished	Quantitative	LONGFS
	Sets over continental shelf	Binary	SCS
Environment	Sea Surface Temperature where the setting started	Quantitative	SSTSS
	Sea Surface Temperature where the setting finished	Binary	SSTFS
	Mean of Sea Surface Temperature between SSTSS and SSTFS	Binary	MR
	Absolute variation between SSTSS and SSTFS	Binary	AP
	Moon effect	Binary	MO

2.4 Spatial representation of fishing area and effort

Geographical coordinates of all fishing operations (setting and hauling) were recorded using a GPS (Datum WGS 84). The begin set point was used to represent the fishing effort (number of hooks set). Afterwards, effort values were interpolated to grids of 15 × 15 km in order to maintain confidentiality requirements. Dolphinfish bycatch of each set was represented using CPUE (fishes per 1000 hooks). Maps were projected in UTM, zone 31N.

Spatial representations of fishing effort and dolphinfish bycatch were made using ESRI ArcView 3.2 software and the Spatial Analyst and Xtools extensions.

3 Results

During the 11 years covered in this study, a total of 2968 fishing sets were observed, and the number of dolphinfish bycatches was 6 663 fish in 610 positive fishing operations, the average CPUE was 0.108 fishes/1000 hooks. The **table 3** shows the sampling coverage by gear, year and fleet strata. This table also shows the number of dolphinfish caught and the CPUE in number and weight (CPUEn and CPUEw).

3.1 Fishery description

The primary fisheries targets include swordfish (*Xiphias gladius*), bluefin tuna (*Thunnus thynnus*) and albacore (*Thunnus alalunga*). The Spanish surface longline fleet from the Mediterranean ports for the studied period consisted of 89 vessels (annual average) licensed by Spain for surface longline fishing all year round. Vessel length ranged from 12 to 27 m and fishing trips were often of short duration (1 to 6 days). In addition, more than 2000 smaller boats licensed for artisanal gears including surface/bottom longlines operated mainly in summer (http://www.mapya.es). But from 23 June 2009, only vessels licensed for surface longline were allowed to catch and land swordfish (Order ARM/1647/2009, 15 June of Ministry of Environment and Rural and Marine). The fishing grounds involved a large area of the western Mediterranean basin, between 36° and 44 °N and 02 °W and 05 °E, and included 3 different fishing areas: (1) Alboran Sea, used at least once by approximately 5 % of the operative fleet; (2) south-western Mediterranean Sea (primarily around the Balearic Islands and the Ibiza Channel), used by approximately 80 % of the operative fleet; and (3) north-western Mediterranean Sea (primarily the Ebro Delta), where approximately 15 % of the fleet operated (Valeiras and Camiñas 2003; Camiñas et al. 2006; Báez et al. 2007). Fishing operations were observed onboard from January to December, during years 2000 to 2010. We defined one fishing operation (set) as a daily cycle of longline setting and hauling.

Table 3. Technical characteristics of longline fishing gears operating in the Western Mediterranean

Gear	Hook	Hook size (cm)	Distance between hooks (m)	Miles	Cast hourly	Released time	Deep sea	Bait	Bait size (cm)	Fishing period/year	Coryphaena incidence
LLHB	1500-4000	7,5x2,5	22	20-35	Evening	3-4 hours	>50 f.	Mackerel Small Mackerel Chub Mackerel Sardine Atlantic saury Round sardinella Silver sccabardfish	23 16 23 17 25 20 70	All year but lesser activity from march to april	High
LLAM	900-1300	7,5x2,5	70 - 90	50-60	Evening	4-5 hours	> 150 b.	Squid Mackerel Chub Mackerel Squid Round sardinella	18 23 23 22 20	From 2002 to 2007, all year excepct may to july. Lesser activity in winter. Since 2008, greater activity in Atlantic Ocean	Medium
LLSP	900-1500	7,5x2,5	33	20-30	Early morning	3-4 hours	> 200 f.	Mackerel Chub Mackerel Squid Round sardinella	23 23 22 20	Only since 2006. Mainly summer months after Juny until october	Low
LLPB	600-1000	7,5x2,5	12	6-15	Early morning	1-2 hours	< 250 and > 50 f.	Mackerel Chub Mackerel Silver sccabardfish	23 23 70	Mainly summer months, since july to october. Some cases until december	Low
LLJAP	250-1100	7,5x3,0	50 - 70	5-50	Variable	1-6 hours	> 250 f.	Great squid Great mackerel Bogue	30 33 16	Second half of may to first half of july	Low
LLALB	2000-7000	4,3x1,7	16	20-50	Variable	3-6 hours	> 500 f.	Sardine	15	Mainly summer months, since july to october	High

Table 4. Sampling effort with the annual catch of dolphinfish and CPUEn (Number of fish per 1000 hooks) and CPUEw (weight of fish kg per 1000 hooks).

		Observed effort		Observed gear effort								Observed capture	
Year	On board period	No. of sets	No. of hooks	LLHB	LLALB	LLPB	LLAM	LLSP	LLJAP	*n* observed	CPUEn	weight	CPUEw
2000	29 feb - 1 dic	447	1211546	1027142	18650	18450	0	0	147304	919	0.759	2489.467	2.055
2001	7 may - 19 nov	253	709366	651774	0	2000	0	0	55592	1060	1.494	2949.719	4.158
2002	17 may - 27 nov	164	514463	417007	0	39856	0	0	57600	61	0.119	165.371	0.321
2003	8 may - 20 dic	172	351545	217020	0	13632	47677	0	73216	285	0.811	593.47	1.688
2004	13 may - 4 dic	261	355594	111050	0	25676	166881	0	51987	369	1.038	702.85	1.977
2005	2 may - 19 dic	97	112710	46828	0	0	12150	0	53732	60	0.532	162.66	1.443
2006	5 may - 5 dic	244	514027	147340	245488	30965	72947	0	17287	2708	5.268	2426.27	4.720
2007	22 feb - 18 dic	235	395145	213140	45202	81067	6957	8100	40679	175	0.443	489.99	1.240
2008	28 ene - 21 dic	343	512911	236394	41404	34208	21878	154579	24448	272	0.530	440.83	0.859
2009	21 feb - 12 dic	371	720990	207640	148110	54979	4400	299151	6710	72	0.100	195.835	0.272
2010	02 ene - 21 dic	381	753211	63580	407209	55530	0	180308	46584	682	1.675	600	1.473
Total		*2968*	*6151508*							*6663*	1.083	11216.46	1.82336754

We classified the fleet into six *strata*, according to differences in target species, operational depth and technical characteristics. A general scheme of these gears is shown in the **figure. 2**, and the technical characteristics are summarized in **table 4**. A short description of each gear is detailed below.

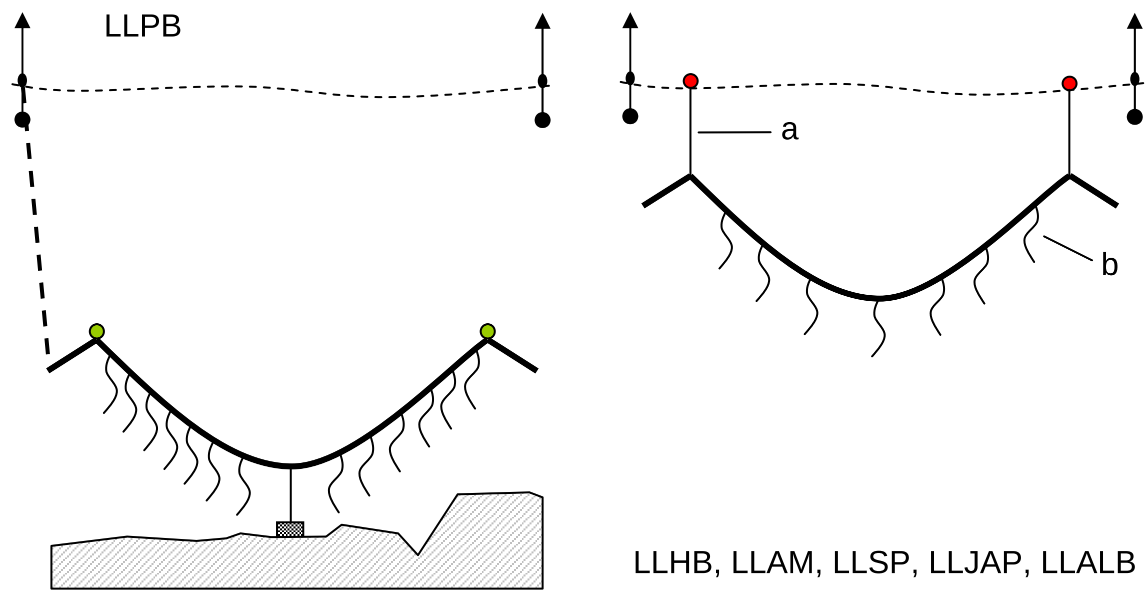

Figure 2. Schemes of longline gears monitored in this study; Left: Bottom longline (LLPB), Right: Traditional longline (LLHB), American longline (LLAM), Semi-pelagic longline (LLSP), Bluefin tuna longline (LLJAP), and Albacore longline (LLALB); Float line length (a) and length of hook line (b) are the two main measures that affect the fishing depth.

Traditional longline (LLHB).

The length of traditional drifting longline targeting swordfish is variable, ranging from 37 to 65 km and capable of setting 1500 to 4000 hooks. The main line hangs from floats and the information recorded by means of depth sensors indicates that the average depth of surface hooks is 30 m (maximum depth 50 m). The dimensions of the hooks used are 7.5 × 2.5 cm, usually baited with mackerel (*Scomber scombrus*) or chub mackerel (*Scomber japonicus*) ranging in size from 25 to 30 cm (total length). Depending on both the fishing season and bait price, hooks can also be baited with forage fish such as Atlantic saury (*Belone belone*) or silver scabbardfish (*Lepidopus caudatus*). In addition, chemical and electrical lights are used to attract prey. Setting of this gear begins in mid-afternoon and lasts until after sunset. Gear retrieval begins in the early hours of the morning and lasts until mid-morning. This gear is used throughout the year.

American longline (LLAM).

American long-line (monofilament) is a gear that was imported from the Italian and American long-liners in the early 2000s. After gaining a strong foothold in the fleet between 2003 and 2005, its use has been relegated mainly to the Atlantic fishing grounds.

Unlike the traditional longline, monofilament long line reaches 90 to 100 km in length with a smaller number of hooks (900 to 1100), implying a greater distance between each hook. Fishing depth is greater, with deepest hooks working at 70 m below the sea surface. Monofilament longline allows the distance between hooks to be varied for each set. Normally, hooks are separated by 70 to 90 m, which allows faster hauling. Furthermore, soak time is larger than for the traditional longline.

Both the mainline and the branch lines are thicker than in traditional longline, and hooks are equipped with weights of 30 to 70 g, which increases the bait sinking rate. As regards the hook type and bait, both are the same as in traditional longline. Like the LLHB, the LLAM is used throughout the year.

Bottom longline (LLPB)

This gear is operated by the longline fleet mainly from July to October, although its use is not regulated by the current swordfish fishing legislation. It is also used by traditional vessels with small Gross Register Tonnage (GRT), operating in coastal waters or grounds near their home port. LLPB is a variant of the bottom longline targeting silver scabbardfish, consisting of a longline similar to the traditional one, but with a shorter distance between hooks and fixed at the bottom by means of a few weights or stones interspersed between floats. It is not a drifting longline and is usually employed close to the continental slope. The number of hooks in each fishing set does not usually exceed 900, reaching only 600 hooks in many cases. The bait used is usually mackerel (*Scomber* sp.) or round sardinella (*Sardinella aurita*).

Half water or semi-pelagic longline (LLSP)

Since 2006, an improved surface longline has been used by the fleet in the Mediterranean. The improvement involves increasing the depth of the hooks during the months when the sea surface temperature is higher (summer). Hooks work at depths around 150 – 200 m deeper. The gear is similar to the traditional longline, but with the peculiarity that the number of hooks between floats is larger and some weights or stones are placed along the mainline (Fig. 2). These modifications give the gear greater stability against the currents and also enhance the depth of hooks in the water column. Because the speed of setting is less than for traditional longline, the number of hooks set does not usually exceed 1500. Bycatch at these depths is very small, with very low catches of sea turtles and sharks. The LLSP is used in a seasonal way, mainly from July to October.

Bluefin tuna longline (LLJAP)

This is a monofilament longline used exclusively during the months of May, June and the first half of July, which is the period when bluefin tuna enter the Mediterranean to breed. The differences between this gear and the swordfish monofilament longline are that the fishing depth is greater, the bait is almost always squid (*Illex* sp.) bigger than 500 g, and the gear remains working for 24 hours. The number of hooks by set does not exceed 1200.

Albacore longline (LLALB)

This is the shallowest longline gear. Both the size of the hook and the thickness and length of the fishing lines are lower than other longlines. Between 2000 and 7000 hooks are set and the bait used is sardine (*Sardina pilchardus*). LLALB is a drift longline, which operates in high-sea fishing grounds at bottom depths up to 1500 m and is employed mainly from July to October.

3.2 Bycatch description

Bycatch of dolphinfish for the 2968 observed fishing sets in the 11-year period covered in this study (6 151 508 hooks) amounted to 6663 fishes of the 2 species: C*oryphaena hippurus* and *Coryphaena equiselis*.

All of the six monitored gears in this study caught dolphinfish. The average CPUEn for the studied period was 0.108 fishes per 1000 hooks and the CPUEw was 1.82 kg per 1000 hooks. Table 5 shows the average CPUEn per gear and year, and the table 6 shows the average CPUEw per gear and year along the studied period.

The mean of fork length (FL) for the bycatch dolphinfish was 62.7cm. **Figure 3** shows the length distribution per fleet strata. Length distributions of LLALB and LLHB have a bi-modal shape. The first mode for LLALB was 30cm and for LLHB was 50cm, the second mode was 90cm for both fleet strata. Exist significant differences between lengths distributions of all fleet strata studied. The lowest sizes dolphinfish were found in LLALB (average length = 45.6cm) followed by LLAM (average length = 50.6cm) and LLHB (average length = 67.6cm). In general, the more in deep was made a set, the more sized were the dolphinfish caught. In this sense the mean length value of the dolphinfish caught by the deeper sets (made with LLSP, LLPB and LLJAP) was 90.4cm. Our results also suggest that the smaller hooks tend to capture smaller dolphinfish, while the larger hooks (targeting swordfish and bluefin tuna) tend to select the larger animals.

Thus, it is very important to consider gear type when making inferences about the dolphinfish populations based on fisheries bycatch data.

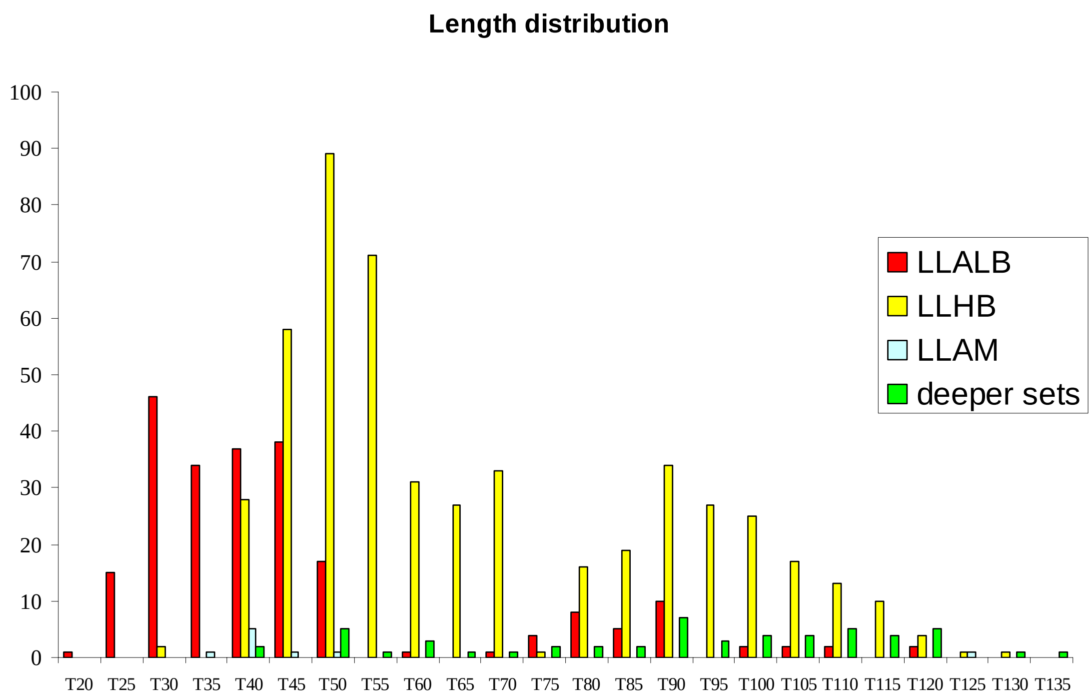

Figure 3. Length distribution per boat strata and gear type. Exist significative differences between boat strata length distribution (chi-squared= 1521.42; df= 69; P< 0.0001).

Our results about length-weight relationships are summarized in the **figure 4**. A significant power curve relationship was found between the length and weight from 155 different individuals of Coryphaena sp (df= 153; R2= 0.97; F= 5031.59; P< 0.001). The resultant length-weight relationship: $W=0.0036\ FL^{3.2117}$ was used to estimate the CPUEw and was also used to model the factors affecting dolphinfish bycatch.

The gears with the highest incidental catch of dolphinfish were LLALB (n = 3353 fishes), followed by LLHB (n = 2842 fishes) and LLAM (n = 399 fishes). There were significant differences in dolphinfish catch between fishing gears (Chi-squared (χ2)= 1521.4; df= 69; P<0.00001).

LLPB (n = 29 fishes), LLSP (n = 25 fishes) and LLBFT (n = 15 fishes) had a very low dolphinfish catch rates.

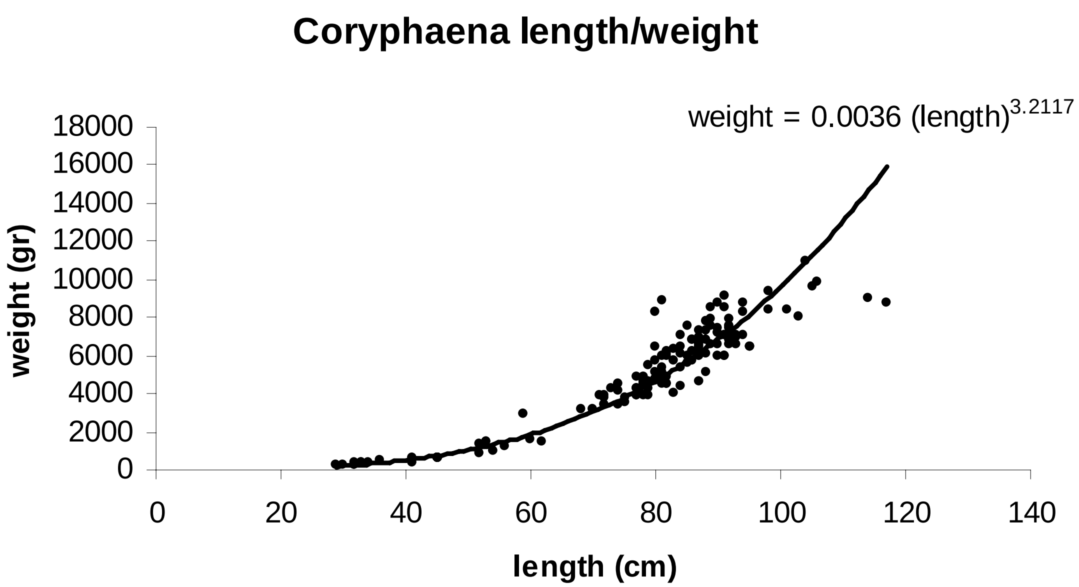

Figure 4. Length-weight relationships, n= 155; df= 153; R^2= 0.97; F= 5031.59; P< 0.001.

LLALB showed a CPUEn of 3.70 fishes per 1000 hooks, the highest CPUEn was recorded in 2006 (9.99 fishes per 1000 hooks) and the lowest in 2000 (0.05 fishes per 1000 hooks). CPUEw show the same trend with the highest catch weight in 2006 and the lowest in 2000. The mean weight of dolphinfish caught by this gear was 0.77kg. **Table 5** shows the annual CPUEn for each fleet stratum, and **table 6** shows annual CPUEw by strata. **Figure 5** shows spatial distributions of sets, effort and its corresponding seabird catch rates for this gear (CPUEn).

LLAM had an average CPUEn of 1.2 fishes per 1000 hooks, lower than that for LLALB. The highest CPUEn and CPUEw were recorded in 2003 (2.29 fishes per 1000 hooks/2.44 kg per 1000 hooks) and the lowest in 2005 and 2009 (0.0 fishes and kg per 1000 hooks). The average weigh of dolphinfish by-caught by LLAM was 1.1kg. **Figure 6** shows observed effort of LLAM and its corresponding dolphinfish catch values

Table 5. Annual CPUEn per gear type.

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
LLALB	0.054	blank	blank	blank	blank	blank	9.996	0.376	5.024	0.061	1.631
LLHB	0.894	1.613	0.146	0.811	1.693	1.281	1.093	0.657	0.122	0.265	0.094
LLAM	blank	blank	blank	2.286	1.085	0.000	1.261	1.150	0.411	0.000	blank
LLSP	blank	blank	blank	blank	blank	blank	blank	0.123	0.116	0.003	0.028
LLJAP	0.000	0.162	0.000	0.000	0.000	0.000	0.000	0.147	0.000	0.000	0.000
LLPB	0.000	0.000	0.000	0.000	0.000	blank	0.032	0.037	0.322	0.127	0.126

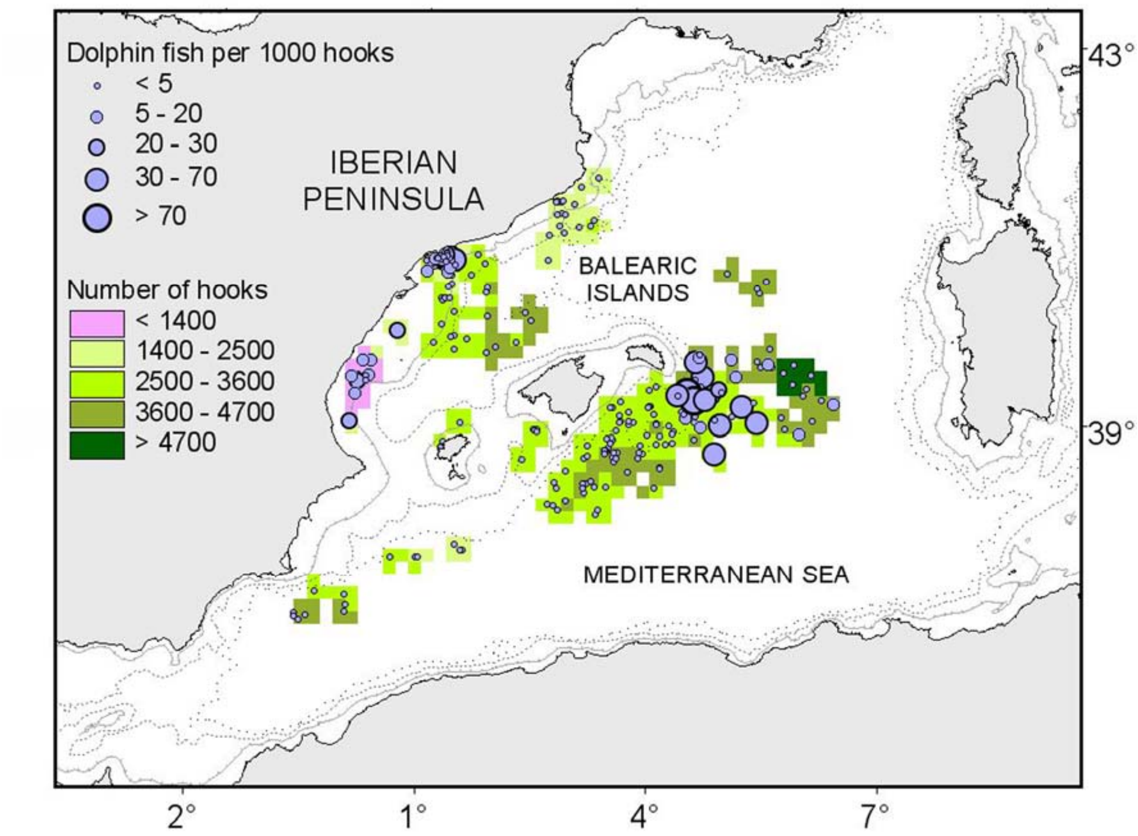

Figure 5. Map of the LLALB fishing ground. We show the fisheries operation observed and dolphinfish by-catches (number of fishe observed per 1000 hooks) per set.

Table 6. Annual CPUEw per gear type.

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
LLALB	0.041	blank	blank	blank	blank	blank	7.687	0.289	3.864	0.047	1.254
LLHB	2.423	4.372	0.397	2.199	4.590	3.474	2.962	1.781	0.330	0.718	0.256
LLAM	blank	blank	blank	2.439	1.157	0.000	1.346	1.227	0.439	0.000	blank
LLSP	blank	blank	blank	blank	blank	blank	blank	0.554	0.522	0.015	0.124
LLJAP	0.000	1.362	0.000	0.000	0.000	0.000	0.000	1.241	0.000	0.000	0.000
LLPB	0.000	0.000	0.000	0.000	0.000	blank	0.360	0.413	3.589	1.421	1.407

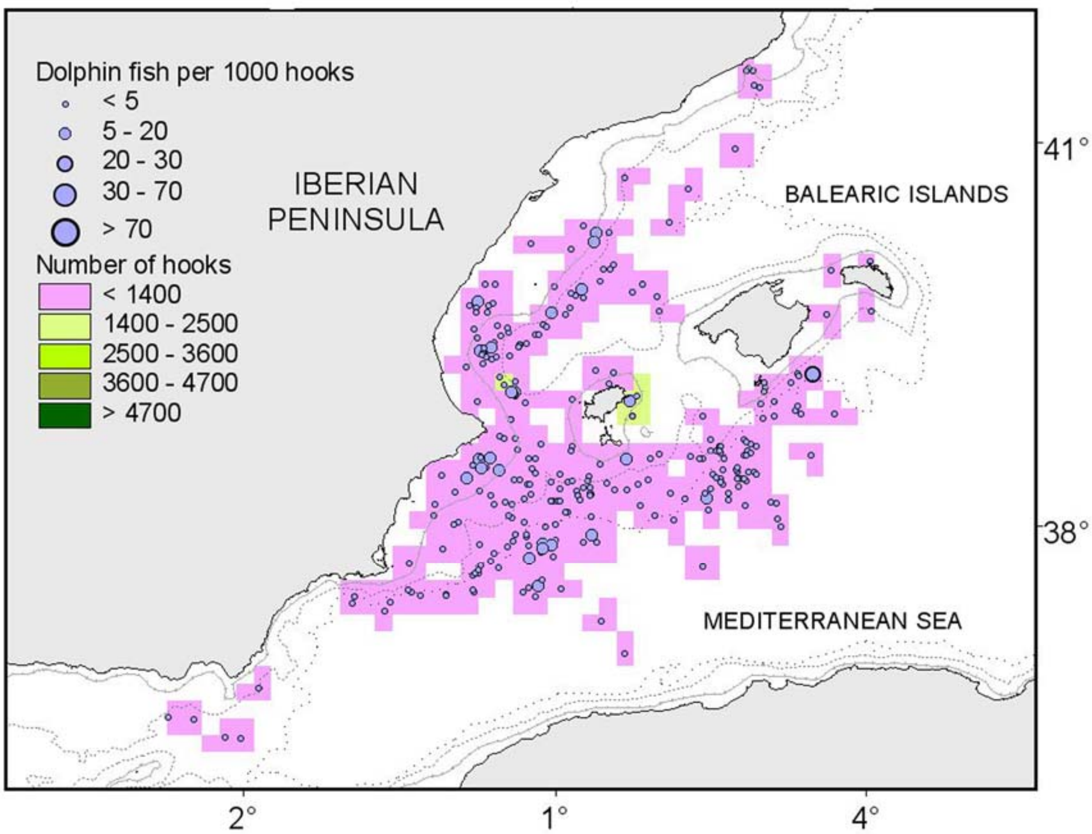

Figure 6. Map of the LLAM fishing ground. We show the fisheries operation observed and dolphinfish by-catches (number of fishe observed per 1000 hooks) per set.

LLHB had an average CPUEn of 0.85, slightly lower than that for LLAM. The highest CPUEn was recorded in 2004 (4.59 fishes per 1000 hooks) and the lowest in 2010 (0.26 fishes per 1000 hooks). CPUEw shows the same trend and the average weight of fishes was 2.7kg. **Figure 7** shows observed effort of LLHB and its corresponding dolphinfish catch values.

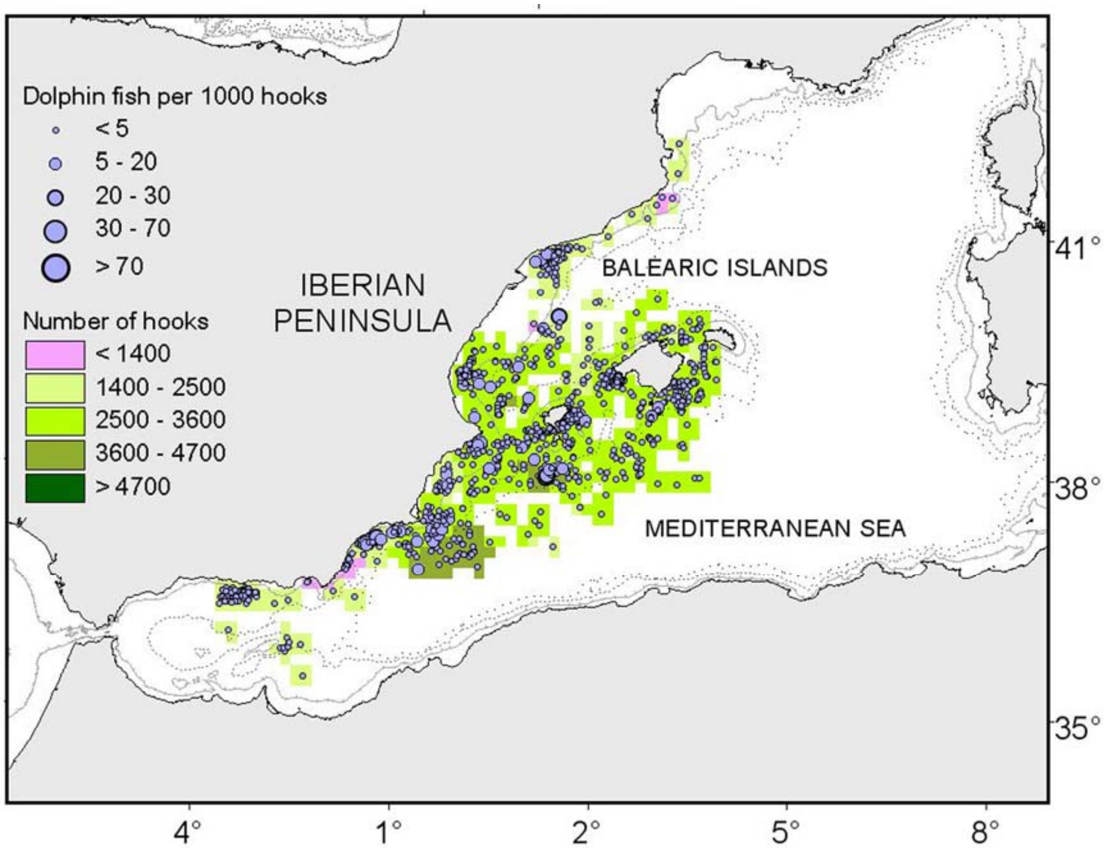

Figure 7. Map of the LLHB fishing ground. We show the fisheries operation observed and dolphinfish by-catches (number of fishe observed per 1000 hooks) per set.

Regarding spatial distribution of the dolphinfish bycatch, our results indicates that LLALB shows the most heterogeneous catch rates distribution with areas with high catch rates like Ebro Delta continental shelf and South East of Minorca Island and areas without catches (**figure 5**). LLAM and LLHB Shows a more homogeneous distribution of catch rates (**figures 6 and 7**). The **table 7** shows the CPUEn for 1ºX1º degree cells, and the **table 8** shows CPUEw for the same geographical coordinates. The cells corresponding to each GSA have been marked in different colours. The highest catch rates corresponding to GSA 5 (mean CPUEn = 1.16) and GSA 6 (mean CPUEn = 0.91).

Table 6. CPUEn (number of individuals per 1000 hooks) by geographical areas (1ºx1º grids). The cell colour indicates the corresponding GSA and the number in red denote the highest CPUEn in the corresponding GSA.

Long/Lat	36	37	38	39	40	41	42	43
-4	0,000	0,392						
-3	**0,065**	0,120						
-2	0,000	0,010	0,884					
-1		2,592	0,821	0,808	1,584			
0			0,072	0,962	0,357			
1			0,533	1,059	1,231	**8,268**		
2			0,350	0,960	0,386	0,959	2,987	
3				0,209	0,480	0,181	0,393	
4				0,042	0,165	0,149	0,000	0,000
5				3,911	**9,531**	0,000		
6				0,000	8,801	0,059		
7				0,000	**2,642**			
8				0,000				
9				0,000				

GSA	
1	Nothern Alboran Sea
2	Alboran Island
4	Algeria
5	Balearic Islans
6	Nothern Spain
11	Sardinia

Table 7. CPUEw (weight in kg. of individuals per 1000 hooks) by geographical areas (1ºx1º grids). The cell colour indicates the corresponding GSA and the number in red denote the highest CPUEw in the corresponding GSA.

Long/Lat	36	37	38	39	40	41	42	43
-4	0,000	1,287						
-3	0,176	0,521						
-2	0,000	0,031	2,452					
-1		**7,026**	2,251	2,161	4,292			
0			0,195	3,752	0,967			
1			0,975	2,738	2,141	6,358		
2			0,714	2,550	0,967	1,146	2,569	
3				0,366	1,361	0,151	0,302	
4				0,050	0,375	0,405	0,000	0,000
5				**3,008**	**7,329**	0,000		
6				0,000	6,768	0,045		
7				0,000	**2,032**			
8				0,000				
9				0,000				

GSA	
1	Nothern Alboran Sea
2	Alboran Island
4	Algeria
5	Balearic Islans
6	Nothern Spain
11	Sardinia

The average annual effort for the Spanish pelagic longline fleet is 13 283 631 ± 1 093 799 hooks. Based on the average annual effort for the Spanish pelagic longline and the average annual CPUE, an average total bycatch estimate for the fleet for this period was around 14 490 dolphinfish per year, this value correspond to approximately 24 176kg per year.

3.3. General Logistic Model

We obtained a statistically significant logistic model with the variables (in order of wald-value): Drifting surface longline targeting albacore (positive relation), October (positive relation), Traditional longline targeting swordfish (positive relation), November (positive relation), September (positive relation), American longline targeting swordfish (positive relation), August (positive relation), Latitude where the setting started (negative relation), Diurnal (positive relation), March (negative relation), May (positive relation), June (positive relation), April (negative relation), and July (positive relation). The model's goodness-of fit-was significant according to the Omnibus test (Omnibus test= 907.744, df= 14, P < 0.001; Hosmer and Lemeshow test= 21.625, df= 8, P= 0.006). R^2-Nagalkerke= 0.4, and its discrimination capacity was outstanding (AUC = 0.856).

The logit function (y) from logistic regression:

$$y = 1.905 + LATSS * -0.147 + LLAM\begin{cases} NOT = -1.282 \\ YES = 0 \end{cases} + LLHB\begin{cases} NOT = -1.879 \\ YES = 0 \end{cases}$$

$$+ LLALB\begin{cases} NOT = -2.543 \\ YES = 0 \end{cases} + DN\begin{cases} NOT = 0 \\ YES = 0.546 \end{cases} + MA\begin{cases} NOT = 2.5 \\ YES = 0 \end{cases} +$$

$$AB\begin{cases} NOT = 2.19 \\ YES = 0 \end{cases} + MY\begin{cases} NOT = 0 \\ YES = -1.788 \end{cases} + JN\begin{cases} NOT = -0.742 \\ YES = 0 \end{cases}$$

$$+ JL\begin{cases} NOT = -0.589 \\ YES = 0 \end{cases} + AG\begin{cases} NOT = -1.003 \\ YES = 0 \end{cases}$$

$$+ SE\begin{cases} NOT = -1.971 \\ YES = 0 \end{cases} + OC\begin{cases} NOT = -3.064 \\ YES = 0 \end{cases} + NO\begin{cases} NOT = -2.305 \\ YES = 0 \end{cases}$$

Key words: LLHB, Traditional longline targeting swordfish; LLAM, American longline targeting swordfish; LLALB, Drifting surface longline targeting albacore; LATSS, Latitude where the setting started; MA, March; AP, April; MY, May; JN, June; JL, July; AU, August; SE, September; OC, October; NO, November.

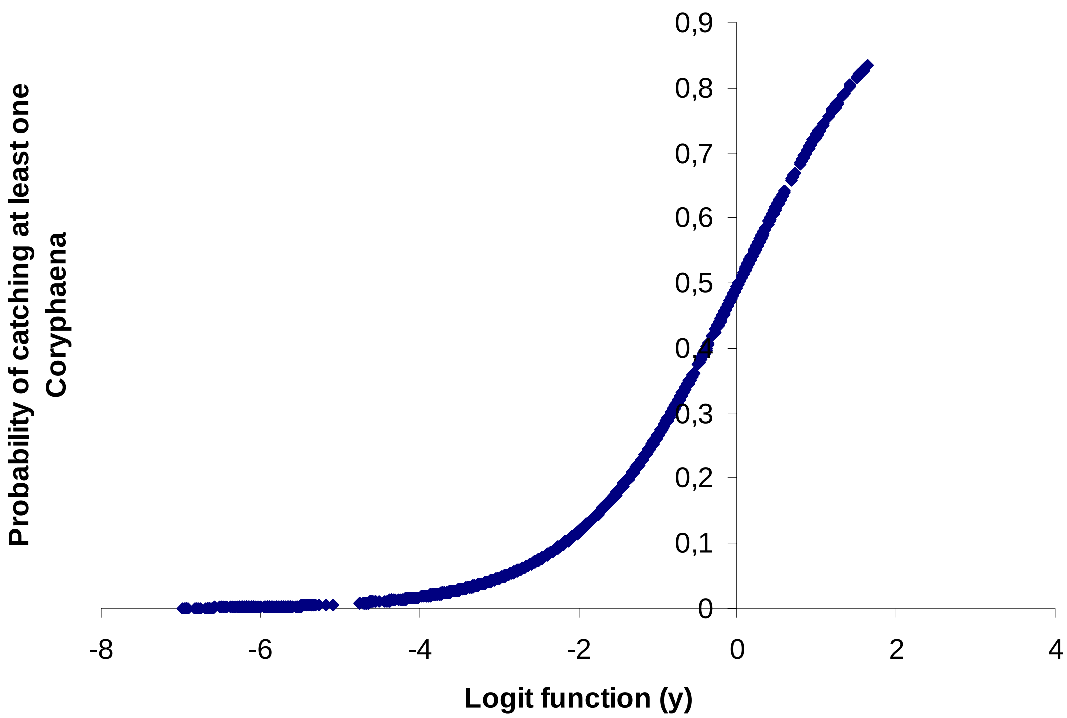

Figure 8. Probability of incidentally catching a dolphinfish (1 or more) in relation to the binary logistic regression.

Taken into account this results, we selected 1411 fishing operation (47.54% of observed sets) operated using LLALB, LLHB and LLAM from May to November, which present the 93 % of total dolphinfish by-catches.

3.4. Partial LR models

We adjusted the probability that a fishing operation present a CPUE value higher than the average CPUE for this boat stratum. We analysed three boat strata: LLALB, LLAM and LLHB, from May to November along all the study period.

For LLALB boat stratum, we obtained a statistically significant logistic model with the variables (in order of Wald-value): Moon effect (positive relation), and Diurnal setting (positive relation). The model's goodness-of fit-was significant according to the Omnibus test (Omnibus test= 18.775, df= 2, P < 0.001; Hosmer and Lemeshow test= 0.501, df= 2, P= 0.778). R^2-Nagalkerke= 0.14, and its discrimination capacity was outstanding (AUC = 0.7).

The logit function (y) from logistic regression:

$$y = -2.164 + MOON\begin{cases} NOT = 0 \\ YES = 1.37 \end{cases} + DN\begin{cases} NOT = -1.549 \\ YES = 0 \end{cases}$$

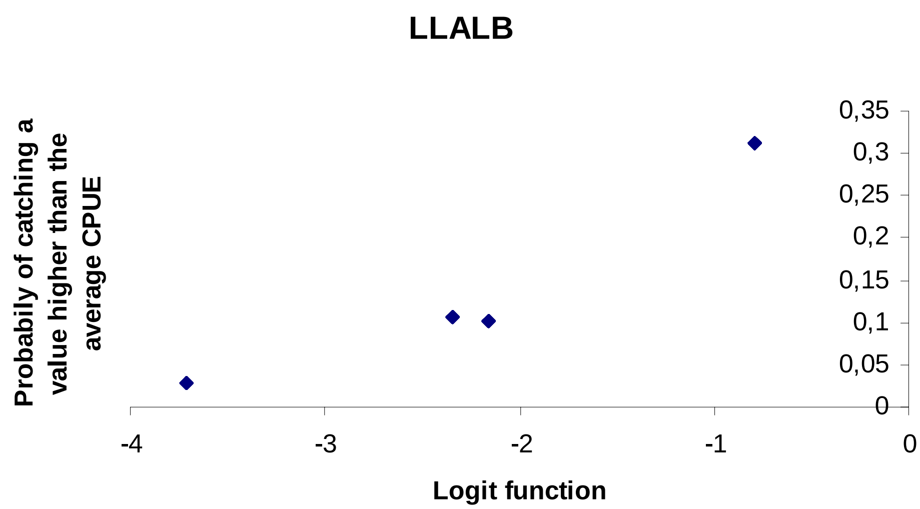

Figure 9. Probability of obtain a CPUEw of dolphinfish in a LLALB set higher than the average CPUEw for LLAB.

In the case of LLHB boat stratum, we obtained a statistically significant logistic model with the variables (in order of Wald-value): Moon effect (positive relation), and Sea Surface Temperature where the setting started (negative relation). The model's goodness-of fit-was significant according to the Omnibus test (Omnibus test= 48.822, df= 2, P < 0.001; Hosmer and Lemeshow test= 28.377, df= 8, P< 0.001). R^2-Nagalkerke= 0.078, and its discrimination capacity was outstanding (AUC = 0.668).

The logit function (y) from logistic regression:

$$y = 2.952 + MOON \begin{cases} NOT = 0 \\ YES = 0.406 \end{cases} + SSTSS * -0.193$$

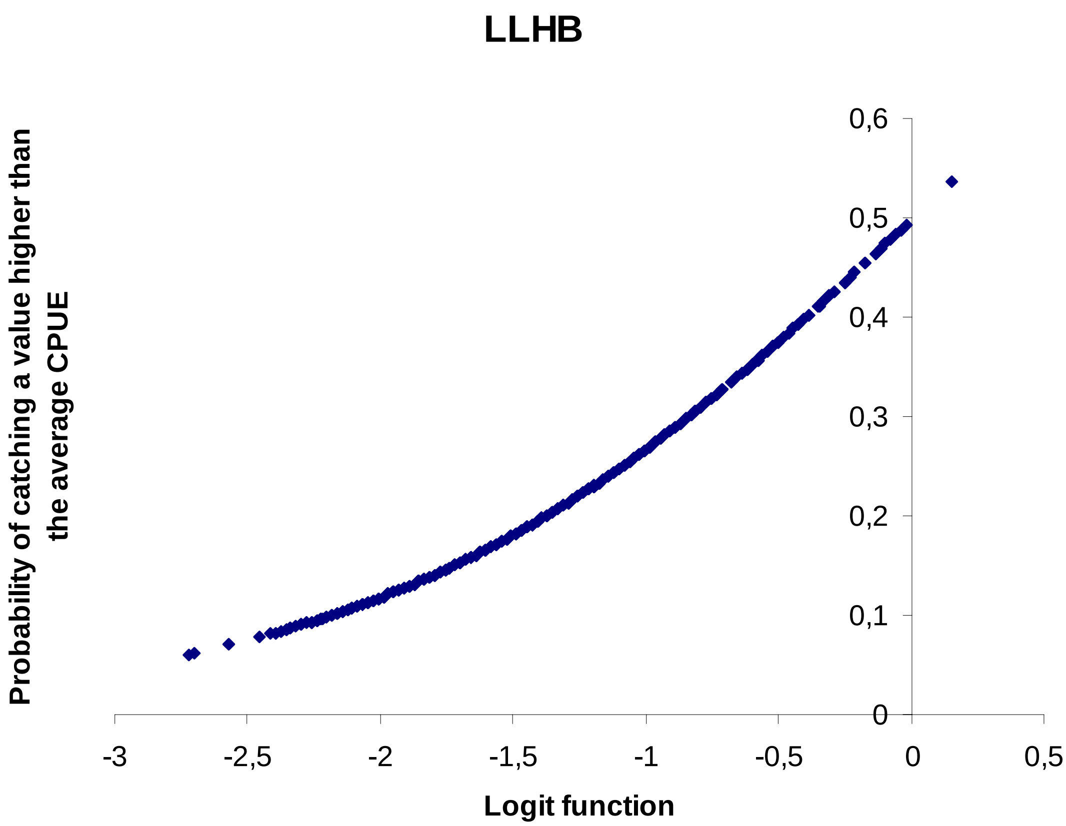

Figure 10. Probability of obtain a CPUEw of dolphinfish in a LLHB set higher than the average CPUEw for LLHB.

In the particular case of LLAM boat stratum, we obtained a statistically significant logistic model with the variables (in order of Wald-value): Longitude where the setting started (negative relation) and Sea Surface Temperature where the setting started (negative relation). The model's goodness-of fit-was significant according to the Omnibus test (Omnibus test= 35.479, df= 2, P < 0.001; Hosmer and Lemeshow test= 18.233, df= 8, P= 0.02). R^2-Nagalkerke= 0.185, and its discrimination capacity was outstanding (AUC = 0.765).

The logit function (y) from logistic regression:

$$y = 9.417 + LONGSS * -0.438 + SSTSS * -0.416$$

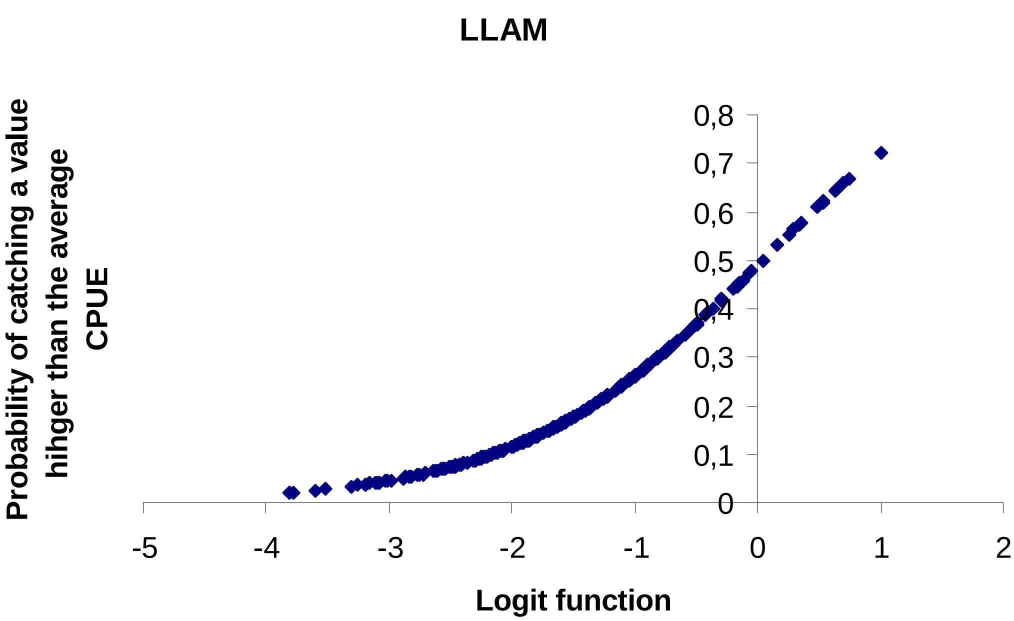

Figure 11. Probability of obtain a CPUEw of dolphinfish in a LLALB set higher than the average CPUEw for LLAB.

4 Discussion

The most common dolphinfish species caught by the longline fisheries in the western Spanish Mediterranean was the *Coryphaena hippurus*. In addition, lesser amounts of *Coryphaena equiselis* are also caught by this fleet in the study area. Our results are referred to Coryphaena sp. due to at the beginning of the time series both species were not distinguished. Nevertheless, the low sizes dolphinfish could be a mixture of both species, being the majority of the specimens *Coryphaena hippurus*. In spite of the possibility of mixing the two dolphinfish species the length-weight relationship obtained adjusts with a high good of fit.

Our results indicate that the impact of the pelagic and semi-pelagic longline on the Dolphinfish population is relatively low (1.083 fishes per 1000 hooks), in contrast with the higher effect on the target species population. LLALB is the gear with a highest effect on dolphinfish populations (CPUEn = 3.7 fishes per 1000 hooks) and have a remarkable incidence on juveniles and probably on *Coryphaena equiselis*. We suggest that this gear could be interacting with other artisanal fisheries targeting dolphinfish around Majorca Island (Lleonart et al, 2009). In this sense is interesting to note the low catch rates of dolphinfish by-caught by LLALB around this area, in contrast with highest CPUEs in areas at South East of Minorca Island and Ebro Delta continental shelf. LLAM (CPUEn = 1.2 fishes per 1000 hooks) and LLHB (CPUEn = 0.9 fishes per 1000 hooks) follow to LLALB in the catch rate ranking. LLAM and LLHB shows a more homogeneous geographical distribution of their catch rates and also lower catch rates by set that LLALB.

In our study, LLJAP, LLSP and LLPB had the lowest catch ratios of dolphinfish. Differences in bycatch rates can be attributed to differences both in selectivity between gears and fishing strategy. In this sense, LLALB operates with smaller hooks and bait, affecting mainly to juvenile fraction of dolphinfish population. Interestingly, LLJAP, LLSP and LLPB, catch the largest dolphinfish, and affect mainly to the adult fraction of the population. We suggest that there were a relation between the fishing deep and the length of the fishes caught by the longline, and also between the size of the hooks and the mean length of the dolphinfish caught. So the largest captures corresponds to LLJAP (105cm) that operates at 250f in deep and with the large hooks, the LLSP follow to LLJAP in mean length of the dolphinfish caught (96.2cm) and operates at 200f in deep and also with large hooks. Finally, LLPB operates between 50f and 250f in deep and obtained a mean length of 79cm for dolphinfish caught. Due to the fact that LLSP had the shortest temporal series (2007-2010) and that sampling coverage was lower, more attention should be paid to this gear in the future in order to determine its real impact on dolphinfish.

The Spanish longline fishery captures of dolphinfish in our study was 14 490 fishes per year (24.2t), which is lower than that reported for artisanal fisheries by other authors in the Mediterranean: 63t in Majorca (Lleonart et al., 1999), and 377.4t in Sicily (Potoschi et al., 1999); But important in terms of assessment and management purposes.

Technical Characteristic of the fishery and Seasonality factors have an important power to explain the absence or presence of dolphinfish bycatch in the different boat strata, gear type, and season. Moreover as we discuss previously, we also noted differences in size and weight of dolphinfish caught by the different gear types. In this context, our results suggest that longline should not be considered a simple *méetier*. In addition, our results indicates a seasonal increase in the catch ratios from June to November, which is agreement with dolphinfish seasonal migrations in the Mediterranean (Potoschi et al., 1999).

Our results about particular LR models (per boat strata) indicate that environment factors could be the most important factors affecting CPUEw. Thus, the relationship between dolphinfish catches and ocean temperature had been cited in many studies (for example, Flores et al., 2008; Kleisner et al., 2010). The majority of these studies suggested positive correlations between dolphinfish catch ratios and sea surface temperatures (SST). However, in disagreement to previous papers we found a negative relationship between

CPUEw per LLAM and SSTSS (see the figure 11). This particular relation could be explained for the oceanographic context in which this fishery takes place. Thus, in the Western Mediterranean Sea during summer period up-welling next to the coast occurs frequently (Rodriguez, 1982). The up-welling increase the nutrient and reduce the SST. Many pelagic fish use these productive up-welling as feeding areas. Dolphinfish could be more abundant in these feeding areas increasing their catchability and consequently the CPUEw. In this line, the negative relationship between LLAM CPUEw and the LONGSS could be related with this trend.

Lunar phase as SST has been frequently used as an explanatory variable affecting catch rates of dolphinfish (Lowry et al., 2007). Generally the lunar phases from new moon to the first quarter increase the catch ratios of this species. Our results, similarly to the SST, disagree with those reported in the literature for both LLALB and LLHB. Nevertheless we found that the highest catch ratios occur in those fishing operations carried out in diurnal hours. For this reason we suggest that our results are more in relation with the gravitational effect related with the Moon phase than to the light effect of moon phases.

Acknowledgements

We are grateful to the skippers and crews of fishing vessels who worked voluntarily with the Onboard Observer Program, to observers of the Spanish Oceanographic Institute, to our colleagues of the Large Pelagic Fisheries department at Málaga. We would also like to express our recognition towards the FAO COPEMED II project.

5 References

Alverson D.L., 1999, Some observations on the science of bycatch. Mar. Technol. Soc. J. 33, 6-12.

Báez, J.C., Olivero, J., Peteiro, C., Ferri-Yañez, F., García-Soto, C., Real, R., 2010c. Macro-environmental modelling of the current distribution of *Undaria pinnatifida* (Laminariales, Ochrophyta) in northern Iberia. Biological Invasions 12, 2131-2139.

Báez, J.C., Real, R., Bellido, J.J., Macias, D., de la Serna, J.M., Camiñas, J.A., 2010a. Validating an ecological model with fisheries management applications: the relationship between loggerhead by-catch and distance to the coast. Journal Marine Biological Association U.K. doi:10.1017/S002531541000069X.

Báez, J.C., Real, R., Camiñas, J.A., 2007a. Differential distribution within longline transects of Loggerhead and Swordfish captured by the Spanish Mediterranean surface longline fishery. Journal Marine Biological Association U.K. 87, 801-803.

Báez, J.C., Real, R., Camiñas, J.A., Torreblanca D., García-Soto, C., 2009. Analysis of swordfish catches and by-catches in artisanal longline fisheries in the Alboran Sea (Western Mediterranean Sea) during the summer season. Marine Biodiversity Records doi: 10.1017/S1755267209990856.

Báez, J.C., Real, R., García-Soto, C., de la Serna, J.M., Macías, D., Camiñas, J.A., 2007b. Loggerhead turtle by-catch depends on distance to the coast, independent of fishing effort: implications for conservations and fisheries management. Marine Ecology - Progress Series 338, 249-256.

Báez, J.C., Real, R., Macías, D., de la Serna, J.M., Bellido, J J., Camiñas, J.A., 2010b. Swordfish *Xiphias gladius* Linnaeus 1758 and loggerhead *Caretta caretta* (Linnaeus 1758) captures associated with different combinations of bait in the Western Mediterranean surface longline fishery. Journal Applied Ichthyology 26, 126–127.

Bono, G., Cannizzaro, L., Gancitano, S., Rizzo, P., 1998. La pesca sui cannizzati quali-quantitativi di uno strumento alternativo al sovrasfruttamento dei grande pelagici. Biol. Mar. Medit., 5(1): 661-664.

Bustamante, J., 1997. Predictive models for lesser kestrel Falco naumanni distribution, abundance and extinction in southern Spain. Biological Conservation 80, 153–160.

Camiñas J.A., Báez J.C., Valeiras J., Real R., 2006, Differential loggerhead bycatch and direct mortality in surface longline according to boat strata and gear type. Sci. Mar. 70, 661-665.

De Metrio, G., Cacucci, M., Sion, L., POtoschi, A., Cannavó, G., Romeo, T., Megalofonou, P., Yannopoulos, C. and Kapiris, C., 1997. Contract CEE Nº 94/079. Catches of juvenile bluefin tuna and swordfish during the albacore long-line fishery in the Mediterranean. Final Report. 1-45.

Flores, M.S.Z., Ortega-Garcia, S., Klett-Traulsen, A., 2008. Interannual and seasonal variation of dolphinfish (Coryphaena hippurus) catch rates in the Southern Gulf of California, Mexico. Fisheries Research, 94, 13-17

Gandini, P., Frere, E., 2006. Spatial and temporal patterns in the by-catch of seabirds in the Argentinian longline fishery. Fishery Bulletin 104, 482-485.

García-Barcelona, S., Ortiz de Urbina, J.M., de la Serna, J.M., Alot, E., Macías, D., 2010a. Seabird by-catch in Spanish Mediterranean large pelagic logline fisheries, 1998-2008. Aquatic Living Resources 23, 363-371.

García-Barcelona, S., Macías, D., Alot, E., Estrada, A., Real, R., Báez J.C., 2010b. Modelling abundance and distribution of seabird by-catch in the Spanish Mediterranean longline fishery. Ardeola 57 (especial), 65-78.

Garrison, L.P., 2007. Interactions between marine mammals and pelagic longline fishing gear in the U.S. Atlantic Ocean between 1992 and 2004. Fishery Bulletin 105, 408-417.

Hall M.A., 1996, On bycatches. Rev. Fish. Biol. Fish. 6, 319-352.

Hosmer, D. W., Lemeshow, S., 2000. Applied logistic regression, 2nd edn. New York. John Wiley and Sons, Inc.

Kelleher K., 2005, Discards in the world´s marine fisheries: an update. FAO Fish. Tech. Pap. 470, Rome, FAO.

Kleisner, K.M., Walter, J.F., Diamond, S.L., and Die, D.J., 2010. Modeling the spatial autocorrelation of pelagic fish abundance. Marine Ecology-Progress Series, 411, 203-213.

Lleonart J., Morales-Nin B., Massutí, E., Deudero S., and Reñones, O., 1999, Population dynamics and fishery of dolphinfish (Coryphaena hippurus) in the western Mediterranean. Sci. Mar., 63 (3-4): 447-457.

Lowry, M., Willians, D., and Metti, Y., 2007. Lunar landings: Relationship between lunar phase and catch rates from Australian gamefishtournament fishery. Fisheries Research, 88, 15-23.

Macías, D. and de la Serna, J.M., 2000. By-catch Composition in the Spanish Mediterranean Longline Gears. Abstract book of "Forth European Elasmobranch Association Meeting" Livorno, 27-30 September.

Massutí E. and Morales-Nin B., 1999. Foreword of the special issue: Biology and fishery of dolphinfish and related species. Sci. Mar., 63 (3-4): 1.

Morales-Nin, B., Oliver, P., Castro, J.J., Cannizzaro, L., Potoschi, A. and Pla, C., 1995. Biology and Fishery od Dolphinfish in the Western Mediterranean and Canary Island Area. EEC Contract Nº94/031. Final Report. 1-80.

Potoschi, A., Cannizzaro, L., Milazzo, A., Scalisi, M. and Bono, G., 1999. Sicilian dolphinfish (*Coryphaena hippurus*) fishery. Sci. Mar., 63 (3-4): 439-445.

Potoschi, A. and Sturiale, P., 1996. Distribuzione dei "cannizzi" nel Tirreno meridionale e nello Ionio per la cattura della lampuga (*Coryphaena hippurus* L. 1758). Biol. Mar. Medit., 3(1): 384-386.

Real, R., Barbosa, A.M., Vargas, J.M., 2006. Obtaining environmental favourability functions from logistic regression. Environmental and Ecological Statistics 13, 237–245.

Rodríguez, J., 1982. Oceanografía del mar Mediterráneo. Pirámide, Barcelona. pp. 174.

Sokal R.R., Rohlf F.J., 1995, Biometry. 3rd edition. W.H. Freeman & Co, New York, pp. 19 887.

Valeiras J.,. Camiñas J.A, 2003, The incidental capture of seabirds by Spanish drifting longline fisheries in the Western Mediterranean Sea. Sci. Mar. 67, 65-68.

Ward, P., Myers, R.A., Blanchard, W. 2004. Fish lost at sea: the effect of soak time on pelagic longline catches. Fishery Bulletin 102, 179–195.