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Revision of Dolphinfish Bycatch in Spanish Mediterranean Large Pelagic Longline Fisheries, 2000-2014

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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 hippurus* bycatch collected by the on-board observer program of the IEO in the Western Mediterranean.

Data on dolphinfish bycatch were collected for the period 2000-2014, throughout the year.

Annual differences in bycatch per unit effort (BPUE, fish per 1000 hooks) are reported in this study. In addition, the BPUE series of adult and juveniles are reported separately aiming to compare the incidence of the gear on spawners versus juveniles in the area. The monthly variation in the BPUE of adults and juvenile in the area indicates that the juveniles of dolphinfish began to be recruited to the fishery in May, reaching a pick in October. A spectral analysis and red-noise spectra procedure (REDFIT) algorithm was used to identify the red-noise spectrum from the gaps in the observed time-series of catch per unit effort by number. Our results indicate the presence of cyclic events in bycatches both of immature and mature fishes. Moreover we tested a possible effect of NAO on

these cycles. We obtained a negative significant relationship between the BPUE of juveniles and the average NAO index (six previous months).
In addition, a revision of the Length-weight relationships, a summary of the Mediterranean data sets of dolphinfish catches reported to the ICCAT database, and a bibliography revision on catch of dolphinfish in long line fisheries in the Mediterranean are included in this paper.

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

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1 Introduction

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 past decades (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. Sacco et al. (2015) recently shown the absence of a sharp molecular structuring of the species in the Western and Central Mediterranean basin, as commonly scored in other species. Although connected with the Atlantic, Mediterranean dolphinfish samples seem to maintain a degree of isolation, which preserve an endemic gene pool. Current genetic diversity of Mediterranean dolphinfishes is probably the result a vicariance event followed by a secondary contact between Mediterranean and Atlantic populations.

Dolphinfish 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, Macías et al., 2011). 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*. Macías et al., 2011 described the dolphinfish bycatch rates in the longline fisheries of the Western Mediterranean and modelled the bycatch abundance and distribution of dolphinfish from the Spanish Mediterranean as a function of technical, geographical and seasonality factors. Their 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 populations. Longline targeting albacore is the gear with a highest effect on dolphinfish populations. The technical characteristics of the fishery and seasonality factors have an important part in explaining the absence or presence of dolphinfish bycatch in the different boat strata, gear types, and seasons. Moreover, sea surface temperature also explained additional variability in the models.

The aim of the present study is to update data on *Coryphaena hippurus* bycatch of adult and juveniles collected by the on-board observer program of the IEO in the western Mediterranean for the period 2000-2014, throughout the year. In addition, a revision of the length-weight relationships, a summary of the Mediterranean data sets of dolphinfish catches reported to the ICCAT database, and a bibliography revision on catch of dolphinfish in longline fisheries in the Mediterranean are included in this paper.

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 scientific observer program, planned according to ICCAT recommendations. Observers were assigned according to spatial, temporal and gear bases. The fishing ground and the spatial distribution of the effort of longline gears are shown in **figure 1**.

The IEO on-board observer Program (IEO-OP) provided commercial fish catch and bycatch data collected on longline vessels from 1997 to 2015. Dolphinfish bycatch data were collected from 2000 to the present day. We only have included the 2000-2014 period in the present study. The spatial distribution of the observed effort of longline fishery from 2009 to 2014 is shown in **figure 2**.

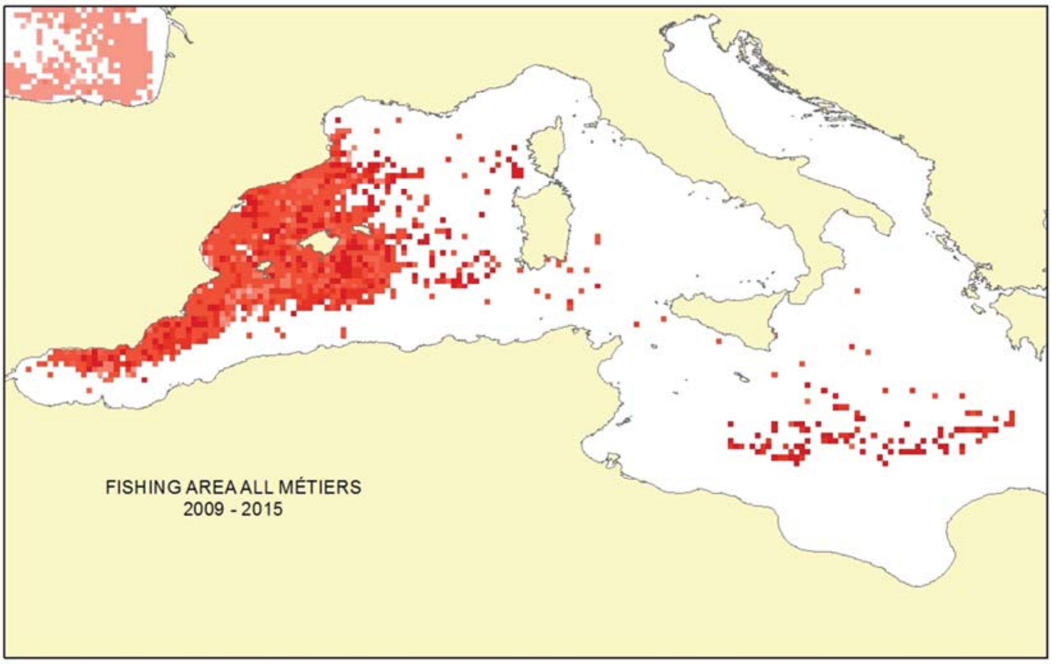

Figure 1. Spatial distribution of fishing effort (2009-2015) and known fishing grounds.

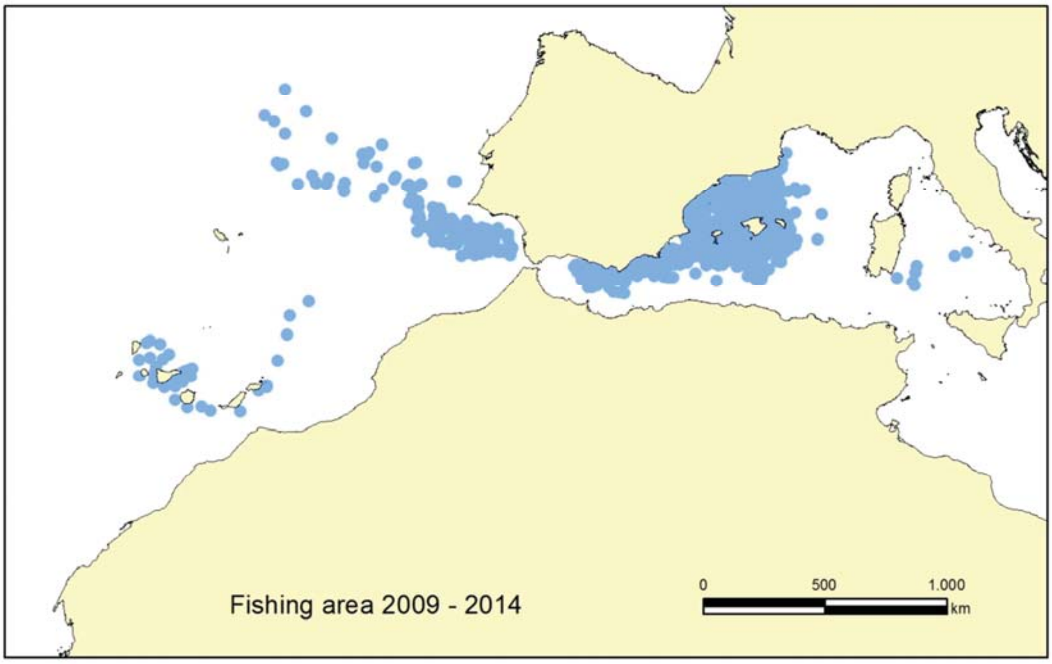

Figure 2. Spatial distribution of observed fishing effort (2009-2014).

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.

With regards to dolphinfish, the objectives of observers were to record captures and identify specimens to the lowest taxonomic level possible.

2.2 Data analysis

We calculated annual/monthly dolphinfish bycatch rates as the total number of individual dolphinfish caught in a year/month divided by the number of hooks deployed in the period (BPUE).

BPUE series was divided into BPUE of juveniles (BPUEj) and BPUE of adults (BPUEa) to explore the dynamic of the recruitment to the gear and possible relationships between the spawning stock and subsequent recruitments. We tested two sceneries, in the first one we consider juveniles all the specimens lower than 65 cm FL (according to Massuti and Morales-Nin, 1999); in the second, we consider juveniles all the specimens lower than 80 cm FL, this second sceneries was tested due to young of the year reach sizes longer than 65 cm FL in November-December, months where the environmental conditions are not favorable to reproduction. Thus we consider the size of the lower individuals in the next season (80 cm FL) as L50.

To adjust Length-weight relationships, power curve regressions were performed:

$$Weight = a * Length^{b};$$

where “a” and “b” are the power regression coefficients, and “Weight” and “Length” are the weight of the individual expressed in grams (g) and the length of the fish expressed in centimeters (cm), respectively (Froese, 2006). Outliers were no eliminated.

We used 499 pair of length-weight data from individual dolphinfish caught in longline fleet during the study period. We selected the best fit among several significant regressions, in accordance with the highest F-value.

We analyzed the temporal series of bycatch of dolphinfish in longline. In a first step, we estimated the BPUE series of adult and juveniles separately aiming to compare the incidence of the gear on spawners versus juveniles in the area. In a second step, a spectral analysis and red-noise spectra procedure (REDFIT) algorithm (Schulz and Mudelsee, 2002) was used to identify the red-noise spectrum from the gaps in the observed time-series of BPUEa and BPUEj. The REDFIT procedure was performed using the PAST software package (Hammer et al., 2001; Hammer and Harper, 2006).

Finally, we tested the relationship between the North Atlantic Oscillation (NAO) and the BPUEj and BPUEa. The BPUE both juveniles and adults were estimated as the mean BPUE observed between June and September. Because previous studied observed a lag between the NAO and its effect on the fisheries (for example Báez et al., 2014; Báez, 2016), we used two different gaps periods: (i) the NAO six previous months (NAOsm), i.e. mean of monthly NAO values from January to June (both inclusive), and (ii) the NAO winter (NAOw), i.e. mean of NAO monthly values from November of the previous year to April.

We obtained monthly average NAO values from NOAA web site: http://www.cpc.ncep.noaa.gov/products/precip/CWlink/pna/nao.shtml

3 Results

During the 15 years covered in this study, a total of 4862 fishing sets (9 849 923 hooks) were observed, and the number of dolphinfish recorded was 8 510 fish, the BPUE of the total period was 0.864 fishes/1000 hooks.

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 27m and fishing trips were often of short duration (1 to 6 days). 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 2014. We defined one fishing operation (set) as a daily cycle of longline setting and hauling.

We classified the fleet into six *metiers*, according to differences in target species, operational depth and technical characteristics (**table 1**). A short description of each metier is detailed below.

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 90m, 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 70g, 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.

Table 1. 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	23	All year but lesser activity from march to april	High
								Small Mackerel	16		
								Chub Mackerel	23		
								Sardine	17		
								Atlantic saury	25		
								Round sardinella	20		
								Silver sccabardfish	70		
								Squid	18		
LLAM	900-1300	7,5x2,5	70 - 90	50-60	Evening	4-5 hours	> 150 b.	Mackerel	23	From 2002 to 2007, all year excepct may to july. Lesser activity in winter. Since 2008, greater activity in Atlantic Ocean	Medium
								Chub Mackerel	23		
								Squid	22		
								Round sardinella	20		
LLSP	900-1500	7,5x2,5	33	20-30	Early morning	3-4 hours	> 200 f.	Mackerel	23	Only since 2006. Mainly summer months after Juny until october	Low
								Chub Mackerel	23		
								Squid	22		
								Round sardinella	20		
LLPB	600-1000	7,5x2,5	12	6-15	Early morning	1-2 hours	< 250 and > 50 f.	Mackerel	23	Mainly summer months, since july to october. Some cases until december	Low
								Chub Mackerel	23		
								Silver sccabardfish	70		
LLJAP	250-1100	7,5x3,0	50 - 70	5-50	Variable	1-6 hours	> 250 f.	Great squid	30	Second half of may to first half of july	Low
								Great mackerel	33		
								Bogue	16		
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

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 – 200m 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. This gear showed the highest dolphinfish BPUE in the western Mediterranean. The effort density of this gear in the Spanish western Mediterranean is showed in **figure 3**.

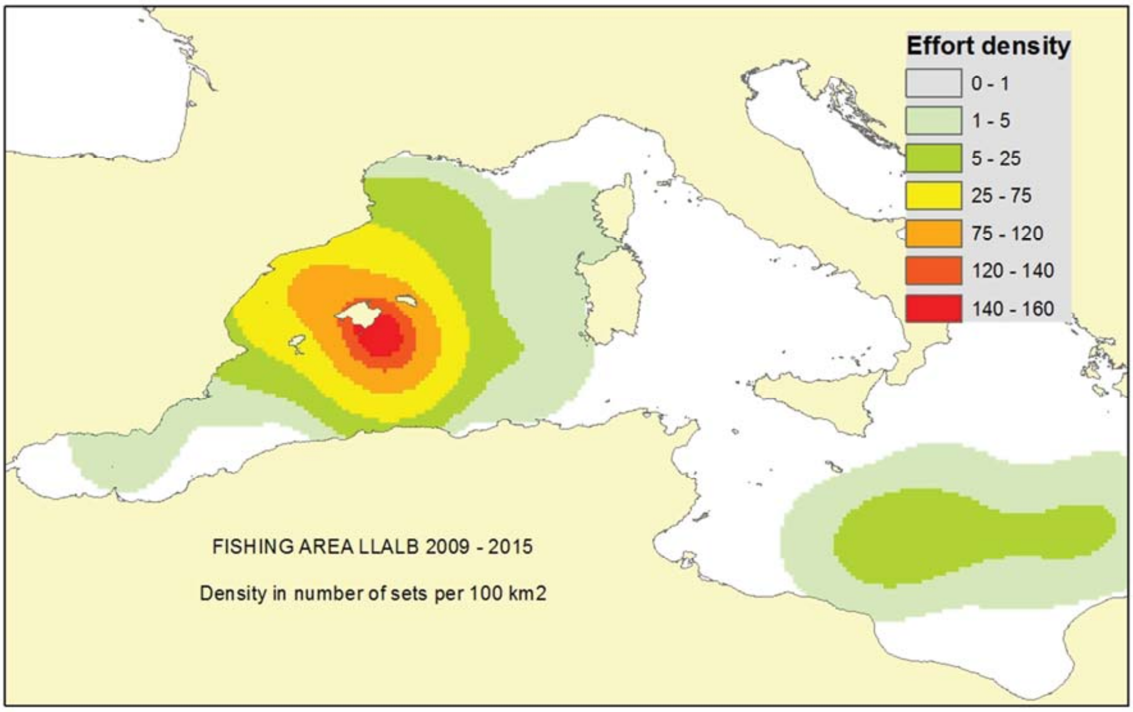

Figure 3. Map of fishing effort density of Spanish LLALB in the western-central Mediterranean.

The total effort of the longline fleet was variable in the studied period with a flat trend slightly downloading in the last years of the series (**figure 4**).

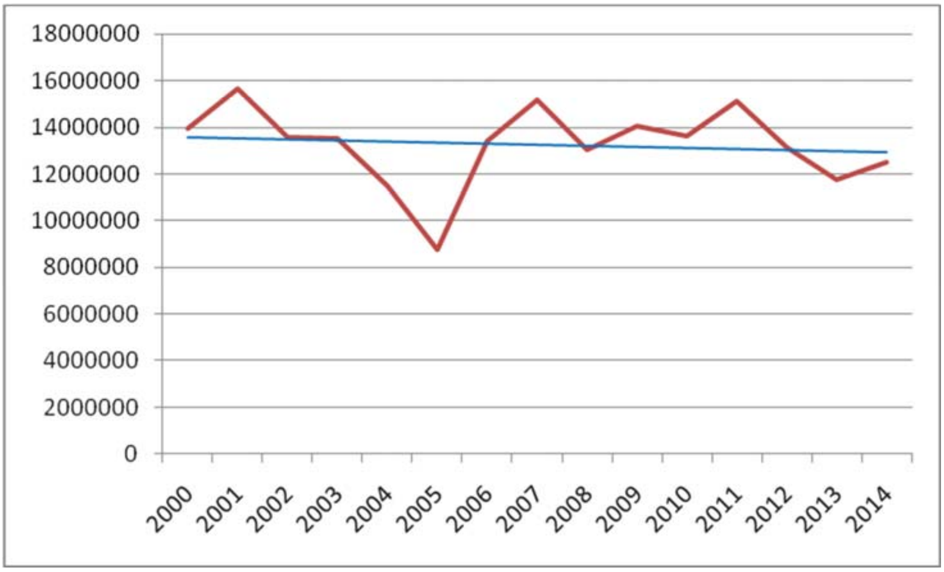

Figure 4. Total effor (number of hooks) of the longline fleet operating in the Spanish Western Mediterranean.

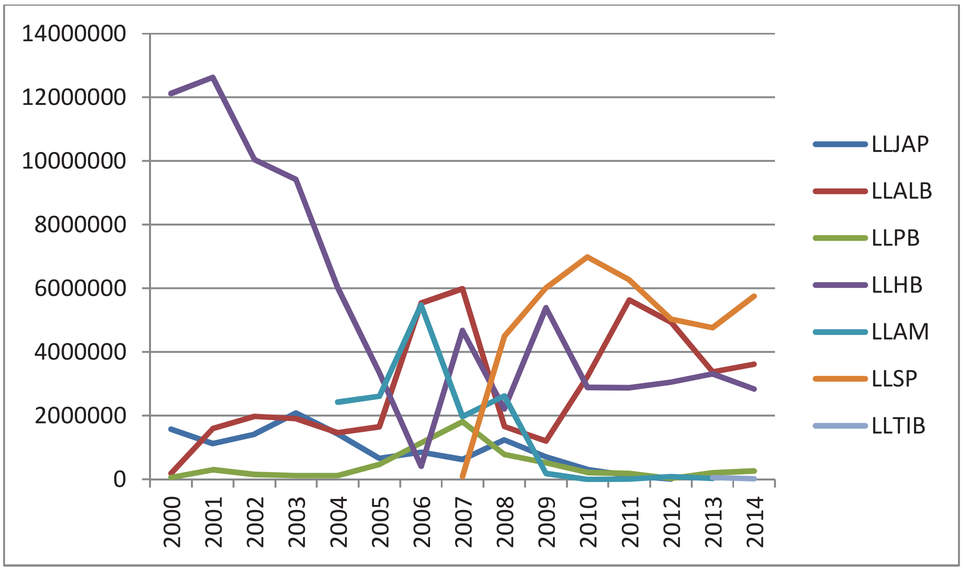

Figure 5. Annual effor by metier (number of hooks) of the longline fleet operating in the Spanish Western Mediterranean.

The fishing fleet is continually innovating and improving the economic profit of the fishery, thus the fleet change the gear type along the seasons and along the time series. For this reason it is necessary to take in mind that the distribution of fishing effort per metier shown a differential effort along the studied period (**figure 5**).

3.2 Bycatch description

Bycatch of dolphinfish for the 4862 observed fishing sets in the 15-year period covered in this study (9 849 923 hooks) amounted to 8510 fishes. The average BPUEn for the studied period was 0.864 fishes per 1000 hooks. **Table 2** shows the average BPUEn per longline and year.

Table 2. Observed BPUE of dolphinfish (nº of fishes/1000 hooks) per type of longline along the time series studied. The blank in the table indicates non observed combinations.

	LLALB	LLAM	LLHB	LLJAP	LLPB	LLSP
2000	0,054		0,894	0,000	0,000	
2001			1,613	0,162	0,000	
2002			0,146	0,000	0,000	
2003		2,286	0,811	0,000	0,000	
2004		1,085	1,693	0,000	0,000	
2005		0,000	1,281	0,000		
2006	9,996	1,261	1,093	0,000	0,032	
2007	0,376	1,150	0,657	0,147	0,037	0,123
2008	5,024	0,411	0,110	0,000	0,322	0,116
2009	0,061	0,000	0,265	0,000	0,127	0,003
2010	1,631		0,094	0,000	0,126	0,028
2011	1,287	0,000	0,000	0,000	0,000	0,004
2012	0,408	0,000	0,021		0,116	0,017
2013	0,263	0,000	0,000		0,000	0,010
2014	1,019		0,013			0,004

All of the monitored metiers in this study (six) caught dolphinfish, but the majority of the catches were done using LLALB (4795), LLHB (3013) and LLAM (398).

LLALB showed a BPUEn of 1.77 fishes per 1000 hooks, the highest BPUEn was recorded in 2006 (9.99 fishes per 1000 hooks) and the lowest in 2000 (0.05 fishes per 1000 hooks). LLAM had an average BPUEn of 1.1 fishes per 1000 hooks, lower than that for LLALB. The highest BPUEn was recorded in 2003 (2.29 fishes per 1000 hooks) and the lowest in 2005, 2009, 2011, 2012 and 2013 (0.0 fishes and kg per 1000 hooks). LLHB had an average BPUEn of 0.81, slightly lower than that for LLAM. The highest BPUEn was recorded in 2004 (1.69 fishes per 1000 hooks) and the lowest in 2011 (0.00 fishes per 1000 hooks).

Table 3. Scenario 1, total BPUEn and BPUE of juveniles (BPUEj) and adults (BPUEa) of dolphinfishes (nº of fishes/1000 hooks) from 2000 to 2014.

Year	BPUEj	BPUEa	Total BPUE
2000	0,48	0,28	0,76
2001	1,18	0,31	1,49
2002	0,08	0,03	0,12
2003	0,67	0,14	0,81
2004	0,63	0,41	1,04
2005	0,53	0,00	0,53
2006	4,33	1,18	5,51
2007	0,05	0,40	0,44
2008	0,74	0,13	0,87
2009	0,08	0,02	0,10
2010	0,83	0,07	0,91
2011	0,47	0,04	0,51
2012	0,17	0,06	0,23
2013	0,25	0,08	0,33
2014	0,62	0,06	0,68

Our results about inter-annual trend of BPUEn in Spanish longline fisheries show a low impact on dolphinfish (**table 3**). The BPUEj are usually highest than the BPUEa except for 2007. The BPUEn both for adults and juveniles reach a pick in 2006. In general, the highest CPUEj are related to high CPUEa (**figure 6**).

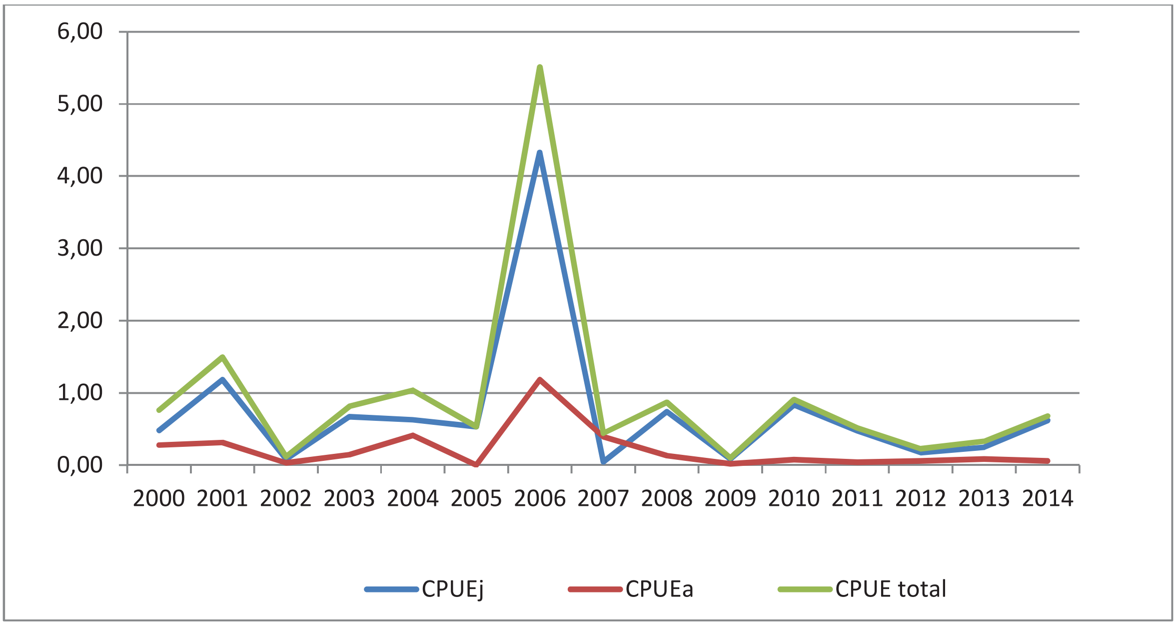

Figure 6. Scenario 1: total BPUEn, BPUEa and BPUEj trends in the 2000-2015 temporal series.

The monthly variation of BPUEn indicates that dolphinfish are out of the fishery catches in the winter season (from January to March). The majority of the catches take place in autumn (from September to November).

Regarding juveniles in the scenario 1, the first catches took place in May, increasing progressively till October; in November the catches of juveniles are still high but lower that in the previous month (**figure 7**). The adult fraction of the population appears firstly in the catches in March, increasing their numbers till September, and after a slight decrement in October, the number increase again till November. This autumn increment of adults could be due to the recruitment of young of the year to the adult fraction (in this paper over 65 cm FL) of the population (**table 4**).

Table 4. Scenario 1: monthly observed effort, total BPUEj, and BPUEa in the studied period.

Month	f obser	Juveniles	Adults	BPUEj	BPUEa	total BPUE
January	212047	0	0	0,00	0,00	0,00
Febrery	233955	0	0	0,00	0,00	0,00
March	425510	0	2	0,00	0,00	0,00
April	293941	0	2	0,00	0,01	0,01
May	735227	3	6	0,00	0,01	0,01
June	1271969	3	126	0,00	0,10	0,10
July	1593180	3	166	0,00	0,10	0,11
August	1748749	11	195	0,01	0,11	0,12
September	1659416	2418	316	1,46	0,19	1,65
October	721636	2862	280	3,97	0,39	4,35
November	476947	1177	769	2,47	1,61	4,08
December	477346	143	28	0,30	0,06	0,36

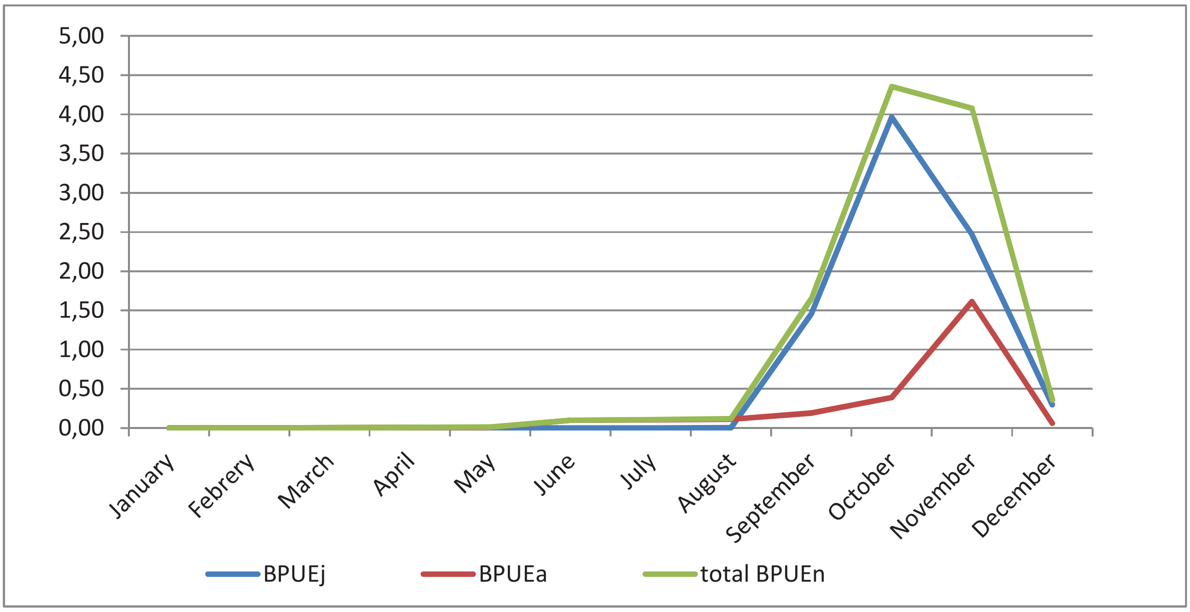

Figure 7. Scenario 1: total BPUEn, BPUEa and BPUEj monthly trends (2000-2015).

In the scenario 2 (**table 5**), the monthly trend follow the same trends that those described in scenario 1 (**figure 8**). The adult fraction of the population appears firstly in the catches in March, However in the scenario 2, the adults increased their numbers till October, and after dropped in December.

Table 5. Scenario 2: monthly observed effort, total BPUEj, and BPUEa in the studied period.

Month	f obser	Juveniles	Adults	BPUEj	BPUEa
January	212047	0	0	0	0
Febrery	233955	0	0	0	0
March	425510	1	1	0,00235012	0,00235012
April	293941	0	2	0	0,00680409
May	735227	6	3	0,00816074	0,00408037
June	1271969	38	91	0,02987494	0,07154262
July	1593180	27	142	0,01694724	0,08912992
August	1748749	40	166	0,02287349	0,094925
September	1659416	2485	249	1,49751479	0,15005279
October	721636	3051	91	4,22789329	0,12610236
November	476947	1762	184	3,69433082	0,3857871
December	477346	171	0	0,35823072	0

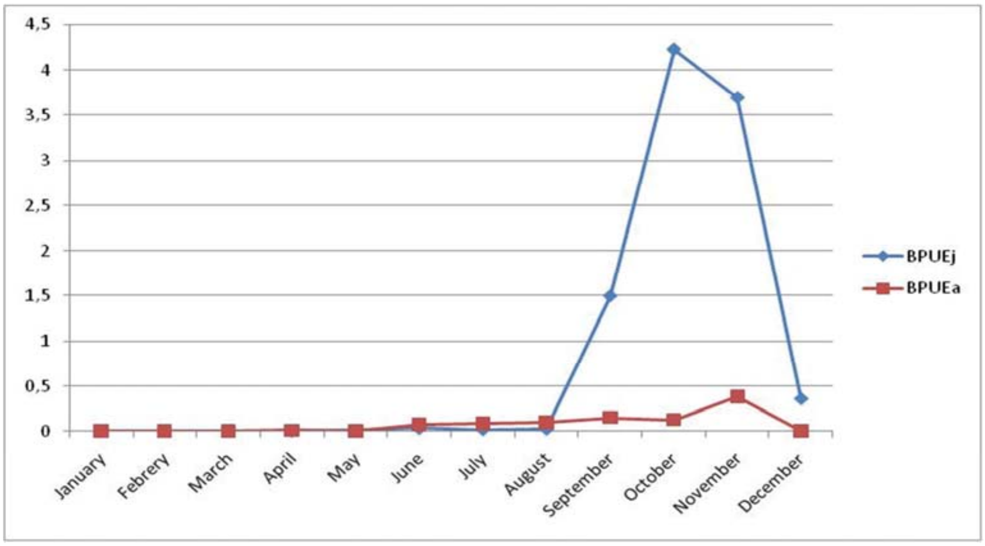

Figure 8. Scenario 2: total BPUEn, BPUEa and BPUEj monthly trends (2000-2015).

3.3. Length composition of the catches.

The mean of fork length (FL) for the dolphinfish in the studied period was 58.8cm. Length range from 20cm to 135cm FL. **Figure 9** shows the monthly variation of the mean FL. Length distributions of the total period and from June to December are summarized in **figure 10**. From March to August the distributions are dominated by adult individuals. From September to December the majority of the dolphinfish caught were juveniles.

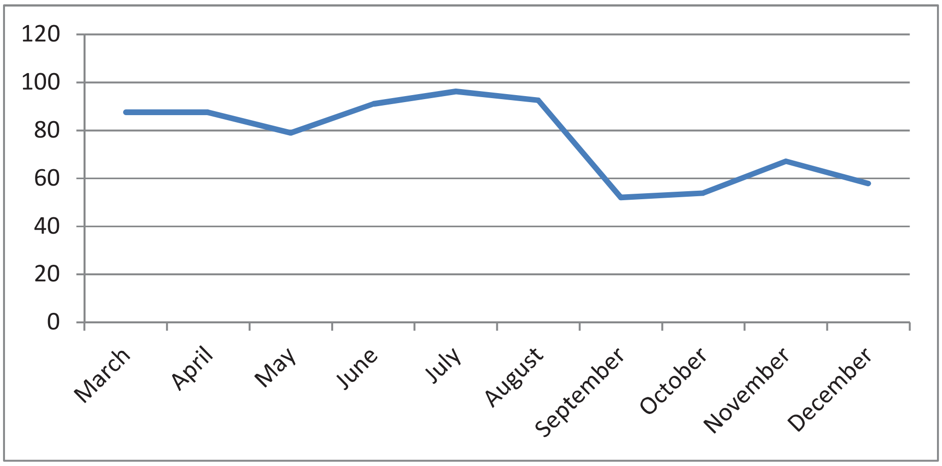

Figure 9. Monthly variation of the mean FL of dolphinfish caught in the studied period (2000-2014).

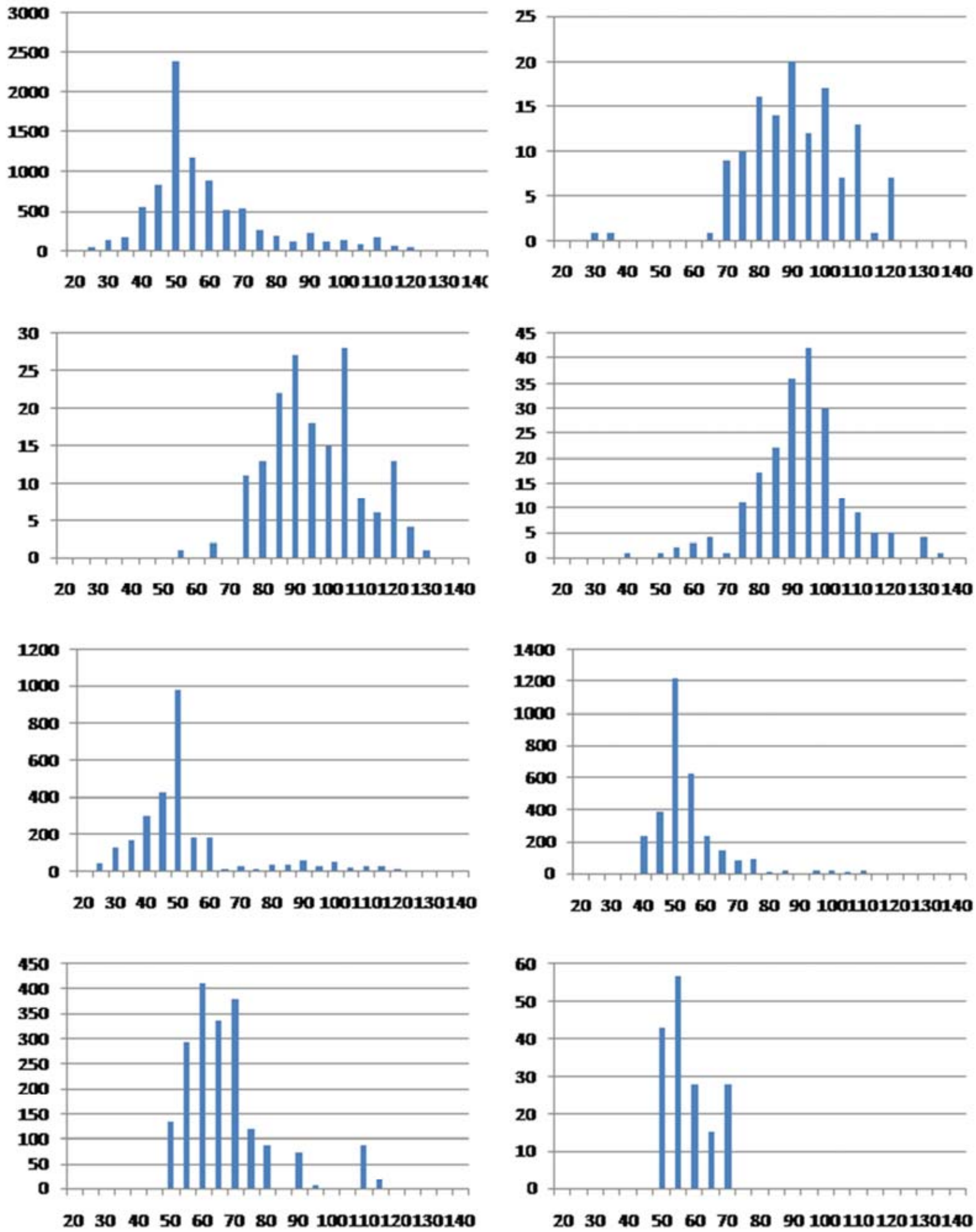

Figure 10. Length distributions of the dolphinfish caught by the longline fishery in the Spanish western Mediterranean. From left to right and top to bottom: Annual length distribution, June, July, August, September, October, November and December.

It is very important to take into account the metier when making inferences about the dolphinfish populations based on fisheries bycatch data, because the high variations of BPUE among longline types, seasons and years. The **table 6** shows the estimates about annual number of dolphinfish caught by the longline fishery in the Spanish western Mediterranean taken into account, the year, the metiers specific BPUE and the metier specific effort.

Table 6. Estimates of annual number of dolphinfish caught by the longline fishery in the Spanish western Mediterranean.

	LLALB	LLAM	LLHB	LLJAP	LLPB	LLSP	total
2000	9,8	0,0	10832,4	0,0	0,0	0,0	**10842,2**
2001	0,0	0,0	20362,5	181,7	0,0	0,0	**20544,2**
2002	0,0	0,0	1468,6	0,0	0,0	0,0	**1468,6**
2003	0,0	0,0	7638,2	0,0	0,0	0,0	**7638,2**
2004	0,0	2635,3	10191,7	0,0	0,0	0,0	**12827,0**
2005	0,0	0,0	4288,2	0,0	0,0	0,0	**4288,2**
2006	55350,5	6905,4	442,9	0,0	36,9	0,0	**62735,8**
2007	2251,8	2265,9	3073,2	91,5	67,0	10,3	**7759,7**
2008	8364,8	1080,0	243,0	0,0	252,3	522,4	**10462,4**
2009	73,2	0,0	1428,0	0,0	65,6	20,1	**1587,0**
2010	5256,2	0,0	272,4	0,0	26,5	193,6	**5748,7**
2011	7245,5	0,0	0,0	0,0	0,0	26,4	**7271,9**
2012	2012,0	0,0	64,9	0,0	3,6	84,7	**2165,1**
2013	887,0	0,0	0,0	0,0	0,0	46,5	**933,5**
2014	3681,6	0,0	37,5	0,0	0,0	21,5	**3740,6**

The average annual effort for the Spanish pelagic longline fleet is 13 237 635 ± 1 700 915 hooks. The average annual bycatch estimate for the fleet for this period was 10 667.6 ± 15 328.6 dolphinfish per year.

3.4 Length-Weight relationships (LRW)

In the current study, we provided a new improved Length–weight relationship (LWR) for dolphinfish by-caught by longline in the Mediterranean Sea. This new improved LWR increased the number of length-weight pairs of data in comparison with previous studies in the area (see for example Macías et al., 2012). Thus, the current LWR length ranked between 29 cm and 124 cm (versus 32 cm and 106 cm from the previous paper Macías et al., 2012).

Table 7 shows the sample size, length range (L), weight range (W), and LWR parameters, and coefficient of correlation (R2) for dolphinfish studied. Our results about length-weight relationships are summarized in the **figure 11**.

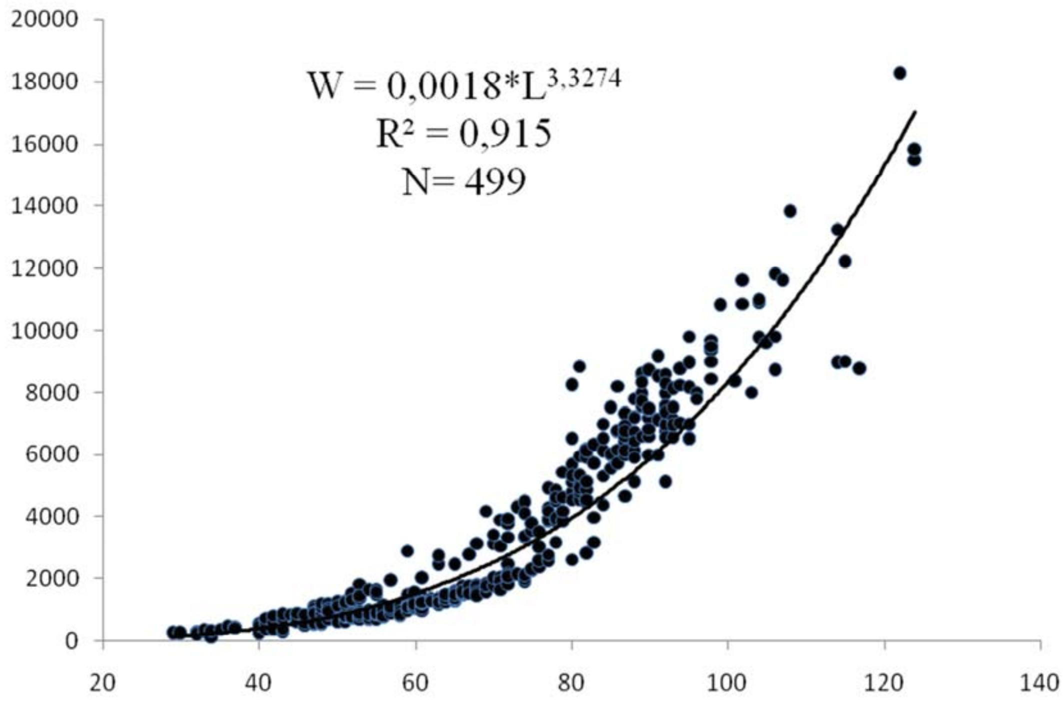

Figure 11. Length-weight relationship for dolphinfish longline by-caught.

Table 7. Sample size, length range (L), weight range (W), and LWR parameters, and coefficient of correlation (r2) for dolphinfish versus Macias et al. (2012).

		Total length (cm)		**Total body weight (gr)**		**Regression parameters**			
Study	N	Min	Max	Min	Max	a	b	R^2	P
Current study	499	29	124	150	18250	0.0018	3.327	0.915	<0.001
Macias et al. 2012	155	32	106	270	10900	0.0036	3.212	0.97	<0.001

3.5. Time series Analysis

The monthly variation in the BPUE of adults and juvenile in the area indicates that the juveniles of dolphinfish began to be recruited to the fishery in May, reaching a pick in September-October.

Our results indicate the presence of cyclic events in by-catches both of immature and mature fishes. The REDFIT procedure showed that the BPUE of juveniles exhibited a clear time-trend with an observed periodicity of 7 months (95%) (**figure 12**), while the BPUE of adults exhibited a clear time-trend with an observed periodicity of 5 months (95%) (**figure 13**).

We obtained a significant negative relationship between the NAOsm and the BPUE of juveniles (R^2= 0.481; F= 12.042; P= 0.004), according to the function:

BPUE of juvenile= 0.37 -0.75*NAOsm

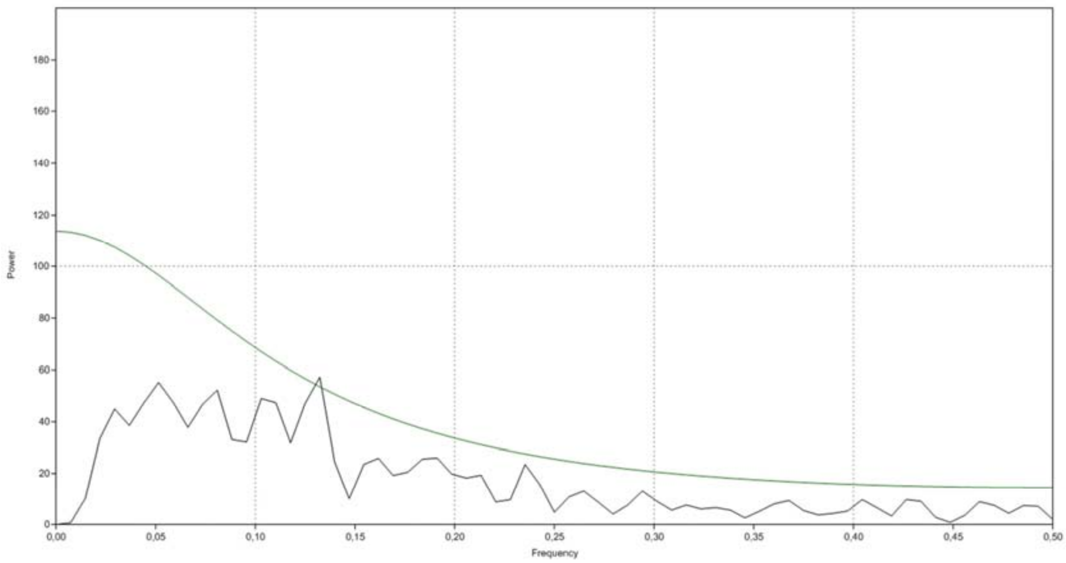

Figure 12. Frequency and periodicity observed from REDFIT analysis for BPUE of juveniles. The significant trend to a 95% confidence interval is lighted in green.

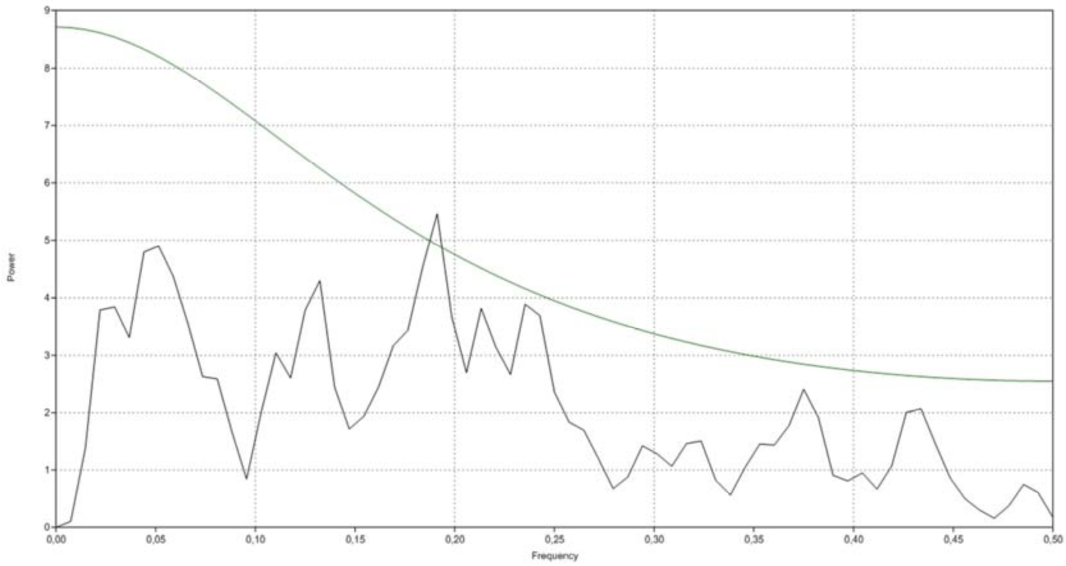

Figure 13. Frequency and periodicity observed from REDFIT analysis for BPUE of adults. The significant trend to a 95% confidence interval is lighted in green.

3.4. ICCAT database summary

The International Commission for the Conservation of Atlantic Tunas (ICCAT) consider dolphinfish since 2007 as a Small Tuna Species (SMT) and ask for information on statistics from this date. Currently the largest data series on dolphinfish came from Caribbean and Brazilian areas in the Atlantic and from Malta (since 1950) in the Mediterranean. The **figure 14** shows the trends in landing of dolphinfish from 1950 till 2013.

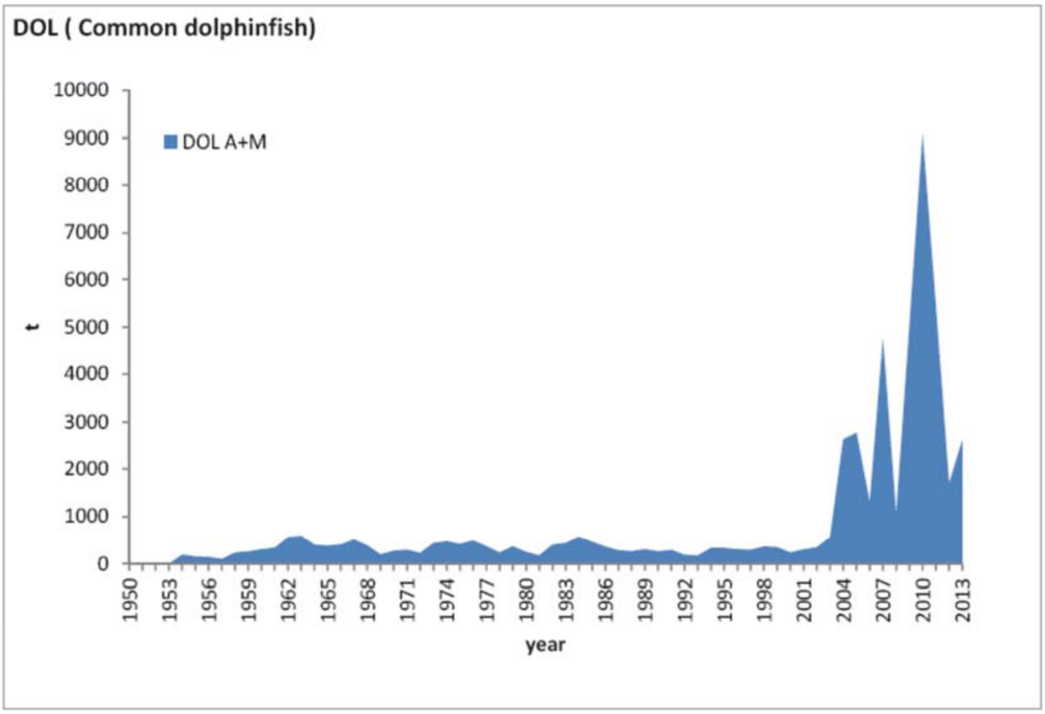

Figure 14. Estimated landings (t) of dolphinfish in the Atlantic and Mediterranean, 1950-2013. The data for the last years are incomplete (font: ICCAT SMT 2014-2015 executive summary).

The **table 8** summarized the available information by country and decades in the Mediterranean. The largest time series corresponds to Malta (mainly with purse seine on pelagic fish with FADS-PSPF-).

Tabla 8. Landings (t) of dolphinfish in the Mediterranean registered in the ICCAT data base (1950-2014) summarized by decades.

	1950	1960	1970	1980	1990	2000	2010
EU.España						20,9	11,3
EU.France						0,1	0,2
EU.Italy							1224,9
EU.Malta	1080,7	4090,8	3604,7	3515,1	2893,5	3896,9	1652,2
Total	1080,7	4090,8	3604,7	3515,1	2893,5	3917,9	2888,5

In the last 16 years only data from Malta (1999-2014), Italy (2013-2014), Spain (2007-2014) and France (2007 and 2014) have been reported to ICCAT by Mediterranean countries. The Italian and Maltese landing data reach a pick in 2013 (**figure 15**).

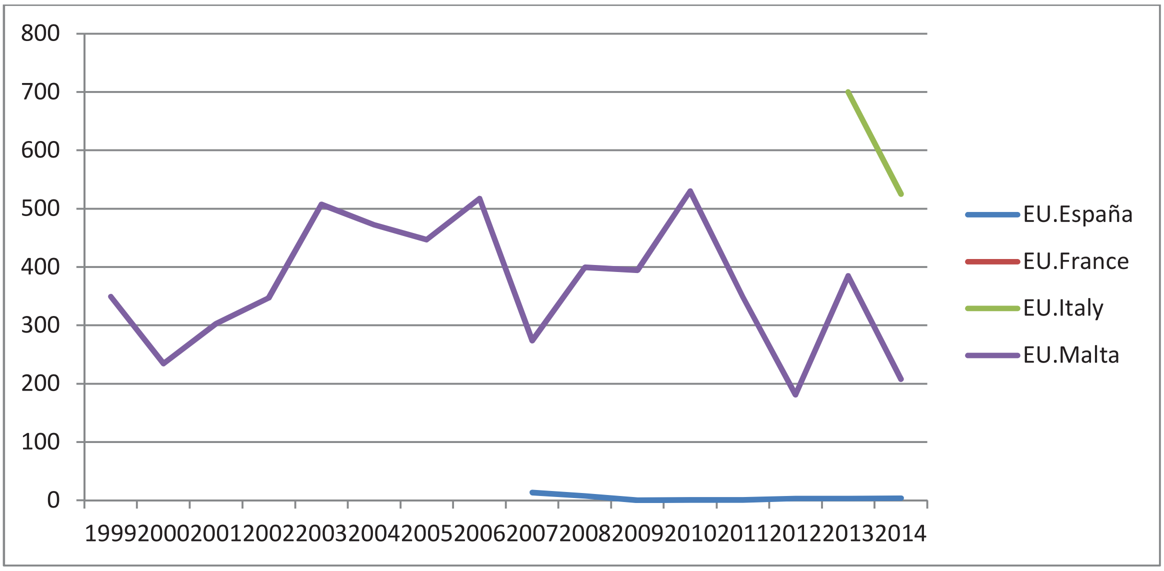

Figure 15. Landings (t) of dolphinfish in the Mediterranean reported to ICCAT, 1999-2014.

Data from Spain corresponds mainly to longline fisheries that catch dolphinfish as bycatch of tuna fisheries. Data coming from France corresponds to sport fisheries (2007), and Trawlers, gillnets, and longline for 2014 (**table 9**).

Table 9. Data on dolphinfish catches (t) reported to ICCAT database (1999-2014) by Spain and France. LL (Longline), GILL (Gillnets), SPOR (sport fisheries), TRAW (Trawlers).

	EU.Spain			EU.France			
	LLALB	LLHB	LLPB	GILL	LL	SPOR	TRAW
2006							
2007		13,262				0,1158	
2008		7,343					
2009		0,323					
2010							
2011		0,832					
2012	2,865	0,3					
2013	2,589	0,724					
2014	3,585	0,334	0,061	0,006	0,116		0,037

Italy has reported data to ICCAT only the two last years (2013-2014). The major catches come from purse seiners and longline fisheries (**table 10**). Finally Malta has reported data on Purse seiners from 1999 to up 2014 and from longline fisheries from 2006 up to now (**table 11**).

Table 10. Data on dolphinfish catches (t) reported to ICCAT database (199-2014) by Italy. LL (Longline), OTH (Other fisheries), PS (Purse seine), UNCL (unclassified catches).

	EU.Italy					
	LL	OTH	PS	PS-FB	PS-FS	UNCL
2012						
2013	212,7			405,9	10,6	71,1
2014	138,2	108,6	255,8			22,2

Table 11. Data on dolphinfish catches (t) reported to ICCAT database (199-2014) by Malta. LL (Longline), PS (Purse seine), TROL (Trolling).

	EU.Malta								
	LL	LLALB	LLBFT	LL-deri	LL-surf	LLSWO	PS	PS-FS	TROL
1999								349,1	
2000								234,3	
2001								302,9	
2002								347,3	
2003								507,1	
2004								472,7	
2005								447,1	
2006				4,5				505,5	7,4
2007				10,8				257,3	5,7
2008				7,7				387,0	4,8
2009				5,8				387,0	2,0
2010				6,1				515,9	8,0
2011				0,9		4,3		341,7	1,8
2012			0,3	5,4		0,4	174,8		0,1
2013			0,5		8,0	1,5		372,0	2,8
2014	2,0	0,2	0,1			1,4		196,0	8,0

According to ICCAT, there is little information about dolphinfish in the Mediterranean. The Committee suggests the submission of all available data to ICCAT as soon as possible. Generally, current information does not allow the Committee to carry out an assessment of stock status of dolphinfish in the Mediterranean. Some analyses will be possible in future if data availability improves with the same trend of the latest years.

3.5. Bibliographic Revision

Only a few papers on dolphinfish bycatch in longline fisheries from the Mediterranean have been found:

Macías et al. (2004), described the landing associated to the longline fishery targeting swordfish in the Spanish Mediterranean, dolphinfish was among the cited species. Later, Baez et al, 2009, analysing swordfish catches and bycatches in artisanal longline fisheries in the Alboran Sea (western Mediterranean Sea) during the summer season, also describe the presence of dolphinfish as bycatch. Finally Macías et al. (2012), analysed dolphinfish bycatch in Spanish Mediterranean large pelagic longline fisheries, in the period 2000-2010.

Regarding the eastern Mediterranean, Akyol et al, (2007) presented a description of longline fishery and Length-Weight relationships for selected fish species in Gökova Bay (Aegean Sea) in Turkey. Gabr et al., (2012), presented some data on catches of dolphinfish by the longline fishery for albacore (*Thunnus alalunga*) in the Mediterranean Sea off Egypt. Finally, Ceyhan et al. (2014) reported some data on dolphinfish by the Turkish surface longline fishery targeting swordfish in the eastern Mediterranean Sea.

A summary of the published data on dolphinfish by longline fisheries in the Mediterranean Sea are shown in the **table 12**.

Table 12. Summary of available information about bycatch rates of dolphinfish in longine fisheries in the Mediterranean Sea. BPUEn (nº of fish/1000 hooks), BPUEw (kg/1000 hooks).

References	Area	Target species	BPUEn	BPUEw	% W capture
Macías et al. (2004)	Western Mediterranean	swordfish	---	---	1.07
Akyol et al. (2007)	Aegean Sea (Turkey)	swordfish	---	---	1.05
Báez et al. (2009)	Alboran Sea	swordfish	0.73	---	1.75
Macías et al. (2012)	Western Mediterranean	swordfish	0.85	2.13	---
Macías et al. (2012)	Western Mediterranean	bluefintuna	0.16	1.3	---
Macías et al. (2012)	Western Mediterranean	albacore	3.7	2.2	---
Gabr & El-Haweet (2012)	Egypt	albacore	---	---	<1.6
Ceyhan & Akyol. (2014)	Aegean Sea (Turkey)	swordfish	0.46	5.64	2.4

4 Discussion

Our results indicate that the impact of the pelagic and semi-pelagic longline on the dolphinfish population is relatively low (0.864 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 = 1.77 fishes per 1000 hooks) and have a remarkable incidence on juveniles. We suggest that this gear could be interacting with other artisanal fisheries targeting dolphinfish around Majorca Island (Lleonart et al, 2009), but in this sense is interesting to note the low catch rates of dolphinfish by-caught by LLALB. LLAM (CPUEn = 1.1 fishes per 1000 hooks) and LLHB (CPUEn = 0.8 fishes per 1000 hooks) follow to LLALB in the catch rate ranking.

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 (Macías et al., 2012). These authors suggested 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.

The Spanish longline fishery captures of dolphinfish in our study was 10667 fishes per year, 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.

In addition longline fishery affect both juveniles and adults fish. The monthly distribution of the bycath indicates that there were no catches in winter (January to March), later in spring and summer the majority of the catches corresponds to adults and finally along the autumn a lot of juveniles are recruited to the fishery. The variations of monthly length distributions, mode and mean size of dolphinfish bycatch support this hypothesis. Current results highlight a significant seasonal periodicity in the BPUE both juvenile and adults of the dolphinfish. This seasonality, could be related with the recruitment of juveniles to the fisheries, which it due be during June and picking in September. Thus, North Atlantic Oscillation (NAO) in previous months could lead to the success of the recruitment. It is widely accepted that the planet is currently experiencing a period of rapid global warming, which is primarily driven by human activity. This global trend could affect the future regional impact of the NAO and thus its effect on marine ecosystem dynamics (Báez, 2016).

The Length-Weight relationships (LRW) reported in current study improved the previous LRW adjusted, because increase the range length and number of individuals used (N= 499).

Regarding ICCAT database there is little information available, and the Committee suggests that countries be requested to submit all available data to ICCAT as soon as possible, in order to be used in future meetings of the Committee (Anon, 2014). In addition, current information does not allow the Committee to carry out an assessment of stock status of dolphinfish. Some analyses will be possible in future if data availability improves with the same trend of the latest years. Assessments of stocks of small tunas are also important because of their position in the trophic chain. It may therefore be best to approach assessments from the ecosystem and regional perspective since these species have limited movements as compared to the major tuna species (Anon, 2014).

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.

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