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Assessment of Splendid alfonsino (*Beryx splendens*) in NAFO Subarea 6

by

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Abstract

Introduction

Alfonsino is distributed over a wide area which may be composed of several populations. Alfonsinos are oceanic demersal species occurring at the top of seamounts and along slopes. They are widespread in the northeast Atlantic from Iceland to the Azores and along the continental slope. Alfonsinos are aggregative. Population dynamics are uncertain with recent estimates suggesting high longevity (>50 years), while other estimates suggest a longevity of ~15 years. Due to their spatial distribution associated with seamounts, their life history and their aggregation behavior, Alfonsinos are easily overexploited by trawl fishing; they can only sustain low rates of exploitation.

The Corner Rise Seamount complex is located in a small area of the NAFO Subarea 6 (34º- 37º N, 47º - 53º W). Figure 1 presents the Corner Rise Seamount complex map of the "Deep Atlantic Stepping Stones: Exploring the Western North Atlantic Seamounts" NOAA exploration. In this area there are at least 13 seamounts and in Figure 1 shows the names proposed by Les Watling for five of them.

Commercial aggregations of alfonsino (*Beryx splendens*) on the Corner Rising and in the area of North Azores were discovered for the first time on board the USSR exploratory vessels the mid-70s of last century. Further fisheries expeditions to the seamounts were repeatedly carried out during which a considerable body of research and commercial data has been obtained. In some years a commercial fishery was conducted on the banks based on the results of the exploratory fisheries. The results of these exploratory surveys were presented by V. I. Vinnichenko (1997, 1998).

In 2006, the Fishery Commission (FC) of NAFO established a ban to use bottom fishing gear on the Corner Rise seamounts. The mentioned restriction is aimed at the protection of vulnerable marine ecosystems (VMEs) and, by now, it has been the only fishery management measure in the area.

At the September 2013 meeting (NAFO, 2013), the SC noted that although this fishery is generally small, this mid-water trawl commercial fishery is not covered under Chapter II of the NCEM (i.e. Bottom Fisheries in the NAFO Regulatory Area) or any other chapter. SC noted that this gap in the NCEMs could result in an ongoing fishery that is unregulated. Consequently the SC recommended that precautionary regulations of the mid-water trawl fishery on splendid alfonsino be put in place. In 2014 and 2018 NAFO Commission request for scientific advice on provide a stock assessment for alfonsino and recommendation. In 2015 and 2017, NAFO SC revised all the information available for the assessment of this resource.

The objective of this document is to present the available information on the alfonsino fishery in NAFO Div. 6G to provide management advice for 2018, 2019 and 2020 requested by the Commission.

Population Structure

There is not much information about the North Atlantic alfonsino population structure. There are two points of view concerning this structure. In the opinion of most investigators this species is believed to form an independent population on each separate seamount of the open North Atlantic, does not migrate to long distances and all stages of its life cycle are developed within the same bank. This approach is proved by the results of genetic investigations (Titova, 1981) as well as by absence of Alfonsino aggregations on the banks for a long time (several years) caused by heavy fishery on these banks (Klimenko, 1983; Melnikov et al., 1993; Vinnichenko, 1995).

The hypothesis of some scientists according to which Alfonsino migrates between the Corner Rising and the Azores banks and there is a single population in that area (Alekseev et al., 1987) appears doubtful not only in view of the above reasons. Analysis indicates that this hypothesis is largely based on non-representative data on length-age composition of Alfonsino on the Corner Rising and in the Azores area suggesting only large mature fish (reproductive part of the distribution area) to inhabit the area of the Corner Rising whereas the Azores area is inhabited mostly by small immature fish (foraging part of the distribution area). However, materials from a number of research-scouting expeditions suggest that both older and younger age groups of Alfonsino permanently inhabit the Corner Rising and the Azores area (Sherstyukov, Noskov, 1986; Vinnichenko et al., 1993; Vinnichenko, 1996). Besides, it should be taken into account that not a single report on mature Alfonsino migrations in the open ocean has been available (Kotlyar, 1996).

Biological information

The available Corner Rise Alfonsino biological information was presented in 1998 by Vinnichenko based on the USSR 1976-1996 survey/fishery information. Among the results presented are the following:

> The growth rate during the first year of life was found to be relatively high, with the mean length at-age of 1, 2, and 3 year olds being 8, 15, and 22 cm (to the fork), respectively. Sexual maturation was found to begin in the second year of life at a mean length of 18 cm, and by age 5–6 years all specimens had become mature at 25–30 cm length (Pshenichny et al., 1986; Anon., 1993). Based on this information practically all fish caught in the commercial fishery since 2004 are mature individuals.
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> Information from different studies presented in FAO (2016) show some variability in the maximum age / length depending on the geographic region. The maximum estimated age for alfonsino (*B. splendens*) was 10 years (50 cm) in the Azores, 11 years (45 cm) in Madeira and 9 years (44 cm) in the Canaries. Apparent differences in the von Bertalanffy growth parameters between the Azores and the Canaries and between the Azores and Madeira were not statistically significant. Alfonsino female is greater than males on the Southwest Indian Ridge. Maximum age of males was estimated to be nine years (length 36.7 cm and 1 556 g) while for females it was 18 years (55 cm and 6 260 g). Examination of the catch taken by Japanese vessels fishing in the Atlantic showed the alfonsino to have an average maximum life span of 17 years.
>
> On the Corner Rise, Alfonsino were observed to spawn from May-June to August-September (Alekseeva, 1983). The main spawning period was observed in July–August in bottom layers of the water at temperatures of 7–12°C. Spawning of Alfonsino was intermittent, and observed as a number of batches at a time of around 10–12. The duration of individual spawning period was estimated to be about two months. Young Alfonsino of 25–98 mm length were caught by the fry-sampling trawl in the 0–600 m water layers in autumn, where water temperatures were 14–26°C (Sherstyukov and

Noskov, 1986). Alfonsino were reported to feed on different mesopelagic fish species (lanternfishes, hatchetfishes, viperfishes, etc.), squid and shrimp (Pshenichny et al., 1986; Anon., 1993).

Description of the Fisheries

The splendid alfonsino is an aggregating moderately productive bathypelagic deep-sea fish that can be caught using either a bottom trawl or a mid-water trawl. The tendency of increasing in fish size with an increase in towing depth was registered by different researchers (Pshenichny et al., 1986; da Silva et al., 1996; Vinnichenko, 1997).

Based on the information presented by Vinnichenko (2015) and FAO (2016), the development of the Corner Rise fishery was initiated in 1976, when, according to the unofficial data, Russian vessels caught over 10,000 t, mainly splendid alfonsino. Cardinal-fish (*Epigonus telescopus*), black scabbard fish (*Aphanopus carbo*) and oilfish (*Ruvettus pretiosus*) were also of commercial importance. In the following year, there were no stable fish concentrations in the area, and the catch reduced to 800 t. During the subsequent fifteen years, the seamounts were periodically controlled by EVs and RVs, which caught more than 2,000 t in total. Commercial trawlers operated there only in 1987, when their total catch together with one EV was more than 2,800 t. The fishery was resumed after a seven-year break, in the mid of the 1990s, and it was carried out with varying intensity till the end of the last century with the annual catch of 600-4,700 t. Since 2001 there has been no Russian fishery for alfonsino on the Corner Rise and Russian research vessels found no commercial aggregations in the area from 2003 to 2004.

There is no statistics on Russian fishery on separate seamounts, but, in accordance with the approximate estimation, the "Perspektivnaya" bank (known also as "Kükenthal") was considered to be the most important ground where 50-70% of the total catch was taken. Also, the fishery was carried out on the "Vybornaya" ("C-3") and "Rezervnaya" ("Milne Edwards") banks, where the catches were 15-25% of the total yield each.

Pelagic trawls were used by Russian vessels as the basic gear with catching mainly splendid alfonsino (95-100%). In some cases, black scabbard fish (*Aphanopus carbo)* made up the bulk of the catches. The bottom trawl was only applied on the "Perspektivnaya" bank in 1977, at that area, besides alfonsino, wreckfish (*Polyprium ameri*canus), black scabbardfish, cardinalfish (*Epigonus telescopes)* were significant part of catches.

In 2004, one polyvalent Spanish trawler carried out an experimental survey in NAFO Regulatory Area Divisions 6EFGH and 4XWVs (P. Duran Muñoz et al., 2005). In July 2012, the Spanish trawl vessel Esperanza Menduiña carried out an experimental fishery in NAFO Regulatory Area Divisions 6G with two different trawl gears: Pedreira (Bottom Trawl) and Gloria (Pelagic Trawl). Results of this experimental fishery were present to the NAFO Secretariat. The aim of the experimental fishery was to explore the use of the bottom trawl gears in the area.

Base on the information collected in the 2004 experimental survey, a directed commercial fishery had been conducted since 2005 by Spanish vessels. Since 2006 virtually all the effort has been made in the Kükenthal seamount with pelagic trawl gear. Figure 2 shows the Spanish commercial hauls positions from 2005 until 2017 and Figure 3 shows the pelagic gear design used in this fishery since 2006 and.

Commercial fishery data

Figure 4 shows the commercial Alfonsino catches since 1976 in NAFO Div. 6G and Table 1 present the catches as well as the effort (days and fishing hours). Catches have generally been low, less than one thousand tons, except for 1976, 1987, 1995 and 2005 where catches were: 10 200, 2 400, 3 500 and 1 187 t respectively. In this century, annual catches for this fishery ranged from 52 to 1187 t and the annual effort ranged from 16 to 167 fishing hours.

Information on historical length composition was derived from sampling of USSR (1995) presented by V. I. Vinnichenko in 1997 and EU-Spanish commercial catches (2007, 2009, 2012, 2016 and 2017). The length distribution samples were measured to the total length except those of the 1995 and 2007, which were measured to the fork. During the commercial fishery of 2017 and 2018, samplings were carried out to estimate the relationship between the fork and total length. Table 2 shows the different values estimated for the relationship between the fork and total length in cm for different group of data. It can be observed that the parameter values differences between the data groups (year or sex) are very low. It was decided to use in the 2007 length distribution transformation to the total length the parameters values estimated with the 2017-2018 all data (Figure 5). Table 3 present the total catches length distributions since 2004 and Figure 6 shows the length distribution in abundance percentage by year for the same period. It can be observed that these length distributions are quite similar for all years. Catches in all years are in the 30-50 cm range with a mode around 40 cm. These distributions are very similar for the commercial catches (2007, 2009, 2012, 2016 and 2017) and for experimental fisheries (2004-2012). These length distributions are very similar to the length distributions presented by V. I. Vinnichenko in 1997.

Commercial CPUEs

As a consequence of the alfonsino fishery characteristics, the species' association with seamounts and their aggregation behavior, the utility of the commercial CPUE series as an indicator of the stock status is considered to be questionable.

Depending on the data, there are different series of commercial CPUEs that show slight different trends. Figure 7 shows the LN(CPUE) obtained with the information of the NAFO observers and Scientific Observers. The indices based on the NAFO observers data shows a clear decreasing trend since the restart of the fishery in 2005 while the Scientific Observers CPUE information shows a more stable situation in last years.

Survey data

No updated survey information is available. The only information available is the retrospective data from Russian research, exploratory and fishing cruises (Table 4) presented by Vinnichenko (2015). Based on this information, the greatest biomass of mature alfonsino (distribution depths of 400-950 m) was registered on the "Perspektivnaya" seamount. On the "Vybornaya" and "Rezervnaya" seamounts, on the whole, the aggregation biomasses were much lower.

Estimates of Natural Mortality (M)

Some authors consider that mortality rates cannot be estimated from age–frequency data due to migration occurred between different seamounts (FAO, 2016). Gili et al. (2002) estimated natural mortality (M) for Alfonsino in Chile using five empirical methods: those of Rikhter and Efanov, Alagaraja, Alverson and Carney, Roff and Taylor (Table 5).

Ageing studies of alfonsino from various locations in the North and South Pacific Ocean have indicated that the maximum age for this species is probably about 20 years. The oldest alfonsino aged from New Zealand waters was 18 years. Using this maximum age in the Hoenig's (1983) equation gives an estimate of M of 0.26; using the maximum age = 20 gives an M of 0.23. None of the ageing studies has examined unexploited populations, so there is a possibility that the true A is slightly more than 20 years. Massey and Horn (1990) assume that M is in the range 0.20 to 0.26 for the Alfonsino in New Zealand.

Assessment

There is no explicit estimate of alfonsino stock size for the North Atlantic high seas or Corner Rise seamounts. Nonetheless, retrospective data from Russian research, exploratory and fishing cruises suggest comparatively small stock sizes on the seamounts in this area. By the analysis of the data collected in 1980-1995, in the open North Atlantic, the alfonsino biomass was about 50,000-80,000 t, including the one on the Corner Rise being

36,000-40,000 t. Applying the catchability coefficient of 1.0 would be obviously more reasonable, since it is more corresponding to peculiarities of the fish behavior and the precautionary approach. In this case, the calculated alfonsino biomass values obtained on the Corner Rise in 1980-1995 decrease to 11,000-12,000 t. It should be taken into consideration that the data with a time limitation of mainly 20-30 years were used for the calculations mentioned above. Therefore, most of them have obsolete, need correcting, and at present they can only serve as a landmark to determine a possible catch.

If we take into account the special distribution of the populations associated with seamounts and the biology of this species, a separate assessment should be made for each seamount. The Russian catches of the past century are not disaggregated by seamounts. The great majority of the commercial catches since 2004 have been made with pelagic gears in the Kükenthal seamount (known also as"Perspektivnaya"). Bearing in mind that the recovery of the stocks of this species could take 4 or 5 years (Vinnichenko, 1995 and FAO, 2016) and that in that seamount there were no catches in the 5 years prior to 2004, it was tried to apply different estimated MSY methods to the Kükenthal seamount catch information since 2004.

Not analytical or survey based assessment were possible at the moment due to the lack of updated data. The most reliable present data available are the catch time series.

Depletion-Adjusted Average Catch (DCAC)

Berkson *et al.* (2011) and ICES (2012) recommended that one of the possible methods to give advice for stocks with reliable catch data is Depletion-Adjusted Average Catch (DCAC) method (MacCall, 2009). DCAC's main limitation is that it is only appropriate for stocks with moderate to low natural mortality rates (≤ 0.20 yr-1).

This method try to estimate a level of MSY based on the relationship between M and Fmsy and Bmsy with B_{virgin} . The method was applied for the period 2004-2017 (14 years data) for different levels of M (between 0.1 and 0.2) based on the available information. The other input data was maintained constant and with the following values:

Sum of Catch: Is the sum of the total catch for the period 2004-2017. The value is 3305 tons. It was assumed that the catches are quite well known (CV = 0.05) because this catches come from only one vessel and the quality of the catch information are quite good.

Natural Mortality: Based in the information presented by Gili et al. (2002) (Table 5) and Massey and Horn (1990), they were run 5 different M scenarios (0.1; 0.13; 0.15; 0.18 and 0.2) to cover the M range estimated by these authors. The standard deviation of ln(M) has a default value of 0.5, based on the residuals in Hoenig's (1983) regression of ln(M) on log maximum observed age as it was suggested by the DCAD manual.

Ratio Fmsy to M: The Fmsy = M assumption also requires revision, as fishery experience has shown it tends to be too high, and should be replaced by a Fmsy = c*M assumption (Walters and Martell, 2004). Walters and Martell suggest that coefficient c is commonly around 0.8, but may be 0.6 or less for vulnerable stocks. In our case it was decided to use a value of 0.6 because this stock are consider a vulnerable stock. It was assumed a lognormal distribution with a 0.2 standard deviation.

Depletion Delta: This is a measure of the amount of decline in abundance that occurred between the first and last year of the catch series, expressed as a fraction of unfished biomass, i.e., (Blast-Bfirst)/Bunfished. Importantly, Depletion Delta is NOT the final level of depletion, but rather is the change in depletion. In this case, it was considered that a value of 0.5 could reflect the situation of this stock. In the whole period the level of fishing was quite low and we could assume that the 2017 biomass is around the 50% of the 2004 Biomass. Delta was treated as a normal distribution with a 0.1 standard deviation.

Ratio Bmsy to B_{virgin}: There is no well-established value for fishes, although 0.4 is often used for roundfish and 0.25 is used for flatfish. In our case 0.4 was used. A nominal uncertainty in this parameter advice for the author might correspond to St Dev of 0.1.

Table 6 present the values of all input parameters as well as the estimated 10%, 50% and 90% MSY percentiles. The results show a median estimated MSY between 85 and 125 tons depending in the M assumed. The values of M estimated with the methods presented above seem to be closer to values of 0.2 than of 0.1 which is the lower limit.

It also presents a DCAC results in which “depletation delta” has been varied. The values presented are for natural mortalities of 0.18. This value is the average obtained by Gili et al (2002) applying 5 different methods. The depletation delta values presented were chose taken in account the decrease in the CPUE commercial between 2006-2017. The base for 0.6 was base in the information of IEO Observers CPUE and the 0.8 was based on the NAFO Observers. Table 7 present the values of all input parameters as well as the estimated 10%, 50% and 90% MSY percentiles. The results show a median estimated MSY between 91 and 120 tons depending in the depletation delta value assumed.

Only Reliable Catch Stocks (ORCS) Working Group’s Approach

Taking in account the alfonsino spatial distribution associated with seamounts, their life history and their aggregation behavior and due to the limited availability of data it could be advised a scalar approaches to advice the future catch levels by using simple scalar multipliers applied to current or historical catch patterns. Similar approach was following by ICES (2014) and SEAFO (2014) to give the alfonsino advice. The primary reference for this approach is Restrepo et al. (1998) who formalized the concept in their Technical Guidance document for the 1998 National Standard 1.

Berkson *et al.* (2011) proposed a method based on classified the stocks into three broad exploitation categories: lightly exploited; 2) moderately exploited; and 3) heavily exploited for which different scalar (or multiplier) that is based on the stock status category (described above), and a catch statistic derived from a time series of historical catches. Ideally, historical catches should represent a period with a stable harvest rate. The concept of 'pretty good' yield (PGY) provides a theoretical basis for broadly classifying stocks into three broad exploitation categories. Equilibrium stock abundance in a range from B19% to B65% of the unfished biomass provides at least 80% of the MSY yield on a sustainable basis. Stocks above this range would be considered lightly exploited, while stocks below this range would be considered heavily exploited (i.e., overfished). When catch trends are stable and the stock is considered to be moderately exploited, setting the overfishing limit (OFL) to current catch levels is an appropriate action. For these stocks, a multiplier of 1.0 is recommended for the OFL. For stocks that are considered to be heavily exploited suggest that a multiplier of 0.5 is appropriate for the OFL. Results indicate that a multiplier of 2.0 is appropriate for the OFL when the stock is lightly exploited. The main limitation with this approach is that a number of critical decisions are required before it can be made operational. Some would also view this as an advantage, as it provides flexibility in its establishment.

We applied this method to estimated overfishing limit (OFL) in the case of the Kükenthal Alfonsino fishery. This approach needs to uses a recent level of catches and it was suggested to explore different recent periods to estimate the mean catches. In the alfonsino case we think that in addition to estimating the average catch it would also be interesting to estimate the mean of the effort due to the aggregation behavior of this species. It was chosen a value of 0.75 as catch multiplier. This is a compromise value between the proposed values of 0.5 for the heavy exploited stocks and the values of 1.0 of the moderately exploited stocks.

Table 8 present the mean catches and effort for the different periods as well as the 0.75 catch levels, possible OFL, for these periods. The OFL estimated deepening in the chosen period to estimate the catch levels range from 79 with the shorter period to 127 tons with the longest period.

Replacement Yield

Replacement Yield Computation method was applied to the Kükenthal seamount alfonsino fishery catch information since 2005 and the NAFO Observers CPUE.

Replacement Yield Computation method formulation:

Biomass dynamics assumed $B_{y+1} = B_y + RY - C_y$
RY=average surplus production

$B_{n+1} = B_1 + nRY - \sum_{y=1}^{n} C_y$ $\quad B_{n+1} = B_1 + nRY - n\bar{C}$ $\quad$ Where $\bar{C} = \frac{1}{n}\sum_{y=1}^{n} C_y$

$RY = \bar{C} + \frac{B_{n+1} - B_1}{n}$

$RY = \bar{C} + \overline{\Delta B}$ Where $\overline{AB}$= Average annual biomass change

$I = qB$ Where I= Index Abundance and q=catchability

$RY = \bar{C} + \bar{B} * \frac{\overline{\Delta B}}{\bar{B}}$ $\quad RY = \bar{C} + \bar{B} * \frac{q * \overline{\Delta I}}{q * I}$

$RY = \bar{C} + \bar{B} * r$

Where r is the relative change of the index per year and it is the estimate of the slope in the regression NAFO Observers LN CPUE again the time year. Figure 8 shows this regression and the estimated regression parameters values for the NAFO Observers LN CPUE from 2005 till 2017.

Table 9 presents the results of the Replacement Yield. It can be observed that the yields for all levels of the mean biomass are negatives. This means that the actual yields seems to be unsustainable.

Conclusion

Due to the characteristics of the fishery, the available data and the biology of the species, this document only analyzes the situation of the alfonsino on the Kükenthal seamount (known also as“Perspektivnaya”) and recommend that the exploitation of new seamounts should not be allowed to prevent the exploitation of populations that have not yet been fished.

With the available data an attempt has been made to estimate a sustainable level of catches in Kükenthal seamount with different methods (Depletion-Adjusted Average Catch, Only Reliable Catch Stocks and Replacement Yield). The results show different levels of MSY depending on the methods. The methods based on catch information are more optimistic than those based on the commercial CPUEs. Due to these different results, the SC considered the results as uncertain.

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Table 1. Commercial alfonsino catches (tons) in NAFO Div. 6G by year as well as the effort, CPUE and number of vessels.

Year	Catch (t)	Effort (days)	Effort hours	CPUE (Kg/hour)	Vessels
1976	10200				17
1977	800				8
1978	130				1
1979	530				2
1980	200				1
1981	390				2
1982	210				2
1983	160				3
1984	240				1
1985	10				1
1986	110				1
1987	2300				4
1994	400				1
1995	3500				5
1996	710				1
1997	780				1
1998					
1999	628				1
2004	415	50	104	3990	1
2005	1187	29	162	7327	3
2006	130	6	44	2955	1
2007	52		16	3256	1
2008					
2009	479	28	167	2868	1
2010	52	4	66	788	1
2011	152	9	68	2235	1
2012	302	22	165	1830	1
2013	114	17	87	1310	1
2014	118	15	117	1009	2
2015	122	13	92	1326	2
2016	127	16	116	1095	1
2017	51	12	68	750	1

Table 2. Alfonsino relationship parameter value (*b*), number of fish measured (N), and the coefficient of determination (R^2) between the fork length (cm) and total length (cm) estimated with the data collected during the 2017 and 2018 Spanish fishery in Div. 6G.

	LF=*b**LT		
Data	N	*b*	R^2
2017-2018	688	0.834	0.944
2017	460	0.834	0.936
2018	228	0.836	0.949
Males 2017-2018	419	0.834	0.944
Females 2017-2018	260	0.835	0.924

Table 3. Alfonsino NAFO Div. 6G catches length distributions for the commercial fishery and for the experimental fisheries. The 2004, 2009 and 2012 length distribution was measured to the total length while those of the 2007 were measured to the fork.

Beryx splendens	2004 (Exp. Fhisery)			2007			2009			2012			2012 (Exp. Fhisery)			2016			2017		
Length (cm)	**Males**	**Females**	**Total**	**Males**	**Females**	**Total**	**Males**	**Females**	**Total**	**Males**	**Females**	**Total**	**Males**	**Females**	**Total**	**Males**	**Females**	**Total**	**Males**	**Females**	**Total**
19																			0	0	53
20																			0	0	0
21																			0	0	0
22																			0	0	0
23																			0	0	0
24																			0	0	0
25			0						0			0						0	0	0	0
26			0				88	88	176			0						0	0	0	0
27	0	405	405				0	88	88			0				11	0	11	0	0	0
28	0	0	0				0	318	318			0				11	0	11	0	0	0
29	0	0	0				0	90	90	202	0	202				0	0	0	0	0	0
30	0	0	0				117	0	117	0	0	0				83	58	141	33	0	33
31	327	0	327				119	74	193	0	0	0				0	0	0	0	0	0
32	735	0	735	181	151	332	164	991	1155	825	311	1136	23	0	23	590	179	769	101	367	468
33	3017	1136	4153	237	207	444	2075	207	2282	1939	642	2581	108	39	147	778	784	1562	1280	132	1411
34	4670	732	5402	191	228	419	5044	2346	7390	1446	1026	2472	117	104	221	1305	531	1835	722	442	1164
35	8484	3113	11597	241	390	631	10264	5413	15677	2239	1773	4012	288	120	408	3186	926	4112	2364	674	3038
36	7607	2959	10566	912	290	1203	25939	8883	34822	10937	3574	14511	418	158	576	7177	3363	10540	2781	670	3452
37	15744	6320	22064	1219	246	1465	30731	13000	43731	11353	5217	16570	1102	176	1278	9909	5131	15040	3856	2575	6431
38	22613	10481	33094	932	412	1344	40401	19106	59507	20339	9001	29340	855	386	1241	11777	7367	19144	6040	2735	8775
39	30117	8473	38590	914	695	1609	33793	25555	59348	22327	11403	33730	1075	432	1507	13619	8845	22464	5158	3514	8672
40	38241	18477	56718	1095	1227	2322	34391	21893	56284	27636	18183	45819	987	715	1702	12277	9510	21788	4608	4044	8652
41	42073	22008	64081	588	1572	2160	39701	29763	69464	23517	18788	42305	1023	775	1798	11151	10520	21671	4199	3399	7598
42	42030	26942	68972	439	1207	1646	30295	28038	58333	21948	20195	42143	923	732	1655	6524	7266	13790	2729	2946	5675
43	31656	29833	61489	679	2201	2880	20869	29559	50428	14099	17228	31327	413	696	1109	4817	6016	10832	1580	2676	4256
44	24296	29871	54167	352	1120	1472	15819	21958	37777	8826	11685	20511	296	390	686	2796	4735	7531	1292	2140	3431
45	23185	25533	48718	219	821	1040	12693	18534	31227	3957	7221	11178	42	281	323	1402	2464	3866	926	1324	2250
46	17266	27245	44511	272	1304	1576	9971	13243	23214	1988	6716	8704	98	238	336	605	1479	2084	785	843	1628
47	9283	20675	29958	49	407	457	4862	6893	11755	2014	5628	7642	41	54	95	152	683	835	536	641	1177
48	8825	10244	19069	0	49	49	4059	6272	10331	515	2179	2694	0	41	41	188	519	707	328	400	728
49	674	6266	6940	0	154	154	1697	2976	4673	479	1973	2452	0	0	0	135	220	355	189	171	359
50	520	6074	6594	0	91	91	586	2727	3313	90	1277	1367	0	41	41	23	89	112	95	79	174
51	275	1036	1311	0	31	31	1631	824	2455	73	404	477				23	38	60	5	338	344
52	1083	1486	2569				31	476	507	0	0	0				0	59	59	0	401	401
53	0	656	656				0	816	816	0	0	0				0	84	84	0	168	168
54	0	195	195				0	88	88	0	342	342				0	13	13	15	15	30
55	113	212	325				0	0	0	0	168	168						0	0	0	0
56			0				0	991	991	0	0	0						0	0	0	0
57			0						0	0	0	0						0	0	0	0
58			0						0	0	0	0						0	0	33	33
59			0						0	0	95	95						0			0
60			0						0			0						0			0
Total	332834	260372	593206	8521	12803	21325	325340	261210	586550	176749	145029	321778	7809	5378	13187	88536	70879	159416	39621	30726	70400
Ind. Sampled			3262			147			3127			1602			491			4465			2264
Samples			24			4			31			17			6			29			16
Catch (tons)			414.8			18			474			297.6			10.94			127			55
SOP			0.73			0.99			0.93			1.07			1.01			1.11			1.06

Table 4. Biomass of splendid alfonsino pelagic concentrations on the Corner Rise seamounts by the research data at Russian vessels using a catchability coefficient of 1.0.

Seamount	Period		Vessel	Biomass, 000, t
	Year	Month		
"Perspektivnaya"	1980	September	EV "Pavel Kaikov"	6,6 (22,0)
	1981	March	EV "Kapitan Demidov"	6,5
	1987	May	RV "Kapitan Shaitanov"	0,2
	2001	January	RV "Atlantida"	no concentrations
	2009	July	RV "Atlantida"	1,9
	2009	December	RV "Atlantida"	no concentrations
"Vybornaya"	1978	July	RV "Evrika"	1,0
	1981	March	EV "Kapitan Demidov"	5,7
	1984	September	EV «Nikolay Kuropatkin »	4,1 (13,8)
	1987	May	RV "Kapitan Shaitanov"	0,13
	1995	June	FV "Petr Petrov"	1,7 (5,5)
	2001	January	RV "Atlantida"	no concentrations
"Rezervnaya"	1981	March	EV "Kapitan Demidov"	0,7
	1985	May	EV "Menzelinsk"	4,4 (14,6)
	1987	May	RV "Kapitan Shaitanov"	0,12
	2001	January	RV "Atlantida"	no concentrations
	2009	December	RV "Atlantida"	no concentrations

Note: the biomass values calculated using the catchability coefficient of 0.3 are given in brackets

Table 5. Estimates of natural mortality for alfonsino in Chile using different methods.

	Rikhter & Evanov (1976)	**Alagaraja (1984)**	**Alverson & Carney (1975)**	**Roff (1988)**	**Taylor (1958)**
Males	0.148	0.178	0.323	0.199	0.116
	(0.136,0.160)	(0.158,0.198)	(0.286,0.359)	(0.212,0.187)	(0.103,0.129)
Females	0.136	0.158	0.287	0.211	0.103
	(0.129,0.143)	(0.147,0.170)	(0.265,0.307)	(0.203,0.218)	(0.096,0.111)
Both sexes	0.134 (0.128,0.141)	0.155 (0.145,0.165)	0.281 (0.263,0.299)	0.213 (0.207,0.220)	0.101 (0.095,0.108)
Model: $M =$	$\frac{1.521}{t_m^{0.720}} - 0.155$	$\frac{-\ln 0.01}{t_\infty}$	$\frac{3k}{e^{t_\infty 0.025k} - 1}$	$\frac{3ke^{-kt_p}}{1 - e^{-kt_p}}$	$t_0 - \frac{\ln(0.05)}{k}$

Note: 95% confidence intervals in parentheses
Source: Numerical estimates from Gili *et al.* (2002)

Table 6. DCAD for the Kükenthal seamount 2004-2017 catch data input parameter values and the estimated 10%, 50% and 90% MSY percentiles.

Input data				MSY (tons)		
Natural Mortality	Ratio Fmsy to M	Depletion Delta	Ratio Bmsy to B_{virgin}	10%	50%	90%
0.10	0.6	0.5	0.4	47.2	85.6	133.2
0.13	0.6	0.5	0.4	57.8	100.3	148.3
0.15	0.6	0.5	0.4	64.2	108.5	156.2
0.18	0.6	0.5	0.4	73.0	119.2	165.7
0.20	0.6	0.5	0.4	78.5	125.4	170.9

Table 7. DCAD for the Kükenthal seamount 2004-2017 catch data input parameter values and the estimated 10%, 50% and 90% MSY percentiles.

Input data				MSY (tons)		
Natural Mortality	Ratio Fmsy to M	Depletion Delta	Ratio Bmsy to B_{virgin}	10%	50%	90%
0,18	0,6	0,5	0,4	73	119,2	165,7
0,18	0,6	0,6	0,4	64,6	108,2	155,1
0.18	0,6	0,8	0,4	52,5	91,5	137,9

Table 8. Alfonsino NAFO Div. Kükenthal seamount mean catches and effort for three different periods.

Period	Mean Catches	75% Mean Catches	Mean Effort (days)	Mean Effort (Hours)
2014-2017	105	79	14	98
2013-2017	107	80	15	105
2011-2017	141	106	15	102
2009-2017	169	127	15	105

Table 9. Replacement Yield estimated with the 2005-2017alfonsino NAFO Div. 6G mean catches estimated for different levels of mean biomass (tons) in Kükenthal seamount.

Mean Biomass	NAFO r	Mean Catches (2005-2017)	Replacement Yield
9000	-0.1732	240.5	-1318
8000	-0.1732	240.5	-1145
7000	-0.1732	240.5	-972
6000	-0.1732	240.5	-799
5000	-0.1732	240.5	-626
4000	-0.1732	240.5	-452
3000	-0.1732	240.5	-279

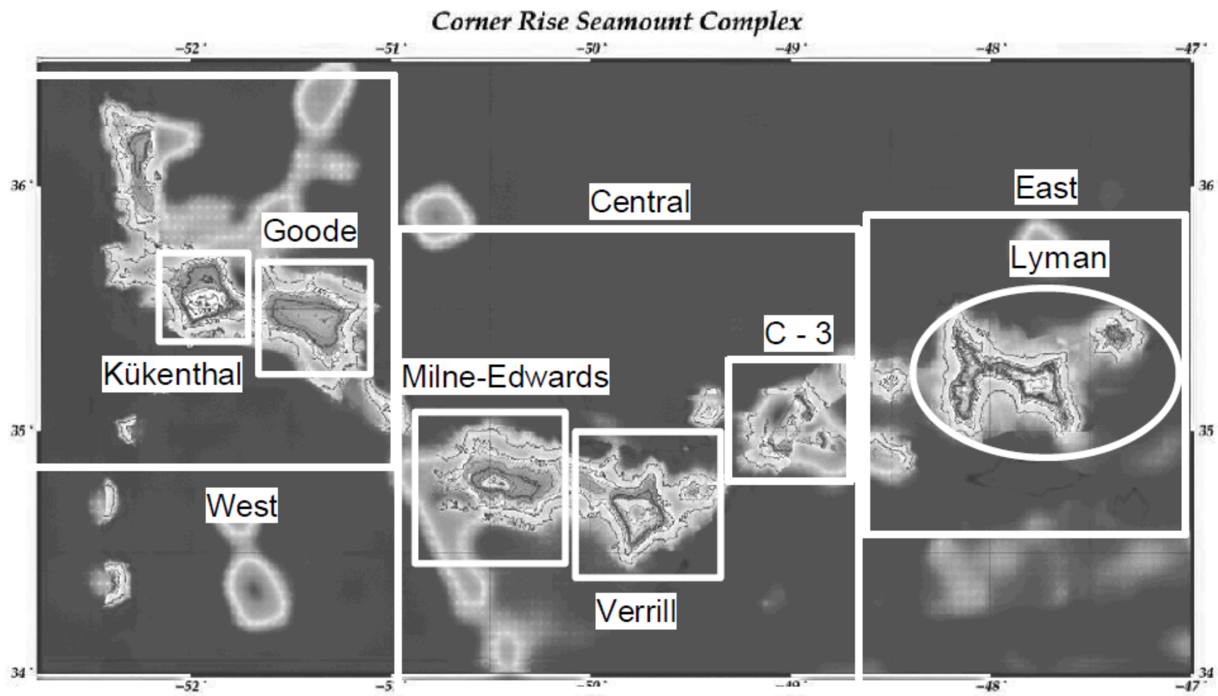

Fig. 1. Corner Rise Seamount Complex map with areas and peak names.

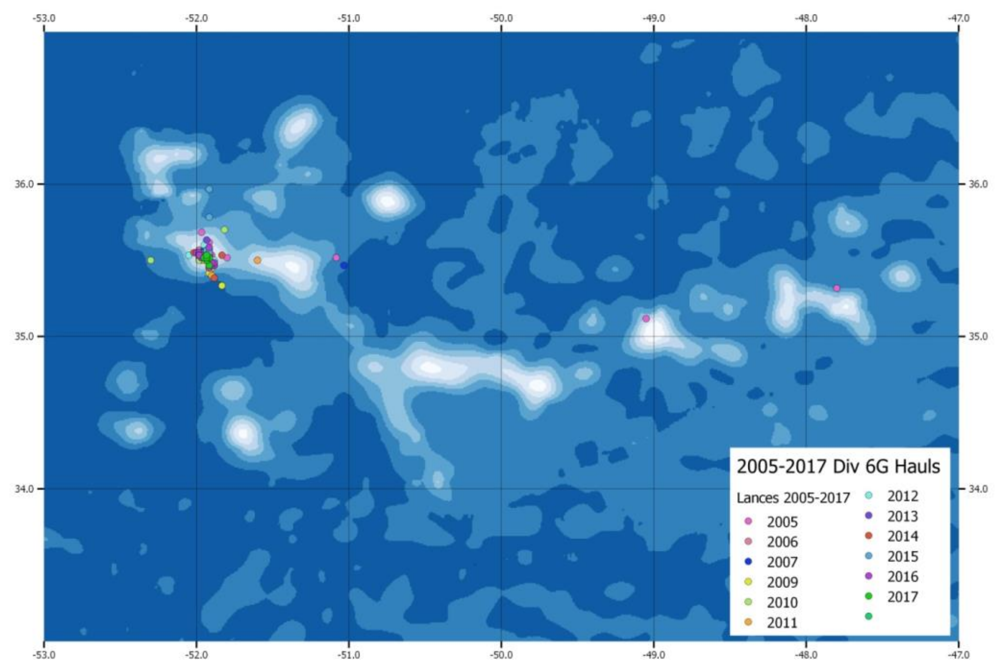

Fig. 2. Corner Rise Seamount Complex map with 2005-2017 hauls positions based on the NAFO Observers information.

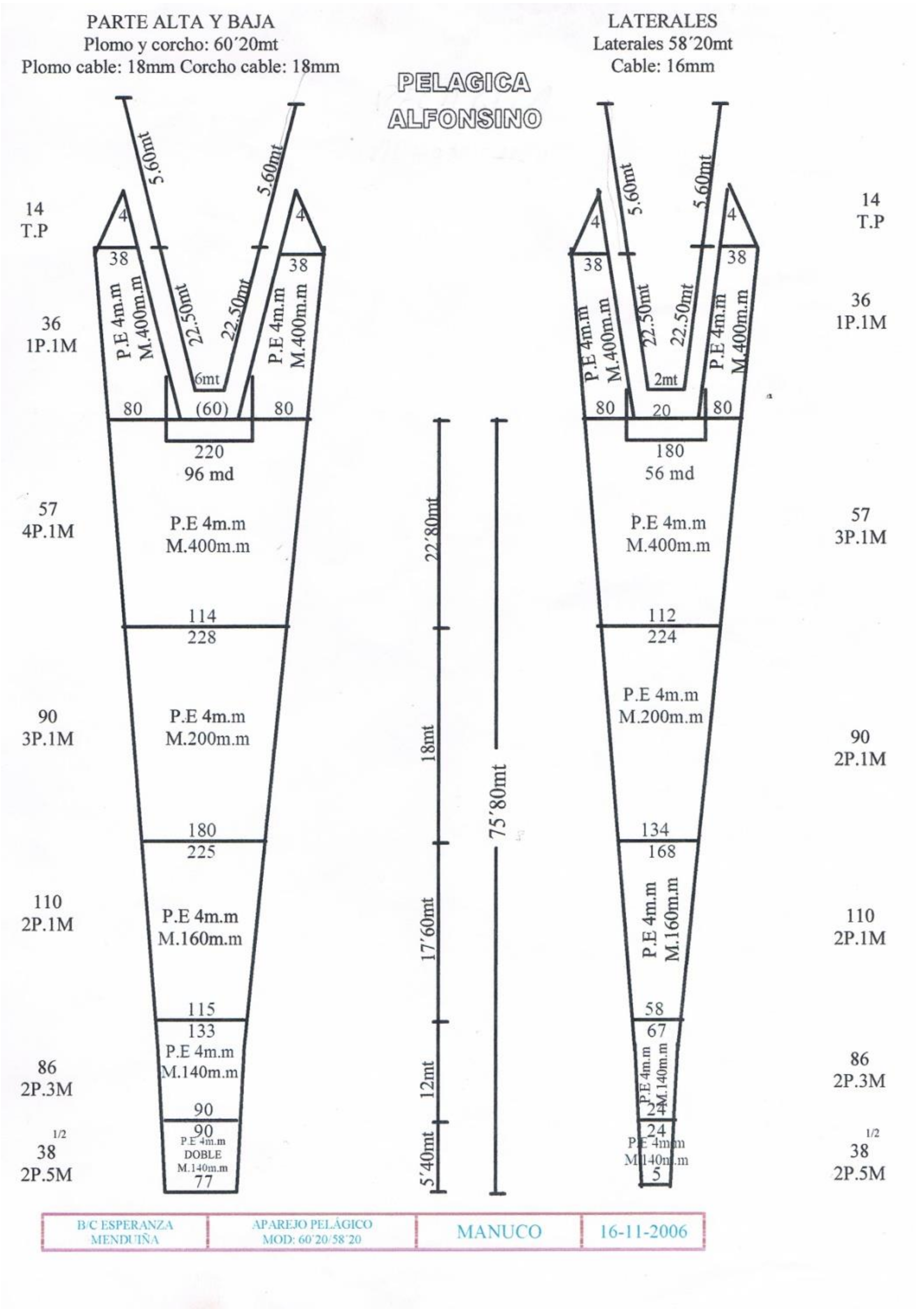

Fig.3. Pelagic trawl design used in the alfonsino Div. 6G fishery.

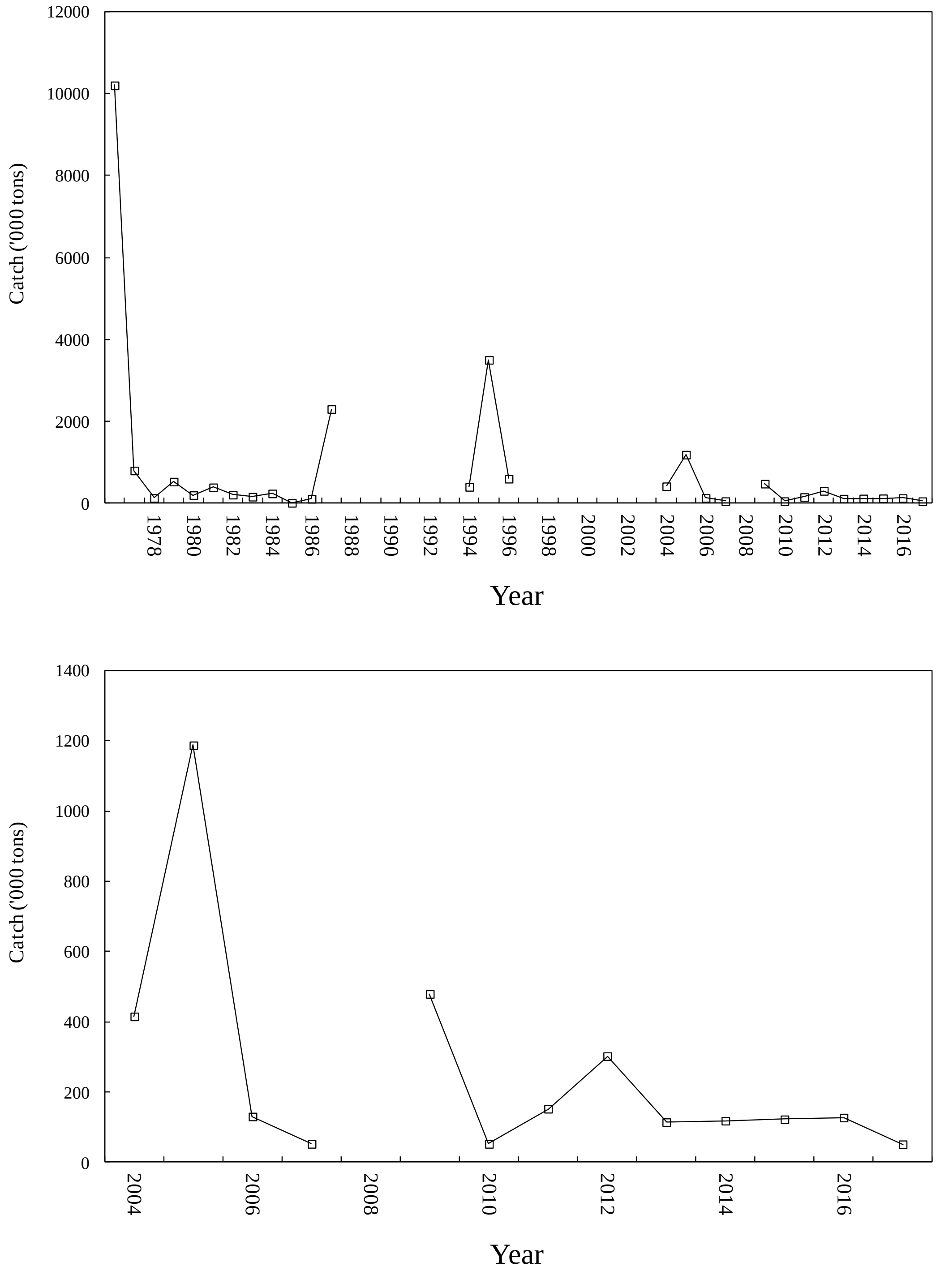

Fig. 4 Alfonsino (*Beryx splendens*) catches since 1976 in NAFO Div. 6G.

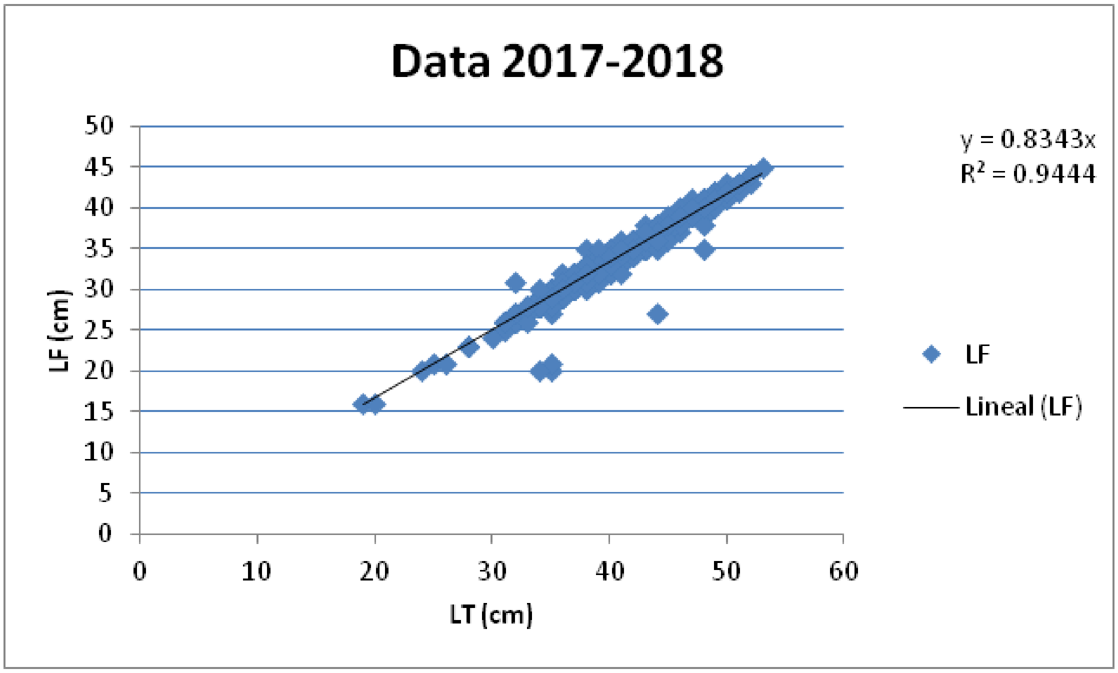

Fig. 5. Alfonsino relationship between the fork length(cm) and total length (cm) estimated with the data collected during the 2017 and 2018 spanish fishery in Div. 6G.

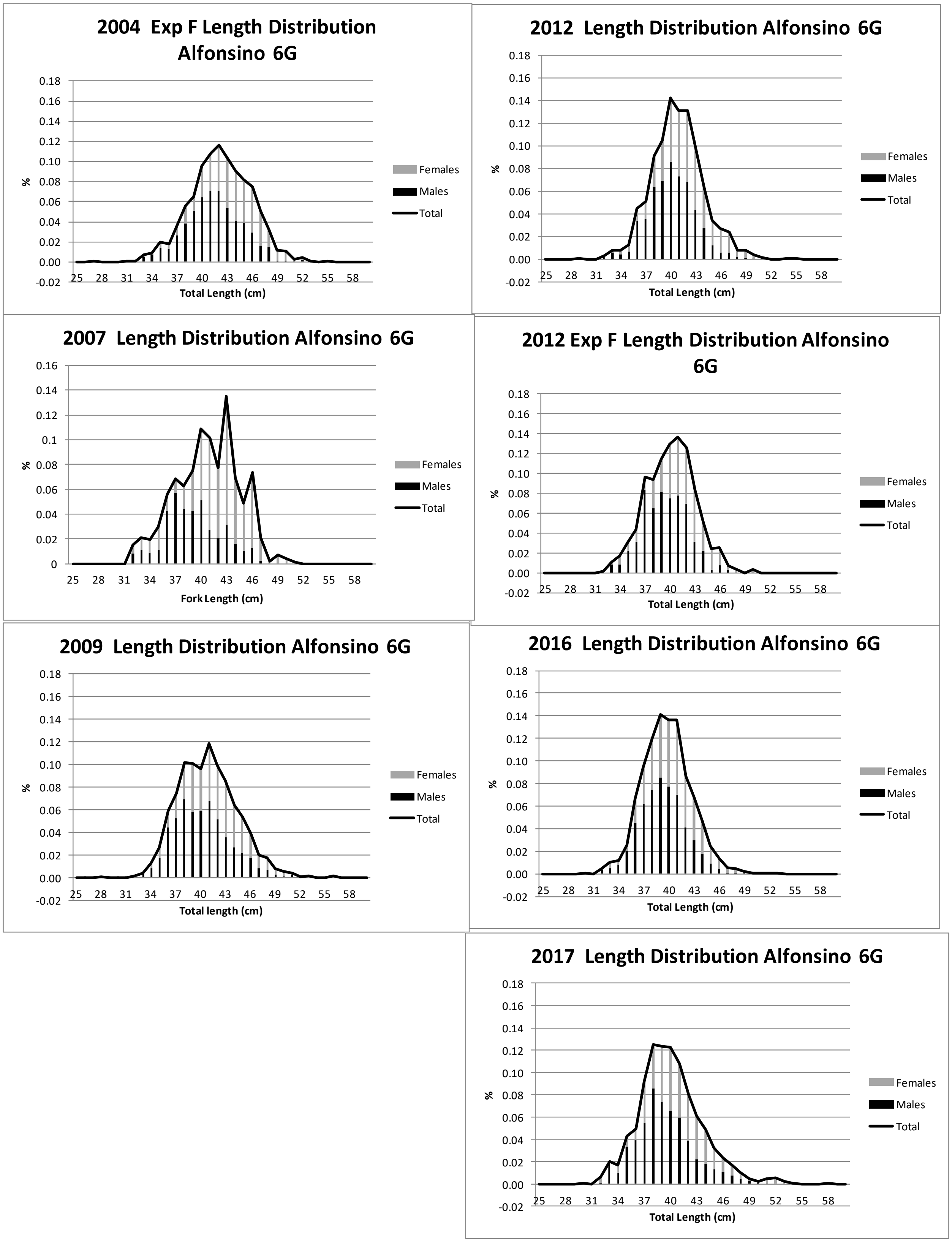

Fig. 6. Alfonsino NAFO Div. 6G commercial and exploratory fisheries length distributions since 2004.

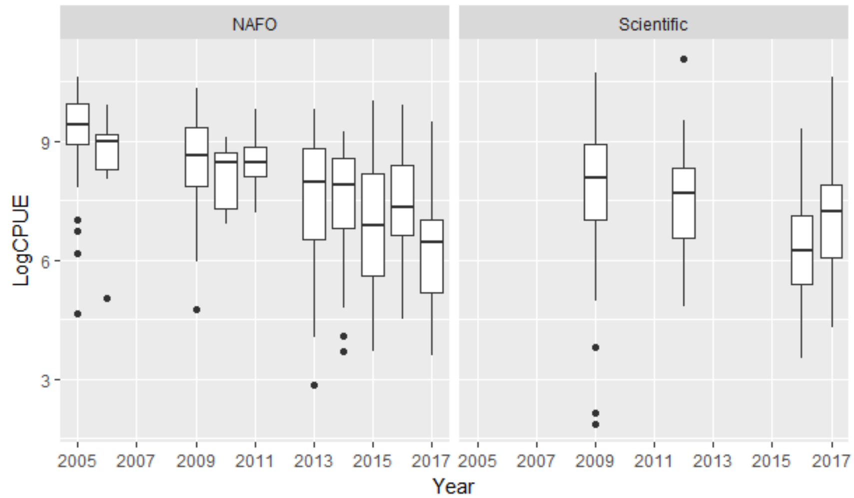

Fig. 7. Alfonsino LN CPUE (kg/hour fished) for the Kükenthal Peak (Div. 6G) midwater trawl fishery based on the NAFO Observers (left) and Scientific Observers data (right).

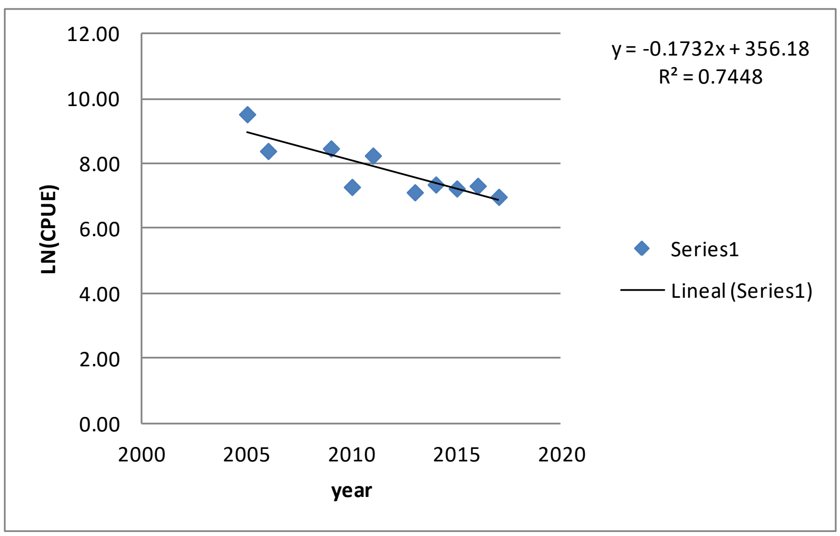

Fig. 8. Regression between the Alfonsino NAFO Observers LN CPUE (kg/hour fished) and the year for the Kükenthal Peak (Div. 6G) midwater trawl fisher with the relationship parameters values and the R square.