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The fishing strategy of foreign seiners in relation to spatial dynamics of the Sardine (Sardina pilchardus) in the North western African Atlantic region: Case of Spanish fleet fishing in the area between Cap boujdour and cap Blanc

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ABSTRACT: The Spanish purse seiners fishing in the area between Cape boujdour (26 ° N) and cape blanc (21 ° N) during the fishing agreement between Morocco and the European Union in 1995-1999, have realized in 1998 the largest catch of sardine (*Sardina pilchardus*) despite the very small number of ship represented by 2%. To understand the fishing strategy of the Spanish purse seiners in 1998, general linear model (GLM) was applied to the catch per unit of effort (CPUE) to analyze the purse seiner's activities in relationship with the distribution of sardine in space and time.
The result of GLM method analysis showed that the distribution of Spanish seiners was concentrated in the area between 24°N and 25°N and from the coastline to 50m of deep. Also the most important catch was realized in autumn. The same area and period that contains the high concentration of sardine (between26°N and 23°N).
This explains that Spanish seiners were able to exploit the different conditions favoring the realization of important catches for a specific period. These conditions are the best fishing season: Autumn, the best fishing area near the coast, the technical equipment (GRT) and latitudinal dynamics of the species between 25°N et 23°N.

KEYWORDS: fishing activity, catch, CPUE, sardine, GLM.

1 INTRODUCTION

The North western African Atlantic area has topographical and hydrological advantages which make it suitable to be among the richest regions in fisheries resources in the world. Indeed, it is characterized by a continental shelf which parts are very wide, especially between 26°N and 20°N. In addition, this area is favored to be among the areas where is manifested the phenomenon of upwelling, which promotes the durability of fisheries resources, especially pelagic fish, through enrichment of the water column in mineral materials [1],[2],[3],[4].

Small pelagic fish catches, mainly sardines, sardinellas, anchovies, mackerel, horse mackerel, are more than 2.4 million tons during the period 2008-2012 [5].It's the first fished species with about 35% of the total landing of small pelagics in the same period. The area between Cape Boujdour (26°N) and Cape Blanc (21°N) remains the main important zone of sardine in term of biomass with 80% of the total sardine biomass (around 4 millions) in the North West Africa, while the species represent 28% of term of catches. The annual landings of sardine vary under the influence of environmental fluctuation and fishing effort.

This species was exploited by the Moroccan national vessels and foreign vessels (Russian, European Union) operating under fisheries agreements since the 1980's.

Between 1980 and 2012, five fisheries agreements have been signed between the Government of Morocco and the European Union, authorizing the European vessels to fish in the zone economic exclusive (ZEE) of Morocco. The 1995-1999 agreement, recorded the largest catch of sardines, made by Spanish purse seiners although they account only 2% of all the European ships.

The objective of this work is to clarify the fishing effort characteristics of Spanish purse seiners between Cape Boujdour (26°N) and Cape Blanc (21°N) in the year 1998, when sardine catch was extreme by foreign fisheries. We hypothesized that the application of fishing strategies and tactics with specific gears, in relation to distribution of sardine, resulted in the extremely high catch. We examined the hypothesis based on a combination of the visual analysis and statistical analysis in the relationship among effort characteristics, catch per unit of effort (CPUE) and distribution of sardine.

2 Material And Methods

2.1 Study area

The study area is focused in the southern zone (zone C) between Cape Boujbor (26°N) and Cape Blanc (21° N) (Fig.1). This area belongs to the Moroccan Atlantic coastline that is generally subdivided into three main areas according to the main sardine stock locations: the northern stock, located between Tanger and Cape Cantin, the central stock, extending from Cape Cantin to Cape Boujdour; and the southern stock, from Cape Boujdour to Cape Blanc [6].

The exploitation of sardine in this area began in 1968 as a secondary jack mackerel, horse mackerel and sardines [7]. This stock has experienced rapid growth due to several mass reproductions in the early 70s [8] which resulted in a considerable increase in catches. From the 80s, this stock has been the subject of exploitation by foreign fleets in the bilateral framework agreements with two types of fleets: seiners (Moroccan and Spanish) and pelagic trawlers (Russian, Ukrainian and others).

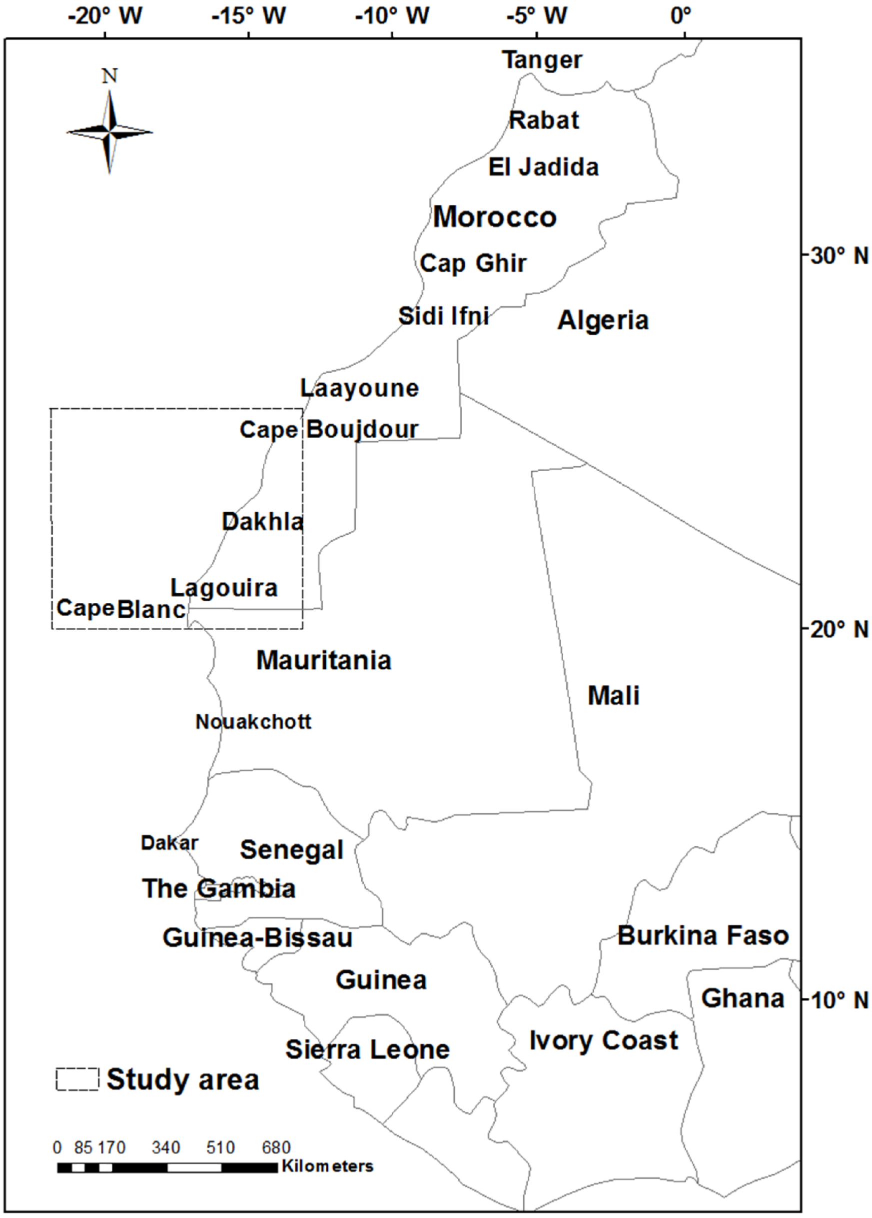

Fig.1 Study area located between Cape Boujdour and Cape Blanc

2.2 DATA COLLECTION

Two main types of data were collected, in aim to conduct our analysis (fig.2): commercial fisheries logbooks of Spanish purse seiner operating in the study area in 1998 and scientific accoustic surveys carried out in 1998, by Dr Fridjof Nansen vessel and Atlantida vessel in the Moroccan Atlantic coast.

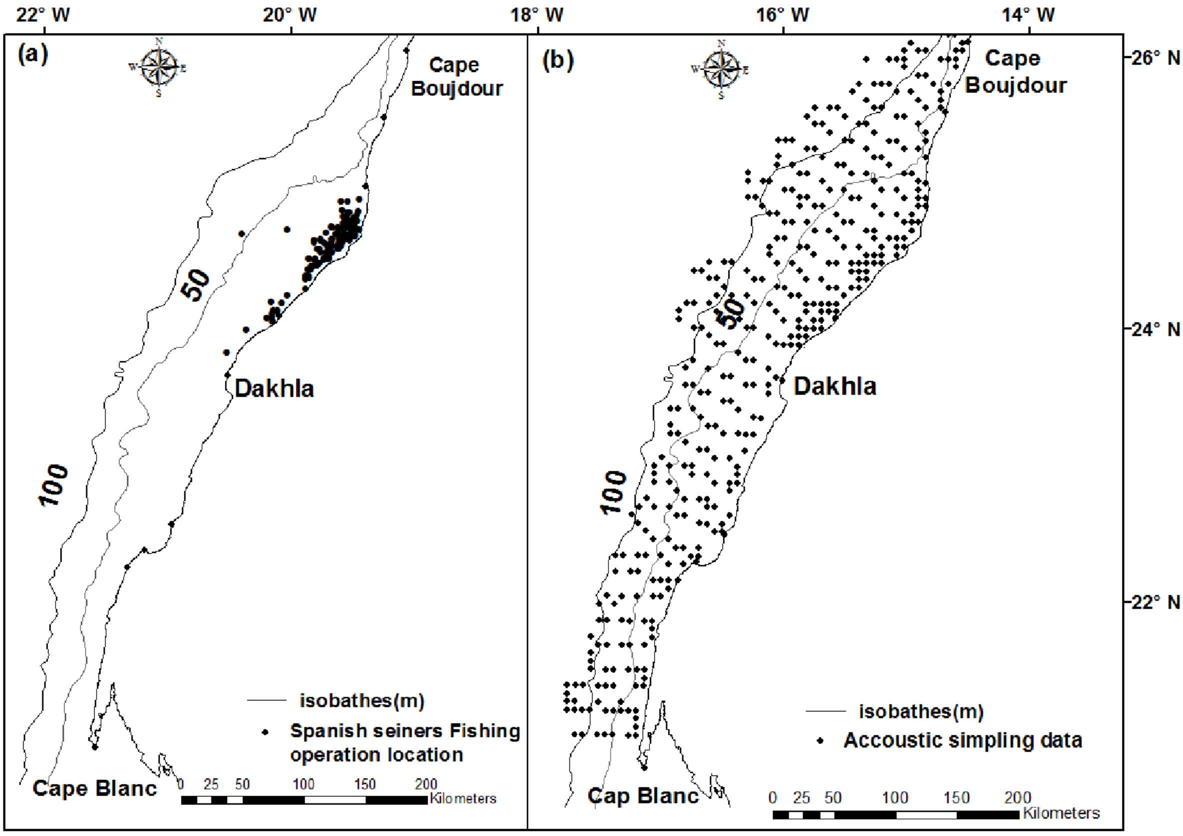

Fig. 2 Data used in this study, the map (a) represents the operation fishing of Spanish vessel, specially purse seiners of pelagic fish whiting the study area in 1998, the map (b) represents the schema of the acoustic surveys conducted by research vessel FRS'Dr Fridtjof Nansen and Atlántida vessel in 1998.

2.2.1 COMMERCIAL FISHERIES LOGBOOKS

The commercial logbook records were provided by the Moroccan ministry of fishery and agriculture. The used data represents 82% of Spanish purse seiner authorized to fish in the study area (The sampled vessels number was 9, from a total of 11). The database was structured in ACCESS Microsoft software, and included vessel characteristics information, fishing operation start and stops time, positions (latitude and longitude in degrees and minutes), in total, 203 fishing operation data records were used in this work.

Table. 1 Logbooks information of Spanish purse seiners

Data	Unit
Gear	(m)
Season	Autumn, Summer, Winter
Gross register tonnage of vessel	GRT
Lenght_Max of the vessel	(m)
Year of construction	date
System of conservation	Freezing, fresh, refrigeration
Maximal speed	node
Engine power	Cv
Number of crew	number
Depth	(m)
Time of fishing	(Min)
Zone of fishing	longitude and latitude
Target species(Sardine)	(t)

2.2.2 SCIENTIFIC SURVEYS

The Scientific surveys data were provided by the Fisheries Research Institute (INRH) for the months: July, November and December 1998.For this study, values of Sardine density were imported into ESRI ArcGIS 10.0 in points feature organized in parallel transects spaced 10 nautical miles (n.mi.), extended from about 10m to the more than 1000m and having a mean distance between two successive points of 5 n.mi.

2.3 ANALYSES

2.3.1 VISUAL ANALYSIS

For the visual analysis of each survey data, we created an interpolated raster surfaces using the Inverse Distance Weighted (IDW) function [9], all data processing including simulation and interpolations used UTM_ZONE_28 projection to minimize the spatial distortion of the map in the region that included the study area.

The produced maps will represent a comparison between the distribution of sardine and the fishing effort with a resolution of 5-km to visual interpolation of the indices on the map. The same best-fit models for each variable in the statistical analyses were used. The density sardine values were plotted over the sardine catch, surface of seine and GRT on the GIS platform. ArcGIS ver. 10 (ESRI) was used for all data processing and analyses addressing spatial trends and geostatics.

2.3.2 STATISTICAL EVALUATION OF RELATIONSHIP BETWEEN CPUE AND DISTRIBUTION OF SARDINE

The nominal catch per unit of effort (CPUEnm) is used as a variable to be explained in a Generalized linear models (GLMs). The $CPUE_{nm}$ is obtained by dividing the sardine catch (in tonnes) per duration of fishing operation (fishing time in minutes) (eq.1):

$$CPUE_{nm} = C/E \quad (eq.1)$$

C: is the catch made during a fishing operation.

E: the duration of fishing operation corresponding.

Generalized linear models (GLM), formally introduced by Nelder and Wedderburn (1972) and advanced by McCullough and Nelder (1989), are commonly used to standardize the catch and effort data [10], In our study, in aim to evaluate relationship between CPUE and distribution of sardine, and having regard that 13% of the nominal catch rates value is 0, which can sometimes contains information, we used a Delta-GLM composed of two sub-models types: model 1,(presence-absence) where is the predicted probability of presence; **and** model 2,(non zero observations) which is predicted abundance if present.

Full models were compared based on the the Akaike information criteria [11], The variables used in these two models are: the date (month), the depth of the fishing, the distance from the coast, and the characteristics of vessels. A stepwise regression procedure was used to determine factors that significantly explained the observed variability in each model. Model evaluation and diagnosis was carried out through residual analysis [12], Analysis and model formulations for the delta model were done using the R statistical software packag

3 RESULTS

3.1 VISUALIZATION OF SARDINE DENSITY, SARDINE CATCH, AND EFFORT FISHING DISTRIBUTION

The map obtains for the density distribution in 1998, shows that the most important densities of sardine is located inside the territorial waters, under the 50 meter of isobaths, between the latitude 26°N and 22°N. In the same area, where the density of sardine is height, the Spanish catch was important (fig.3), especially between the latitude 26°N and 24°N.

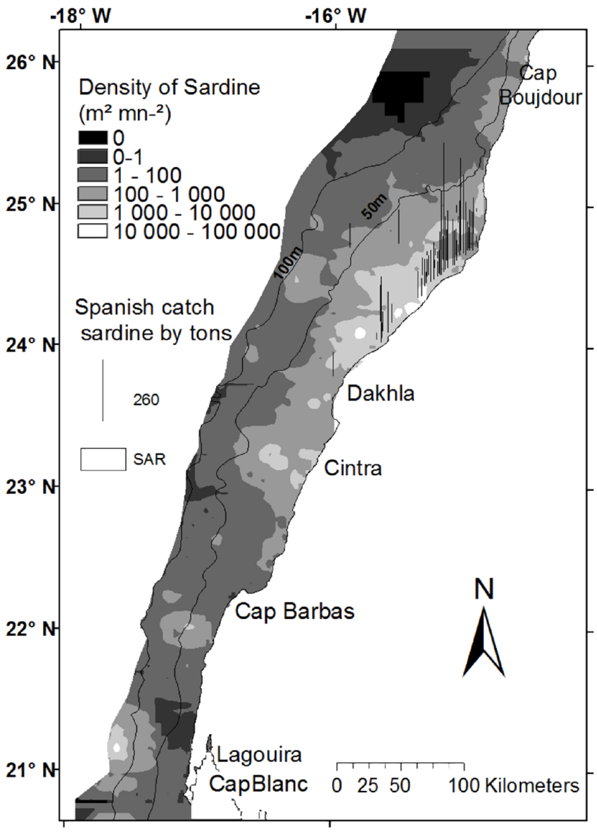

Fig. 3. Sardine density spatial distribution in comparison with the Spanish catch sardine in 1998.

The distribution of sardine density and catch was varying in space during the seasons. The density map of sardine in summer (fig. 4) showed an important concentration of sardine located between the latitude 26°N and 24 ° N, while high capture was realized exactly between the latitude 25°N and latitude 24,5°N.

In the autumn season, the concentration of sardine was more showed between the latitude 25°N and 23°N (fig. 5), while the high capture was showed in the zone between 25°N and 24°N

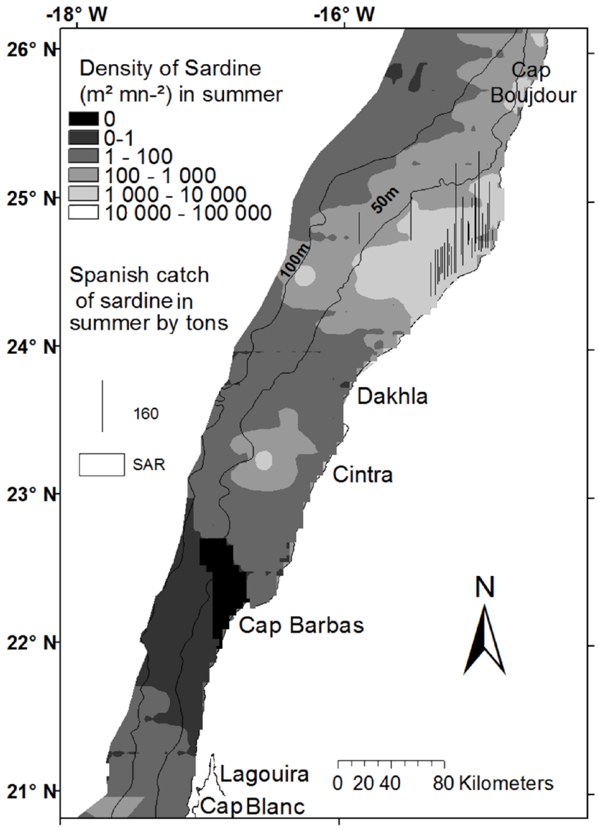

Fig.4 Sardine density spatial distribution in comparison with Spanish sardine catch in summer 1998.

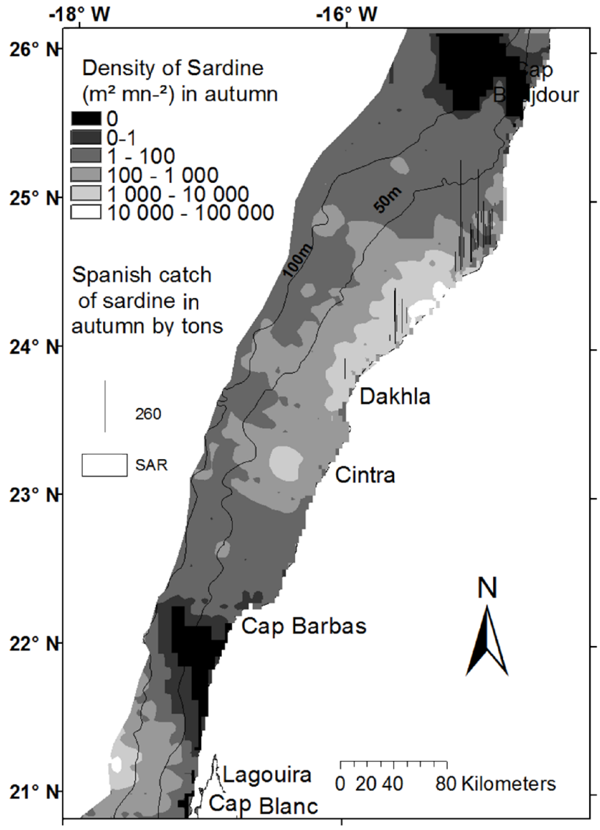

Fig.5 Sardine density spatial distribution in comparison with Spanish sardine catch in autumn 1998.

The fishing efforts t deployed in the operation of fish were the surface of seine and GRT of vessels. From the analysis of the distribution of effort in relation with the latitude and distance from the coast (fig. 7,8), results showed that big value of GRT, and large surface of seine were used, especially in a distance from the coast less that 20 km, and between the latitude 23,8°N and 25°N.

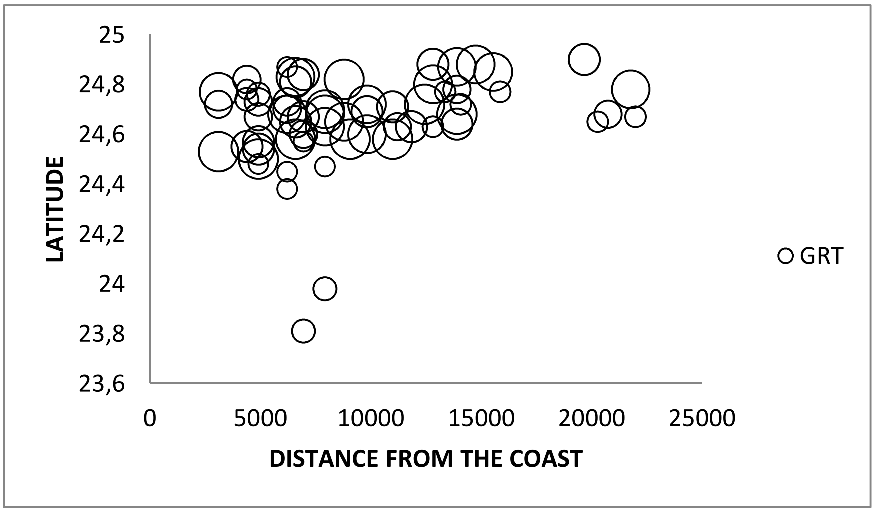

Fig. 6 the distribution of GRT effort in relation to the latitude and distance from the coast.

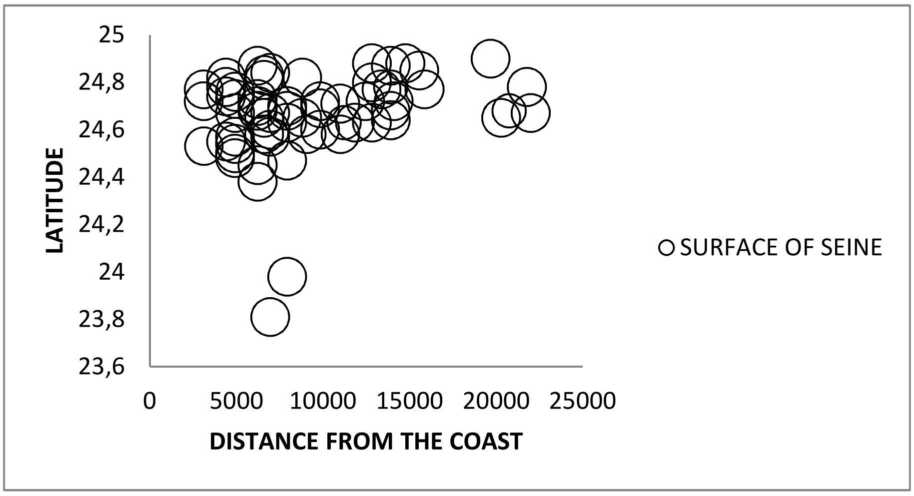

Fig. 7 the distribution of surface seine effort in relation to the latitude and distance from the coast.

3.2 DELTA MODELS (GLM) AND STATISTICALLY BETTER MODEL:

The results from the two models: presence-absence and presence model both represented a deviance explain respectively of 70 and 82% (tab.2). The explanatory factors depth of fishing, date (months), and surface of seine explained more the 3% of the deviance percentage in the models.

Table 2. The deviances explain and AIC of the best sub-models.

BEST MODELS	AIC	Deviance explain (%)
logit (*CPUE*0/1) ~ months+ distance from the coast + depth of fishing+ surface of seine	94,67	70%
Log(*CPUE*$_{>0}$) ~ months+ distance from the coast + GRT of vessel.	184,64	82%

After the selection of best models was done, based on the AIC value, the relationship between the CPUE and variables showed that the probability of presence CPUE has a positive relationship with the depth of fishing, and surface of net used, while for the distance to coast was negative (table. 2).

Table 3. Results of the regression relationship between the catch per unite of effort and distribution of sardine from the model of presence-absence.

Variables	Estimated coefficients	Standard error
Intercept	4.20	2.28
Month_June	-0.19	1.03
Month_May	-0.32	1.07
Month_November	1.14	0.93
Month_October	0.64	1.08
Month_September	-0.34	1.13
Distance from the coast	-0.29	0.12
Depth of fishing	1.53	0.79
Surface of seine	0,94	0.44

Results from the model of presence, showed that GRT has a positive relationship with the CPUE, big GRT value conduct to an important catch of sardine, contrary to the distance of coast which has a negative relationship with CPUE values (Table. 3).

Table 4. Results of the regression relationship between the catch per unite of effort and distribution of sardine from the model of presence.

Variables	Estimated coefficients	Standard error
Intercept	-2.31	0.26
Month_June	0.44	0.21
Month_May	0.25	0.30
Month_November	0.51	0.20
Month_October	0/56	0.25
Month_September	0.02	0.33
Distance from the coast	-0.05	0.03
TJB	0.015	0.004

4 DISCUSSION

The hypothesis on the relationship among catch per unit of effort (CPUE) and distribution of sardine was approved. The visual and statistical analysis results showed that Spanish seiner's vessels operated in the zone of high concentration of sardine density, which led to an important catch of sardine between the coast and 50 m of depth **(fig. 3).**

Seasonal distribution visual analysis of Spanish purse seiners fishing effort shows a concentration of fishing activity in the area between the coast and depth of 50m. In addition, the fishing area was concentrated between the lines of latitude 25°N and 24°N, knows an extension to the line 23 °N in autumn. The large catch recorded in autumn is due to the abundance of adult sardines between the coast and 50 m depth in autumn (Fig. 5) while in summer, adult sardines or on reproduction, are less important in terms of quantity (Fig. 4) [13].

Statistical analysis for the first model (presence-absence) of catch, showed that the main factors affecting the CPUE were: date (months), distance from coast, depth of catch, and surface of seine. When the distance is small, depth between 20 and 50m, by using large surface of seine (fig. 7), the probability of present catch becomes strong. Also the model proved that the presence of catch was not depending on the position (latitude and longitude), in a regional scale.

The second model of presence catch, main factors were: date (month), GRT, and distance from coast. In term of effort, large value of GRT vessel was deployed, between the latitude 23°N and 25°N, concentrated in a distance less that 25 km (Fig. 6). Removed variables were the surface of gear, and depth of catch, in this case, the catch was depending on the aggregation of fish in relation to the distance from the coast.

5 CONCLUSION

This study showed that Spanish seiners were able to exploit the different conditions favoring the realization of important catches for a specific period. These conditions are the best fishing season: Autumn, the best fishing area near the coast, the technical equipment (GRT) and latitudinal dynamics of the species between 25°N et 23°N. Based on the knowledge of conditions affecting the concentration of sardine in the area of study, and its seasonal migration which is important key to understand his behavior in seasonal time, the strategy of operation fish was successful during the year 1998 for the Spanish vessels.

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