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Theme Session K. Incorporacion of External Factors in
Marine Resources Surveys

Sardine (*Sardina pilchardus* Walbaum) characterisation off the Spanish Atlantic coast.

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Abstract

In 1983 both Spain and Portugal begun to conduct acoustic surveys in the Atlantic waters of the Iberian Peninsula. The main goal for these surveys was the assessment of the main pelagic fish species, but focussed on sardine. Some years the surveyed area was extended as far as the distribution of blue whiting, but in general covering only the continental shelf. Since 1988 the Spanish surveys are undertook in spring, during the spawning period of this fish species. As most of the pelagic fish species sardine occurs in schools. From the school data base gathered during the acoustic surveys, the echo-traces were allocated into fish species following a criteria. This scrutiny is based on the fish proportion found at the fishing station, but a learning process was also used which consisted in relating school characteristics (shape and energy) and its location (geographical location, distance to the coast, sea bottom typology among others) with fish species. This paper describes the main characteristics of the sardine schools, which have been extracted manually from paper echograms from 1992 to 1997 surveys (except 1994). A series of variables for each school were obtained: position (latitude, longitude, time, distant to the next school, distant to coast, minimum school depth and total water column depth), morphologic (height, length, area and perimeter), energetic (school energy -S_A value- and density -energy/area-) and environmental parameters (temperature and salinity). These were described by box plot, scatter plot and other basic exploratory methods. From this analysis, differences among years and geographic areas have been found in sardine schools. The relation of such changes with the total sardine abundance estimates as well as the implication in the survey design were also discussed.

Introduction

Sardine in Atlantic Iberian waters have supported one of the oldest fisheries of both Portugal and Spain. The earliest document of Spanish skippers date from the 13th century. Nowadays the sardine fishery is still artisanal and has important social and economic overtones. Because of its importance, a specific research project to study the biology and dynamics of this population was established. This also included direct abundance estimates.

Since 1986, the Instituto Español de Oceanografia undertakes acoustic surveys in spring, in coincidence with the main spawning period of sardine in the Spanish waters. Being pelagic species, sardine mainly occurs in shoals. These can be defined as an aggregation of fishes for social reasons (Kennedy and Pitcher, 1975; Pitcher 1983). A comprehensive review of the social implications of the shoaling behaviour have been made by Fréon and Misund (1999). These can be summarised in three major groups: i) Antidepredator mechanism; ii) Foraging functions; and, iii) Hydrodinamics advantages. From this last function, groups of synchronised and polarised fishes are termed schools. This kind of spatial distribution can be measured by means of echo-sounders. Under the frame of the EU project ?Aggregation patterns of commercial pelagic fish species under different stock situations and their impact on exploitation and assessment, CLUSTER, the reliability of school measurement was checked.(Diner et al 1999). In order to achieve a high accuracy and precision in schools measurements, an algorithm was implemented. This algorithm basically corrects school image in function of school depth and density, transducer beam and acoustic threshold.

On the other hand, along this period, trend in the Spanish catches show an sharp decreasing since 1985 when landings yielded around 100 000 tonnes to only about 14 000 in late nineties, This trend was also observed in the acoustic survey time series. The changes in stock size occurred in others sardines and also anchovies led to reduction in its lifespan and also in migration range (Lluch-Belda et al, 1989).

This paper examines the sardine schools found during the Spanish acoustic survey performed from 1992 to 1997.

MATERIAL & METHODS

Sea Sampling

Five acoustic surveys carried out in the northwestern and north Atlantic waters of the Iberian Peninsula, corresponding to years 1992, 1993, 1995, 1996 and 1997 were analyzed. Surveys have been carried out in March - April, coinciding with the spawning period of sardine in the zone (García *et al.*, 1991). Surveys design and strategies are described in Porteiro *et al.* (1996). In all years the surveyed area covering the whole continental shelf, between depths of 19 and 1754 m, (Fig. 1), except the year 1996 in which the surveyed area was extended as far the distribution of blue whiting (*Micromesistius poutassou*).

The acoustic equipment consisted on a Simrad EK-500 echosounder-echointegrator working at 38 kHz which was calibrated prior each survey. A PC controled all the general features of the echosounder (i.e. automated change of the scales, GPS signal recognition and integration values outputs by layer and ESDU expressed as backscattering units or S_A values(m^2/nautical mi^2). The survey speed was 10 knots and the ESDU was 1 nmi. Acoustic track was recorded both day and night and the sampling procedure according to time was evenly distributed. Acoustic data are available on paper recorded at a normal threshold of -70/-75dB. Integram line was also recorded at –80 dB threshold.

Extract and Collate Data Base on Schools Parameters

Along the surveyed area sardine was seen either in schools or in other aggregation patterns (i.e. layers, dispersed among others) We only examined those structures corresponding to schools. Schools were directly extracted from the echograms using a semi-automated method. Echograms were scanned and the digitized images were treated with commercial software (i.e. Corel Draw and Autocad LT) The image of each school was re-scaled in order to get the true proportion between axes. From each school several descriptors were directly extracted: Morphological (Height, Length, Area and Perimeter) and Location (water column depth and vertical position). Geographical position was derived from the GPS gathered at the beginning and at the end of each nautical mile assuming straight line navigation and same ship speed. Total echo-integrated energy was assumed to be equal to the integram line. Oceanographic variables (temperature, salinity) was gathered from the nearest CTD station using the values obtained at the same depth of the school. School distant to coast was computed as a normal minimum distance from the coast line (extracted from the GEBCO using a great resolution) to a particular school. Moreover, morphological variables were corrected using the Nöel Diner´s algorithm (1998). This algorithm allows the school be properly measured since its image is distorted because of the beam angle of the transducer, the acoustic properties and size of the echo-trace itself and the depth at which is located.

Finally, schools were allocated into fish species by scrutiny of the echograms. This has been made according to the experience regarding echo-traces (shape, density, bottom typology and roughness among others) which were corroborated by fishing stations.

This semi-automated procedure was tested using an full automatic system. For this purpose, data from 1997 acoustic survey were stored and pot-processed with SonarData Echoview, applying the school detection algorithm.

Statistical Analysis of Data

Data were divided into two geographical areas. The southern part, from the Spanish Portuguese border and 43°N of latitude (Rias Baixas) and the Cantabrian Sea (from 43°N to the inner part of the Bay of Biscay. The southern part is characterized by the presence of wide estuaries (around 20 nmi long and 8 nmi wide) in which most of the sardine schools occurred.

School variables were described using both univariate and multivariate analysis. Box-plots were used to characterize each variable by area. Analysis of variance (ANOVA) was performed to test the relation between time and the school parameters was carried out to test the effect of the zone (Rias Baixas, Cantabric Sea) on time.

Relationship among school descriptors was analyzed by PCA performed each year. For this purposes School length, height, area, perimeter, energy and density variables was log transformed. Variables were grouped according to PCA results. Further analysis were carried out using a single variable of each group. Interaction between year and zone were analyzed by Multivariate analysis of variance (MANOVA).. Finally, hierarchical clustering distances were computed over mean values of the selected variables.

RESULTS

Table 1 shows the number of nautical miles analyzed each survey, the sardine school occurrence and the total sardine biomass. Number of nautical mile varied according to survey design and survey strategies. In 1992, 1993 and 1997 the surveys covered as well the blue whiting distribution (i.e. until 1000 m or more if blue whiting occurred further offshore) as shown in figure 1. Moreover, sampling intensity during these years was higher than the sampling intensity undertaken in 1995 and 1996. In 1992 and 1993 survey design consisted in a grid with zig/zag transects whilst for the other surveys the was covered using parallel tracks, normal to the coast line.

Table 1 also shows the number of schools to which real size was determined (called "*valid*" schools) and the schools whose real size was not able to be extracted (i.e. "*non valid*" schools). The length of these schools in relation with its depth was lower than twice the beam angle transducer and, therefore no measurements can be obtained. The number of "non valid" school sardine ranged from 17.5% to 33%. This percentage was lower than that obtained from the whole data set, which included all fish species. (from 23 to 41%) Total number of sardine schools considered valid was 798. There was no relation between number of schools and sampling intensity nor between number of school and total sardine biomass estimated.

Sardine school mainly occurred at the inner parts of the surveyed area (i.e. Rias Baixas an the inner part of the Bay of Biscay, Figure 2). A large variation in school geographical occurrence was found both between areas and among years. In 1997 no schools were detected in the Rias Baixas. (Table 2).

In spite the sampling intensity was similar according to time, significant differences were found between school occurrence and time. Most of the schools occurred during daytime (Fig. 3). Besides there was significant differences in time between areas (ANOVA, P<0.001). In the Rias Baixas most of the schools were observed at sunrise while in the Cantabrian sea during light hours the schools occurred with similar probability (Fig. 4).

PCAs were similar for each year. First three axis explained more than the 72% of the variance.. Moreover axis III and IV explain also quite a lot of variance (>6.35%). Axis I explained 41% of the total variance each year (>41.4%), and contrast the morphological variables of school. These variables were strongly correlated among them and with temperature and school density. Axis II explained >16.7% of the total variance each year. It mainly contrasted energetic variables (energy and density) with the location variables (i.e. school and bottom depth and distant to coast.

Two main groups of variable were observed, morphological variables (school length, height, area and perimeter) and the positional variables (school and bottom depth and distant to cost) while the others variables were more dispersed (Fig. 5). Because of the high correlation school area and school depth were selected representing each group of variables as well as temperature, salinity, density and energy to perform further analysis.

Figure 6 show box-plot performed for these variables. There was a large variability between years and zones, being more important the differences observed in temperature and salinity. School density was higher in those school located in the Rias Bixas than those located in the Cantabrian Sea. Nevertheless, excluding year 1993, schools were higher in the Cantabrian Sea. At survey time no water stratification was observed. Water temperature showed an increasing trend along the time series, being 1992 the coldest year.

Although school descriptors seem to be more stables in the Cantabrian sea, temporal and spatial interactions were found (MANOVA, P<0.001 For this reason it is not possible substantiate temporal or spatial differences individually. Cluster analysis shows how the schools of the year 1992 in the Cantabric Sea were very different to the rest of groups (Fig. 7). Cantabrian Sea schools were slightly more similar (mainly the years 1997 and 1995) than the Rias Baixas school although there were not a clear pattern nor between years neither between areas (Fig.7).

DISCUSSION

Pelagic species occurs in schools. The analysis of the Spanish acoustic survey performed in spring from 1992 to 1997 revealed a high variability in sardine schools. The most important conclusions are:

a) The number of schools seems to be independent either from the total biomass estimated and from the sampling intensity.
b) Off the Spanish coast sardine mainly occurs in two main areas, the southern part (Rias Baixas) and in the inner part of the Bay of Biscay.
c) Sardine show a high variability in the selected school descriptors.
d) School morphologic variables area highly correlated.
e) Sardine school occurred near the coast. The distance to the coast is also correlated with the total water depth and the its location in the water column.
f) Significant interactions were found between years and zone for morphological, oceanographic and energetic variables.

The accuracy of the school measurements, which were made using a semi-automated method from paper echograms, was good and no significant differences were found from the 1997 survey between this method and the automatic extraction.

The survey were conducted day and night. In spite some schools were found at night, most of the sardine occurred at night in dense layers, close to the bottom. This kind of aggregation was no analyzed in this paper. Nevertheless, the number of such aggregations did no explain the differences in biomass nor the differences found in sampling intensity.

This acoustic time series shows a geographical age distribution pattern. Younger fish are mainly located close to the Spanish_Portuguese border. From this area there is an age gradient age towards the inner part of the Bay of Biscay where most of the older fish are found as shown in table 2. This different age pattern could explain the differences in school density and school size found in both areas.
In spite some characteristics can be observed in each area or in particular year, no general pattern on the sardine school occurrence in this area can be defined. Multivariate analysis revealed a great complexity in the variability in the number and the morphology of the sardine schools. It seems that the year, zone and the oceanographic variables have no a direct impact on the school occurrence, and this might be driven by an interaction of different factors whose relative incidence each year could be different. In this context, further analysis area suggested.

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Table 1. Total number of miles in the acoustics tracks, total school number (all species),sardine school number located and sardine biomass estimated by years and geographical areas.

	Total Miles	Total School Number			Sardine School Number					Sardine Biomass (ktonnes)		
	Survey	Uncorrected	Corrected	% Corrected	Uncorrected	Corrected	% Corrected	Rias Baixas	Cantabric Sea	Rias Baixas	Cantabric Sea	Total
Year 92	1443	654	487	74.46	274	209	76.28	61	148	10	35	45
Year 93	1627	686	524	76.38	243	203	83.54	53	150	18	165	183
Year 95	542	673	400	59.44	119	80	67.23	28	52	8	9	17
Year 96	663	644	370	57.45	257	181	70.43	138	43	14	40	54
Year 97	1088	465	284	61.08	152	125	82.24	0	125	7	41	48
Total	5363	3122	2065	66.14	1045	798	76.36	280	518	57	290	347

Table 2. Mean length and mean age of the sardines by years and geographical areas.

	Rias Baixas		East Cantabrian	
	Mean length	Mean Age	Mean length	Mean Age
Year 92	18.15	1.87	21.53	4.53
Year 93	18.35	1.68	22.84	6.48
Year 95	19.54	2.97	22.19	4.29
Year 96	20.61	3.75	21.82	4.03
Year 97	19.69	3.05	20.68	3.00

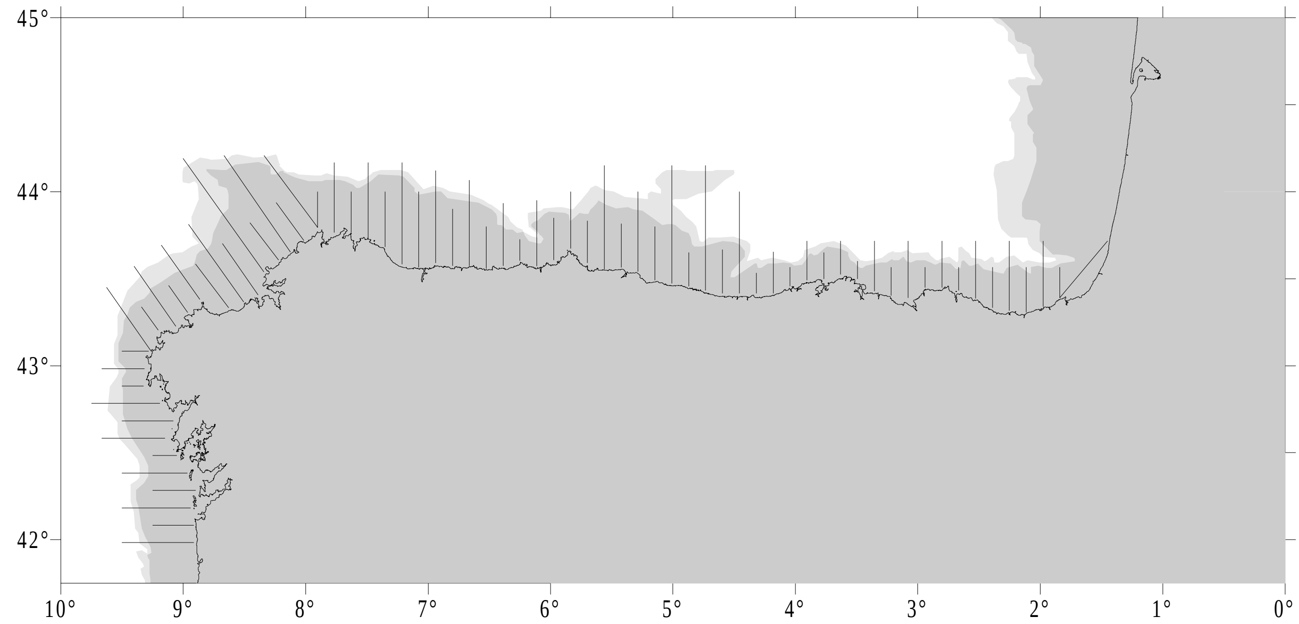

Figure 1. Sampling area with acoustics tracks and 200, 500 and 1000 m isobath.

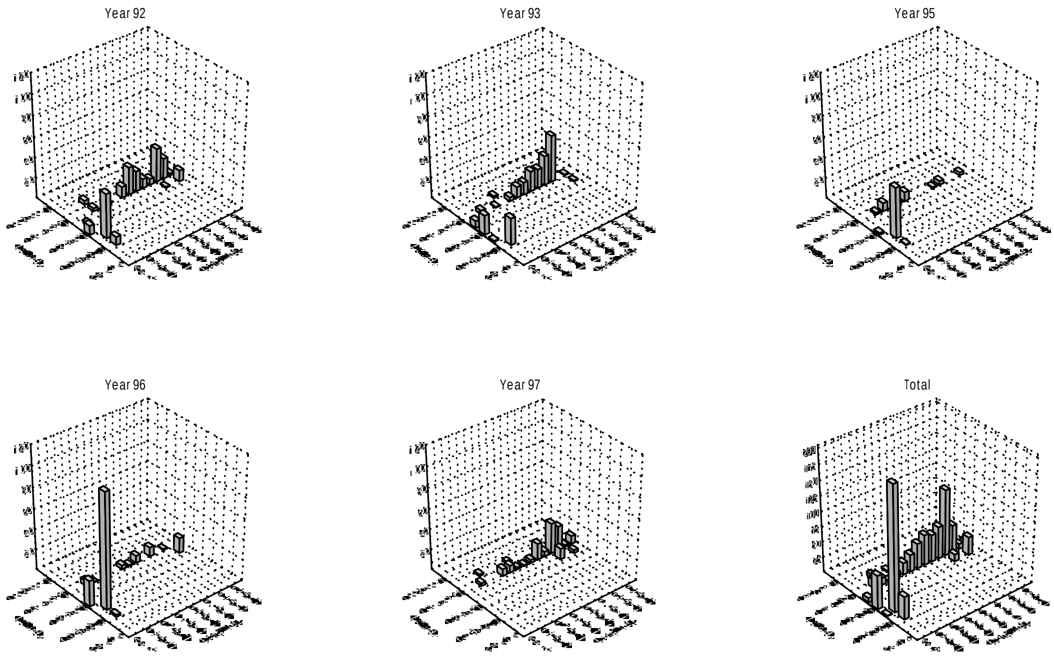

Figure 2. Number of schools by years and total number located by latitude and longitude.

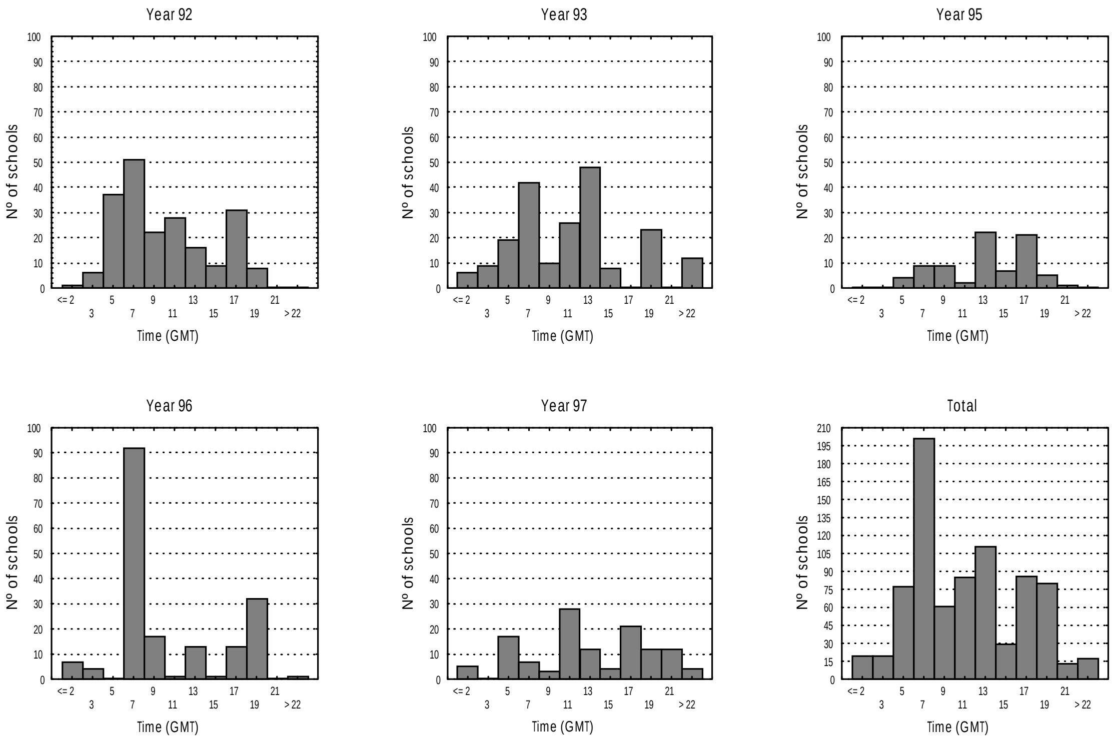

Figure 3. School number located along the daytime by years and total.

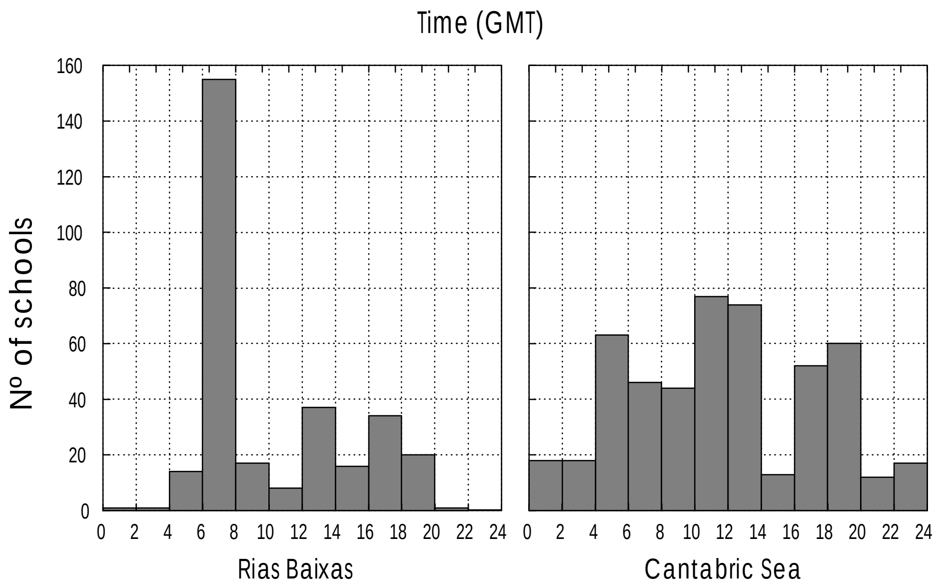

Figure 4. School number located along the daytime by geographical areas

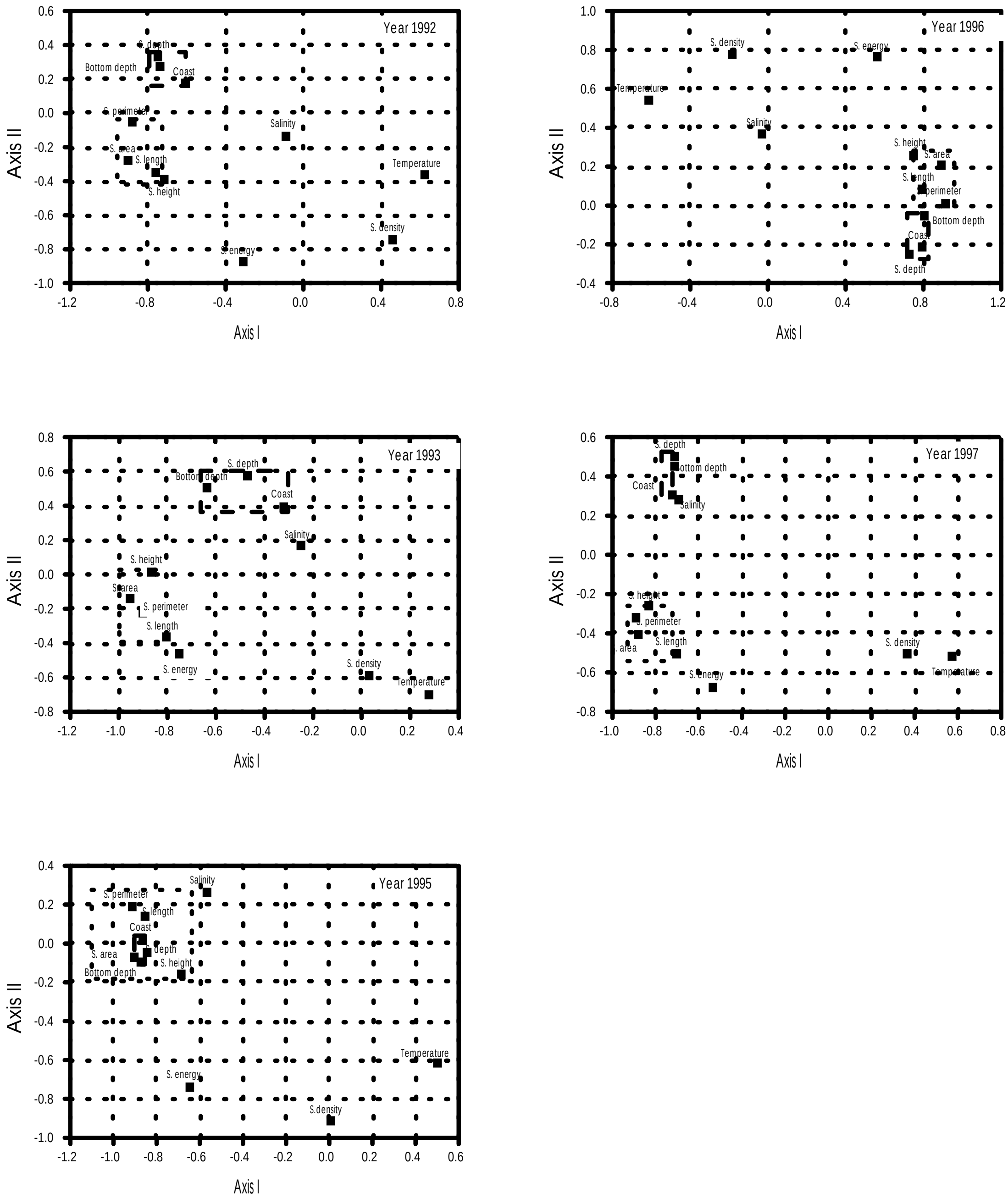

Figure 5. Principal Components Analysis by years. Position of the variables on the axis I/II. Shows variables highly correlated enclosed lines.

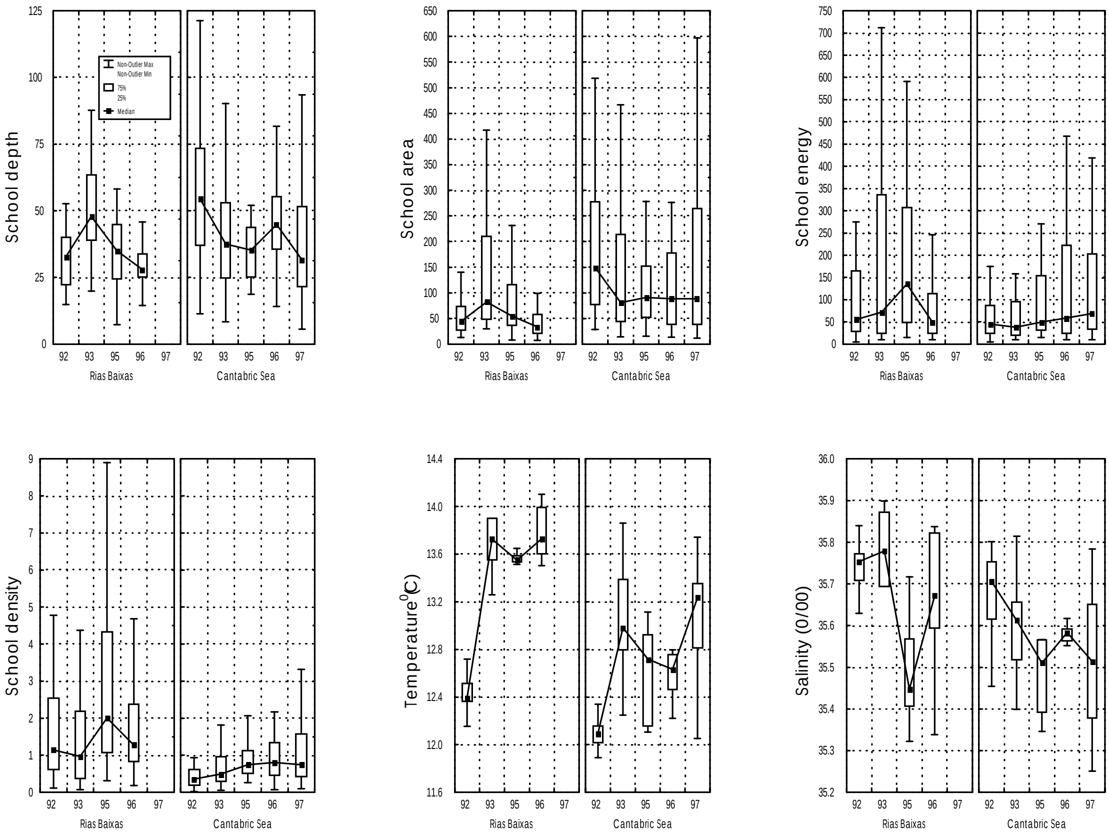

Figure 6. Box-plots of the selected variables (school depth, school area, school energy, school density, temperature(ºC) and salinity (0/00) the different years in the two geographical areas.

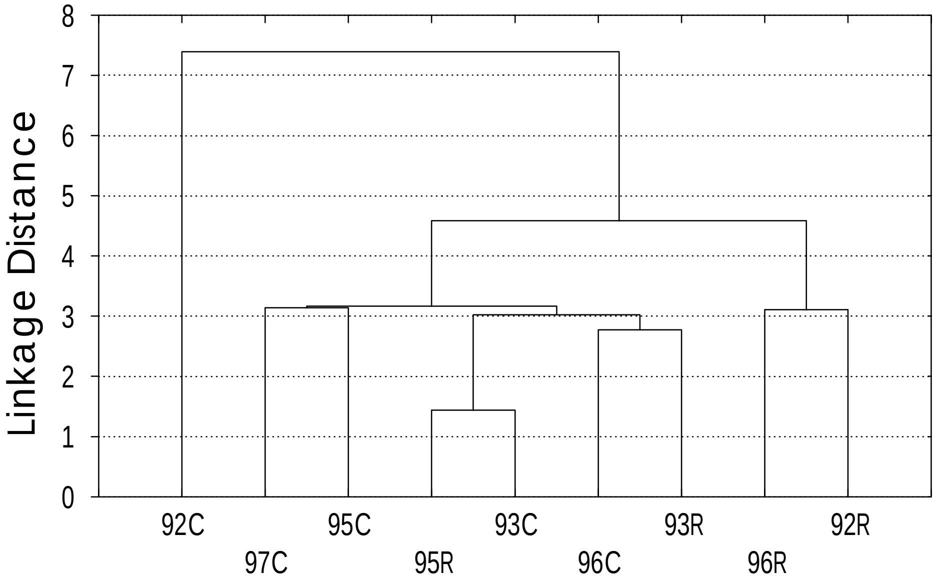

Figure 7. Cluster analysis of the different groups of year/area (R: Rías Baixas; C: Cantabric Sea).