

ABSTRACT

Systematic acoustic surveys to estimate the Spanish fraction of the Atlantic Sardine Stock were begun in 1983. Since 1991, with the use of the new Simrad EK-500 echosounder-echointegrator, the covered area has been extended to 1000 m isobath to observe the distribution of the main pelagic species in the area. The last three surveys, from spring 1991 to 1993, had a range of 20 to 1000 m isobath. They were first analysed using the traditional methodology proposed in Pastor et al. (1986) which does not give any estimation of the variance. Therefore, the data was then analysed using geostatistic techniques, and the resulting relative abundance estimates were compared.

Sardine showed high variability between years and zones in both distribution area and density, expressed as number of fish per square nautical mile. The two methods of analysis gave different biomass estimates by zone, especially in 1993. Variograms computed over areas of fish presence did not show, in general, a clear spatial structure and sills were reached at 3 n.m. of range. The precision of these variograms was low, ranging from 23% to 40%, expressed as relative standard error.

In order to improve precision it seems necessary to increase the sampling intensity and change the survey grid. For sardine, a systematic parallel with random start survey design, with 6 n.m. between transects, would be more appropriate.

Key Words; Acoustic survey, Sarda pilchardus, spatial distribution, geostatistics, Iberian Peninsula.
Survey tracking, was performed over the theoretical distribution area of the main pelagic species (i.e. sardine and blue whiting) and each year consisted of a zigzag design, with 10-12 nautical miles between peaks, a 20 m isobath lower limit (modified when bottom topography, islands or shallows required it) and 1000 m isobath external limit, which was also adapted to the presence of blue whiting.

Based on the information obtained at pelagic fishing stations, total $S_A$ values for each nautical mile was allocated into different species (sardine, blue whiting and others). This kind of allocation did not present great problems and sardine records can be distinguished and allocated even at night. $S_A$ values for sardine, corresponding to one nautical mile with the geographical position, expressed as latitude and longitude, multiplied by the cosine of the mean latitude, were used to calculate distances, surfaces and arithmetic mean values, using two different methods:

a) **Fixed strata:** The surveyed area was divided into 21 geographic sectors with a width of 20 n.m. and each one was also divided into depth strata (20-50 m, 50-100 m and 100-200 m) (Pastor *et al.*, 1986). Means were calculated using all the data values within these areas, with null values included. For the results, the area was split into four zones along the coast as follows: South Galicia, from the Spanish-Portuguese border to 43° N (Cape Fisterra), North Galicia, from 43° N to 7° W, West Cantabrian, from 7° W to 3°20' W, and East Cantabrian from 3°20' W to the Spanish-French border (Fig. 1). These four zones correspond to the sardine age distribution pattern found in these waters, with juveniles and young fish in South Galicia and an age gradient running from there to the East Cantabrian where the oldest sardines can be found (Porteiro *et al.*, 1986).

b) **Distribution area:** The area of sardine presence was determined for each survey. The external boundaries of these areas were defined by the presence of a succession of zero values along transects and/or the lack of positive values in two consecutive transects. In each survey, this definition gave isolated areas along the coast, which correspond, more or less, with the four main zones described above. Inside them, holes in density can be also observed. Spatial structures, surfaces and estimations of the variance were calculated by means of geostatistic techniques (Petitgas, 1993) using the EVA package (Petitgas and Prampart, 1993).

Abundance estimates were calculated according to the methodology proposed in Anon (1986),
Cantabrian. In 1992, the distribution was isolated from that of the West Cantabrian, with no spatial structure. The area was largest in 1993 but, as in the West Cantabrian, it had holes inside.

Relative standard errors of the estimations by areas, calculated using theoretical variograms fitted to each spatial structure, ranged from 23% to 40% except in the West Cantabrian in 1993 where the precision was less.

Biomass estimates for each zone and year for both evaluation methods are shown in table 2. There was no consistency between methods for each zone and year, and differences were higher than 10% except for South Galicia and the East Cantabrian in 1993. In spite of that, for total estimates, differences were less than 11% for 1991 and 1992.

DISCUSSION

The most important characteristic of sardine distribution is the high variability between years. There seems to be a relationship between area and temperature, as was suggested in Porteiro et al (1993). In 1992, the temperature at 50 m depth was the coldest in this series, and the area was the smallest. 1993 was the warmest year and the biggest area was found. This pattern agrees with those found for similar species like Japanese sardine (*Sardinops melanostictus*, Schlegel) (Aoki and Inagaki, 1993). Also changes in stock size may produce a reduction in its lifespan and also in migration range (Luch-Belda et al, 1989). Both phenomena could explain the changes in distribution area detected in this paper.

Differences in total biomass estimates with two methods were negligible for 1991 and 1992, but important for 1993, which was 30% higher when the distribution area method was used. Differences among areas were higher, especially in 1991 and 1992 and in West Cantabrian in 1993. These differences can be explained by the different mean values and areas used in the two methods.

As sardine is distributed mainly close to the coast, especially in 1992, variograms show cyclical structures, related to the scarce pairs values between 6 and 10 nm and this could probably explain the lack of spatial structures. Besides the lack of independence of transects, survey designs in zigzag provide higher local sampling intensity per unit area at the turns compared with other portions of the track (Simmonds et al, 1992). In such conditions, areas with high density


