International Council for
the Exploration of the Sea

C.M: 1998/J:17

Seasonal changes in distribution and aggregation characteristics of sardinella species in Angolan waters

by

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ABSTRACT

The distribution and aggregation characteristics of sardinella in Angola from 1985-1996 are analyzed by comparing the distribution of acoustic recordings (S_A-values) from surveys conducted by R/V "Dr. Fridtjof Nansen" and by relating distribution area to estimated biomass. These comparisons indicate seasonal changes in distribution of sardinella species. Through the surveys, systematically higher estimates have been recorded in the northern region during the southern winter and in the central-southern region during the warm season. There is a southward displacement of the adults as far as Baia dos Tigres for round sadinella (*Sardinella aurita*) and to Lobito-Benguela for the flat sardinella (*Sardinella maderensis*) during the warm season. Northward displacement occurs during the cold season in connection with upwelling.

INTRODUCTION

The hydrographic regime off Angola is characterized by the cold northward-flowing Benguela current and the warm southward-propating waters of the Angola current. These two currents join (at about 15° S) and form the South Equatorial Current(SEC) as part of the South Atlantic subtropical gyre. The warm Angola current is strong in the summer period, which results in rather stratified water masses and higher sea temperatures. On the contrary, the Benguela current is strong in the winter period causing upwelling and colder surface waters.

These seasonal variations of the hydrographic conditions induce temporal and spatial variability of the distribution of the pelagic species off Angola (Dias, 1983a, b). There are indications that seasonal changes in the hydrographic conditions cause north - south movement of sardinella. During the warm season there may be a southward displacement of adult sardinella as far south as Baia dos Tigres for round sardinella and to Lobito for the flat sardinella (Anon, 1995). According to Lukashev (1976) the displacement north-south for both sardinella species is linked to the feeding area as well as the reproduction. It is known that the sardinella species feed both on phytoplankton and zooplankton. Seasonal changes in the hydrophic regime influence the distribution of the phyto and zooplankton, which lead to a redistribution of the sardinella species.

Based on distribution area and estimated biomass found by conventional acoustic surveys by R/V «Dr. Fridtjof Nansen» in the period 1985-1996, we analysed how distribution and aggregation behaviour of the sardinella species change with season.

MATERIALS AND METHODS

In the years 1985, 1986, 1989, 1991, 1994, 1995 and 1996, R/V "Dr. Fridtjof Nansen" conducted conventional acoustic surveys off Angola to map the distribution and estimate the biomass of pelagic fish. The surveys up to 1989 were run with a 38 kHz Simrad EK400 echo sounder connected to an echo integrator. Later surveys were run with a 38 kHz Simrad EK500 echo sounder that from 1994 was connected to a BEI echo integration unit. The echo integration units were calibrated according to standard procedure prior to the surveys. Echo recordings during the surveys were scrutinized manually, and echo intensity allocated to species according to catch composition in trawl catches or appearance on the echogram. Distribution charts with categories for scattered, dense, and very dense recordings for the dominating pelagic species were drawn for each survey. The biomass of these species was estimated by assuming a target strength of 20 log L - 72, and then using backscattering strength, distribution area, and species weight recorded for each survey in the standard calculation method.

The biomass estimates of sardinella from 1985 to 1996 were used for comparisons between the warm and the cold season. For each survey the fraction of biomass was estimated for the three regions: Cunene-Benguela (south), Benguela-Luanda (centre) and Luanda-Cabinda (north)). Similarly the distribution areas of scattered, dense and very dense recordings of sardinella were estimated for each survey by use of a planimeter. Statistical comparisons of the biomass between the three areas were made by Wilcoxon 2-sample test based on both the biomass and the biomass fraction. Correlation coefficients (r_s) between the two seasons, in the

categories scattered, dense and very dense per region, were calculated on the basis of the acoustic recordings.

RESULTS

Generally, the sardinella species were found near the coast (Figs. 1 - 7) over bottom depths from 20 - 200 m along the entire shelf of Angola. In 1985, the sardinella species were consentrated in the Benguela - Luanda region in the warm season, but with a clear northward shift in the distribution in the cold season. In 1986 the distribution of the sardinella species was more similar both in the warm and the cold season. In the later years, especially in 1996, a clear tendency to a northward shift in the distribution of the sardinella species from the warm to the cold season was apparent.

Figure 8 shows the biomass distribution of sardinella species in the summer and winter periods respectively, as observed through the surveys with the RV "Dr. Fridtjof Nansen". The figure shows clearly that in the summer period, characterized by more stratified water masses and higher temperatures in the water column, more than 50% of the biomass were found in the central region. On the contrary, the highest biomass was found in the northern region in the winter period, characterized by upwelling and colder surface waters. This pattern was probably due to north-south migrations that most likely apply to both species.

In general, the biomass fraction in the Cabinda region varied from 0.14 - 0.42 in the warm season to 0.30 - 0.73 in the cold season. For the Luanda region the biomass fraction varied from 0.54 - 0.85 in the warm season, to 0.27 - 0.50 in the cold season. Both the biomass and the biomass fraction of sardinella that were recorded in the Cabinda region were significantly higher in the cold season than in the warm season ($p < 0.05$ in both cases, Wilcoxon 2-sample test). The biomass fraction in this region increased by minimum 0.06 to 0.48 from the warm to the cold season. This indicates that there was a movement of sardinella into the Cabinda region from the warm to the cold season. For the Luanda region, the biomass was not significantly different between the warm and the cold season ($p > 0.05$), but the biomass fraction was significantly higher in the warm than in the cold season ($p < 0.05$). In general, the biomass fraction in the Luanda region decreased by minimum 0.05 (1986) to maximum 0.42 (1985) from the warm to the cold season. This indicates that there was a movement of sardinella out of the Luanda region from the warm to the cold season. Altogether, these results illustrate seasonal shifts in the biomass distribution of sardinella along the Angolan coast with a northward movement in the first part of the year (from the warm to the cold season) and a southward movement in the last part of the year (from the cold to the warm season).

When the total biomass of sardinella increased, the distribution area of sardinella in scattered aggregations increased accordingly ($r = 0.55$, $p < 0.05$, $n = 28$). There was a similar tendency for the distribution area of sardinella in dense and very dense aggregations also, but the correlations between these parameters and the total biomass were not significant ($r = 0.22$, $p > 0.05$, $n = 26$, $r = 0.39$, $p > 0.05$, $n = 21$, respectively). There was a seasonal dependence in the correlation between the distribution area of sardinella in scattered recordings and the total biomass of sardinella, because the correlation was significant only for the cold season (Table 1). The distribution area of sardinella in dense and very dense recordings were not correlated to the total biomass, neither for the warm nor the cold season. None of the aggregation

fractions (scattered, dense, very dense) was correlated to the biomass, neither for the warm, nor the cold season (Table 1).

Table 1. Correlations between acoustic recording categories and biomass of sardinella (r = correlation coefficient, n = number of observations, *: $p < 0.05$).

Correlations	Warm season	Cold season
Scatter vs. Biomass	r = 0.25, n = 15	r = 79* , n = 13
Dense vs. Biomass	r = 0.31, n = 14	r = 0.08, n = 12
Very dense vs. Biomass	r = 0.48, n = 14	r = 0.22, n = 8
Scatter fraction vs. Biomass	r = -0.15, n = 13	r = 0.01, n = 7
Dense fraction vs. Biomass	r = 0.20, n = 13	r = 0.01, n = 7
Very dense fraction vs. Biomass	r = -0.01, n = 13	r = -0.12, n = 7

* = Correlation

DISCUSSION

The survey results show that there were seasonal changes in the distribution of sardinella species along the coast of Angola. Seasonal variability of the hydrographic regime and distribution of phyto- and zooplankton probably cause a clear movement north-south.

Due to the higher temperatures in 1995 (Benguela-El niño) in the first part of the year (from the warm to the cold season), sardinella were redistributed in the northern region over depths more than 700 m (Anon, 1995).

As already pointed out by Dias (1983a, b), a greater activity of the Angola current, with which the species are connected, may cause a seasonal (March-May) movement of single schools as far as the waters off northern Namibia, as observed in 1983 (Thomas, 1984a).The increase and decrease of the biomass estimates observed from 1985 to 1996 indicated the possibility of north-south movements in connection with the upwelling and the Angola current.

Baptista (1977) showed that the movement of the sardinella stock results in seasonality of fishing of individual areas of the coast (Table.3). As may be seen from this table, the same pattern was observed with the time series of survey estimates from the "Dr. Fridtjof Nansen" surveys. With regard to the sardinella species, it is common knowledge that their behaviour is strongly influenced by the seasonal and the environmental conditions encountered in the area (Anon, 1991).

Acoustic sampling has the advantage of covering the fish resources in a relative short time, i.e. to give a snapshot of the abundance of pelagic species. However, the method suffers from a series of biases and sources of variance which are difficult to evaluate and reduce (MacLennan & Simmonds 1992). Of the main problems are those related to fish behaviour, as the day-night variations in fish distribution and density, near-surface distribution and vessel avoidance. These factors may have influenced the acoustic biomass estimates significantly, but our comparisons of acoustic recordings and distribution area for different seasons are probably negliable affected.

At the boundary between Congo and Angola (Mayumbe area, 5° S), there is a spawning area for the sardinella species. Juveniles start moving southward to Angola when about 12-13 cm in length at an age of approximately 2 years. Generally, the adults are found in Angola and a small percentage of the juveniles is found in the southern part of the Luanda region (Pta. das Palmeirinhas). The flat sardinella are generally more coastal and sedentary and live in areas at a sea surface temperature of about 26°C as well as with lower salinity (34 p.s.u). On the contrary, the round sardinella are more offshore and prefer a sea surface temperature of about 24°C as well and higher salinity (35 p.su.) (Gheno and Campos Rosado, 1972; Wysokinski, 1986).

The distribution of sardinella species is very dynamic, and these species are fast-swimming fish with significant changes in behaviour during the day. The most common feature for the sardinella in this region is the concentration in schools at daytime, often close to the surface (Anon, 1985/86). At night the schools tend to dissolve and the fish are spread in somewhat deeper layers, however, still in the upper part of the water masses.

Table 2. Seasonality of sardinella fishing on in dividual sectors of the Angolan coast (after Baptista, 1977).

	Season						
Area	Feb	Mar-Apr	May-Jun	Jul-Aug	Sep-Oct	Nov	Dec-Jan
Northern Angola	good	highest	good	weak	increasing	good	weak
Central Angola	highest	good	decreasing	weak	increasing	good	weak
Southern Angola	average	average	weak	weak	increasing	average	weak

REFERENCES

Anon. 1985-96. Surveys of the fish resources of Angola (Cruise report "Dr. Fridtjof Nansen"). Institute of Marine Research, Bergen, Norway.

Baptista, S.R. da Fonseca, 1977. The distribution and movements of the sardinellas (*Sardinella aurita* Val. and *Sardinella maderensis* Val.) off Angola Coast. Collect Sci. Pap. ICESAF/recl. Doc. Sci. CIPASE/Colecc. Doc. Cient. CIPASO, 4: 21-24.

Dias, C.A. 1983. Note on the evidence of a permanent southward flow of upper oceanic trospheric waters off Angola at 12°S. Colln. Scient. Pap. int. Comm. SE. Atl Fish.: 99-102.

Gheno and Campos Rosado, J.M. 1972. Distribution and seasonal migrations of *Sardinella maderensis* off coasts of Gabon and northern Angola.

Lukashev, V.N. 1976. Distribution of *Sardinella maderensis* and *Sardinella aurita* off the coast of Angola. Trudy VNIRO, T 71, Ser 281-293.[In Russian]

McLennan, D.N. and Simmonds, E.J. 1992. Fisheries acoustics. Chapman & Hall, London.

Thomas, R.M. 1984. Catches of *Sardinella aurita* off South West in 1983. Collect. Sci. Pap. ICSEAF/Recl. Doc. sci. CIPASE/Colecc. Doc. Cient. CIPASO, 11(2):87-90.

Wysokinski,A. 1986. The living marine resources of the Southeast Atlantic.FAO Fish.Tech., (178) Rev.1, 120 p.

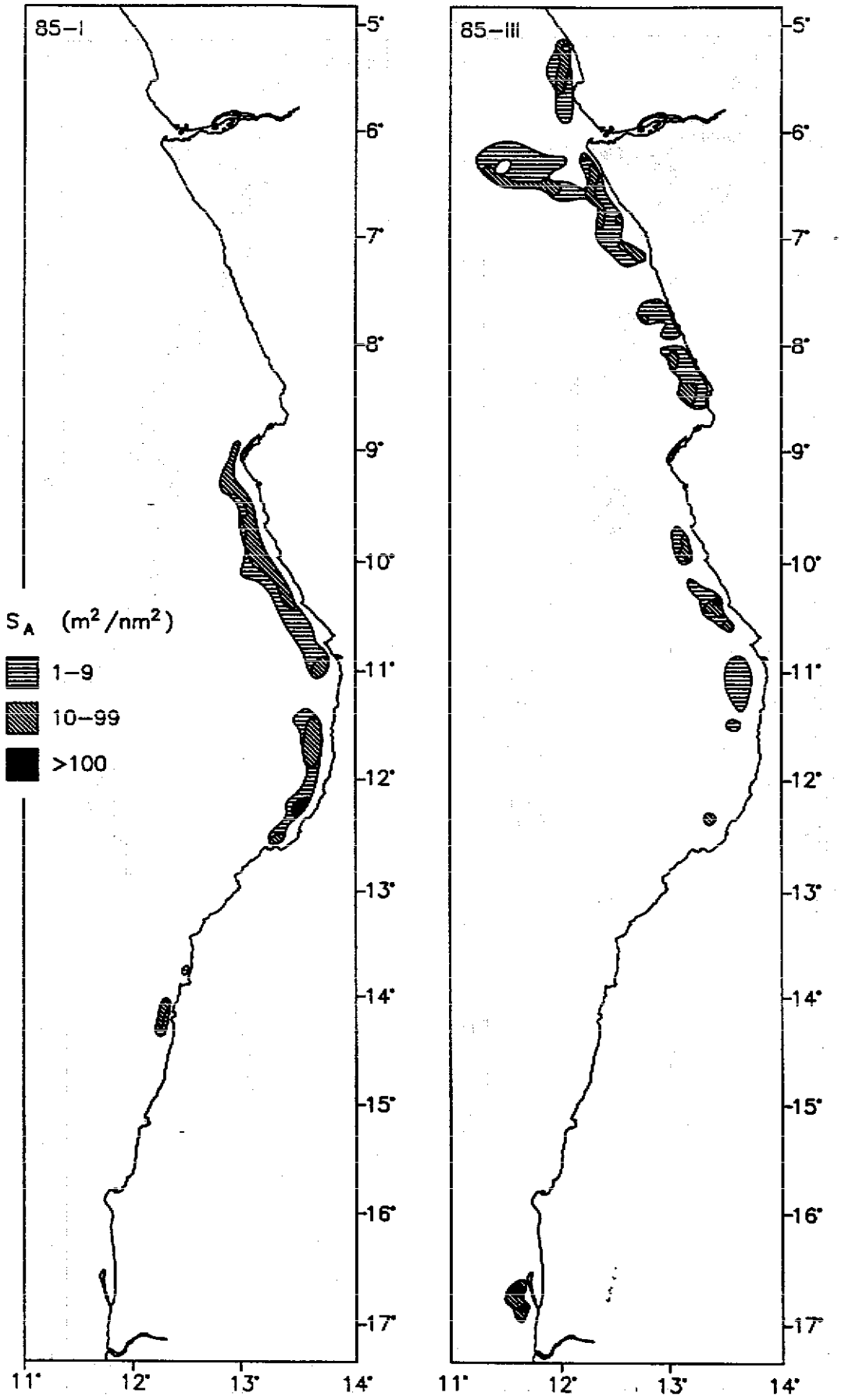


Figure 1. Distribution of acoustic recordings of sardinella off Angola in the summer (I) and winter periode (III) in 1985.

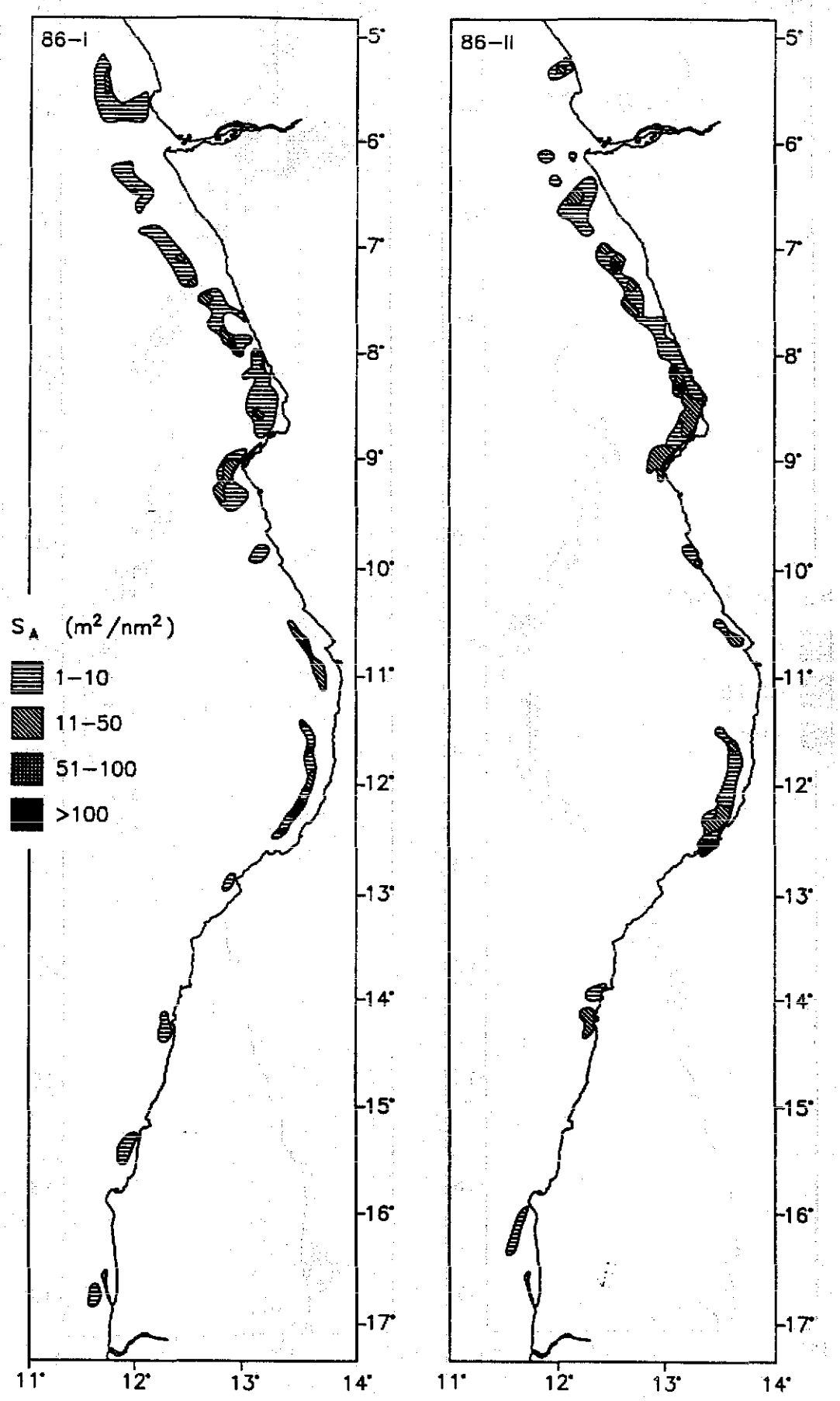


Figure 2. Distribution of acoustic recordings of sardinella off Angola in the summer (I) and winter periode (II) in 1986.

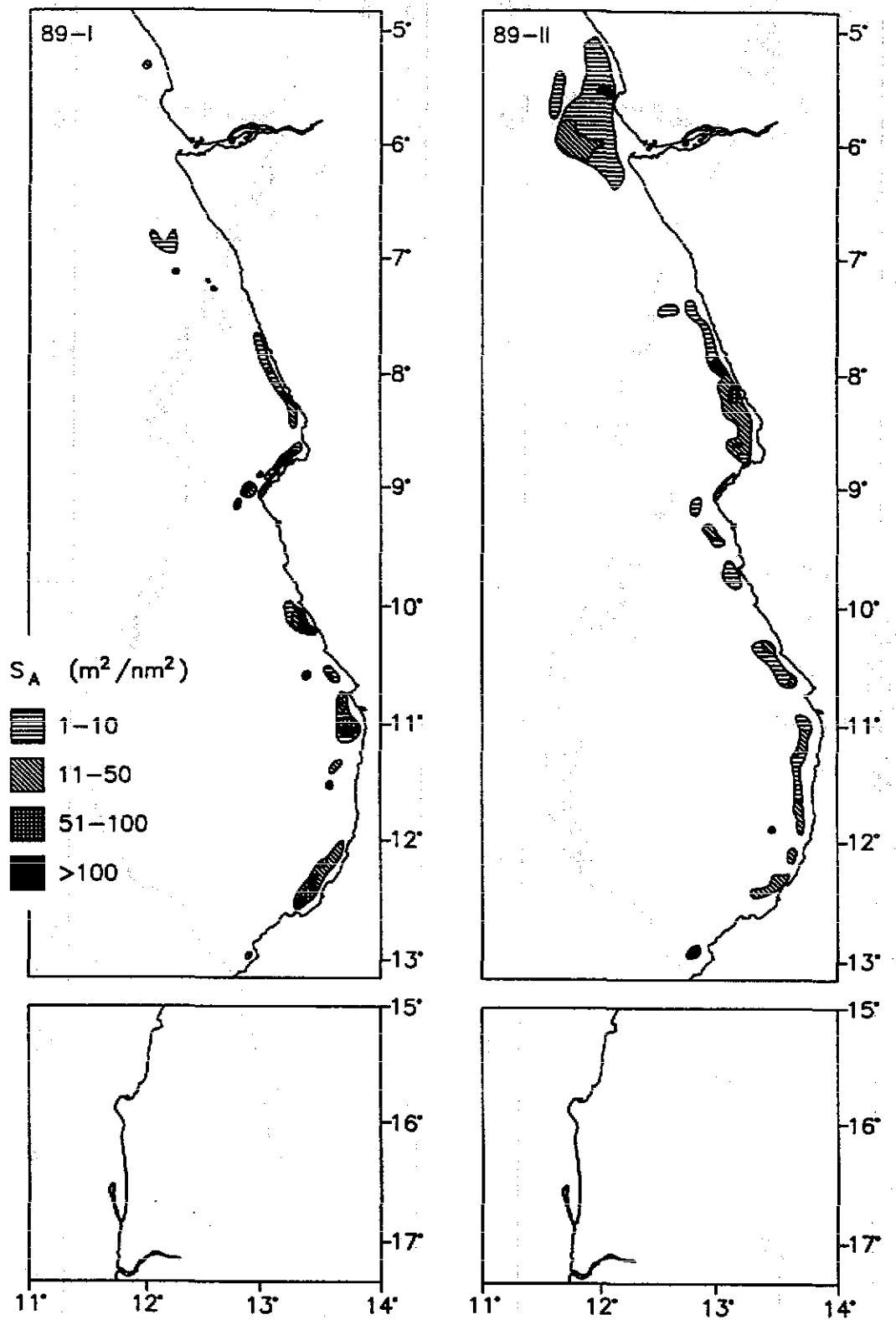


Figure 3. Distribution of acoustic recordings of sardinella off Angola in the summer (I) and winter periode (II) in 1989.

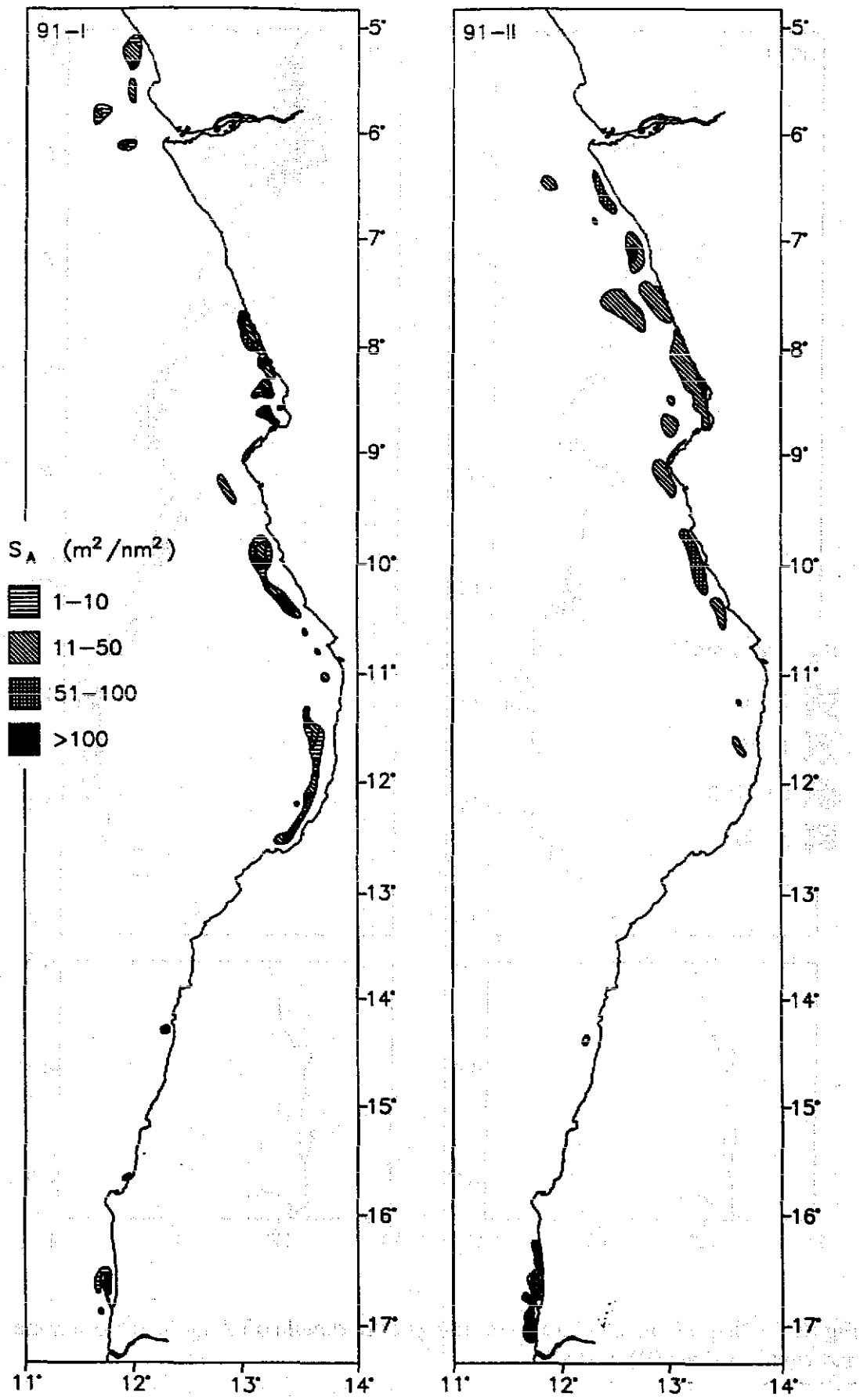


Figure 4. Distribution of acoustic recordings of sardinella off Angola in the summer (I) and winter periode (II) in 1991.

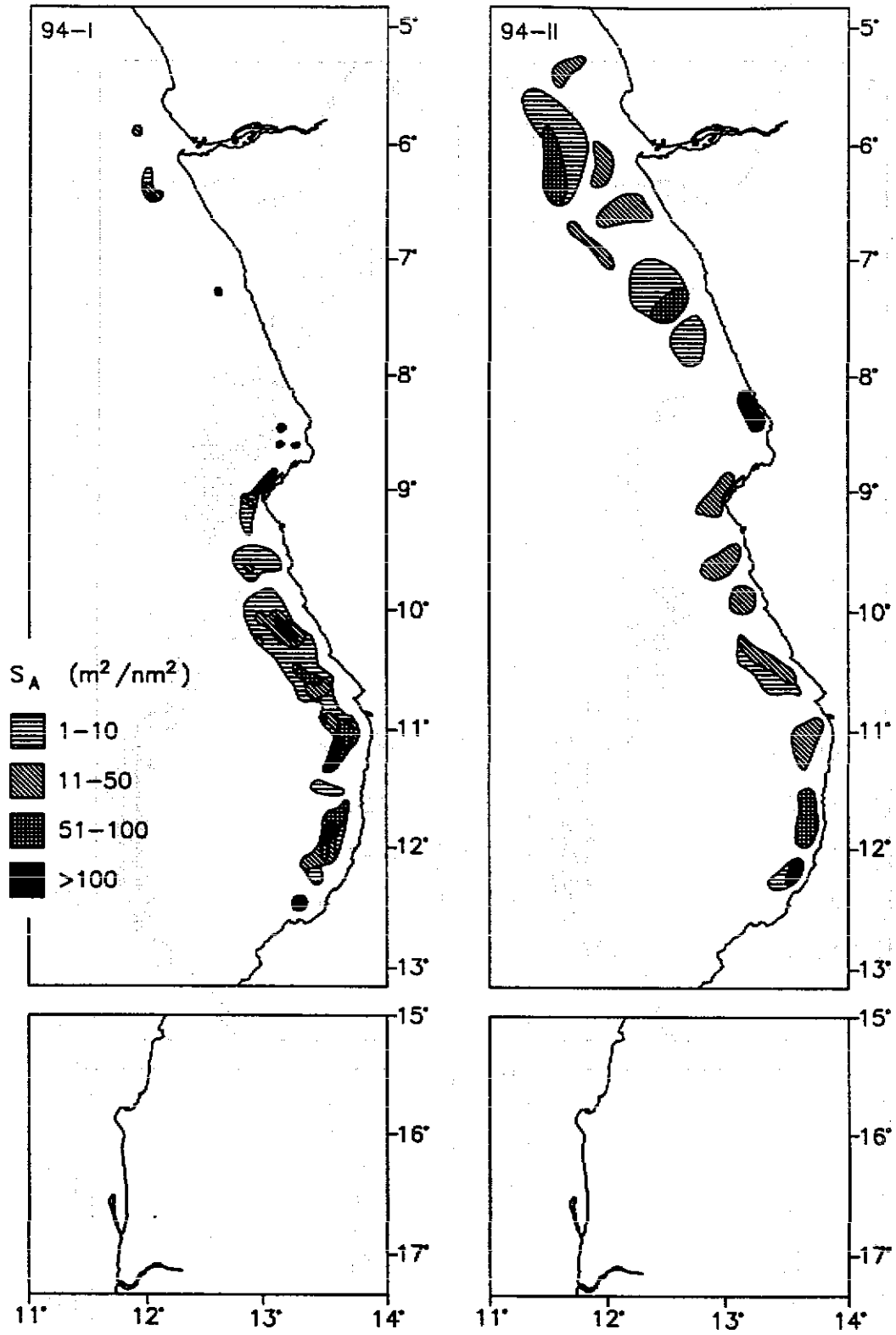


Figure 5. Distribution of acoustic recordings of sardinella off Angola in the summer (I) and winter periode (II) in 1994.

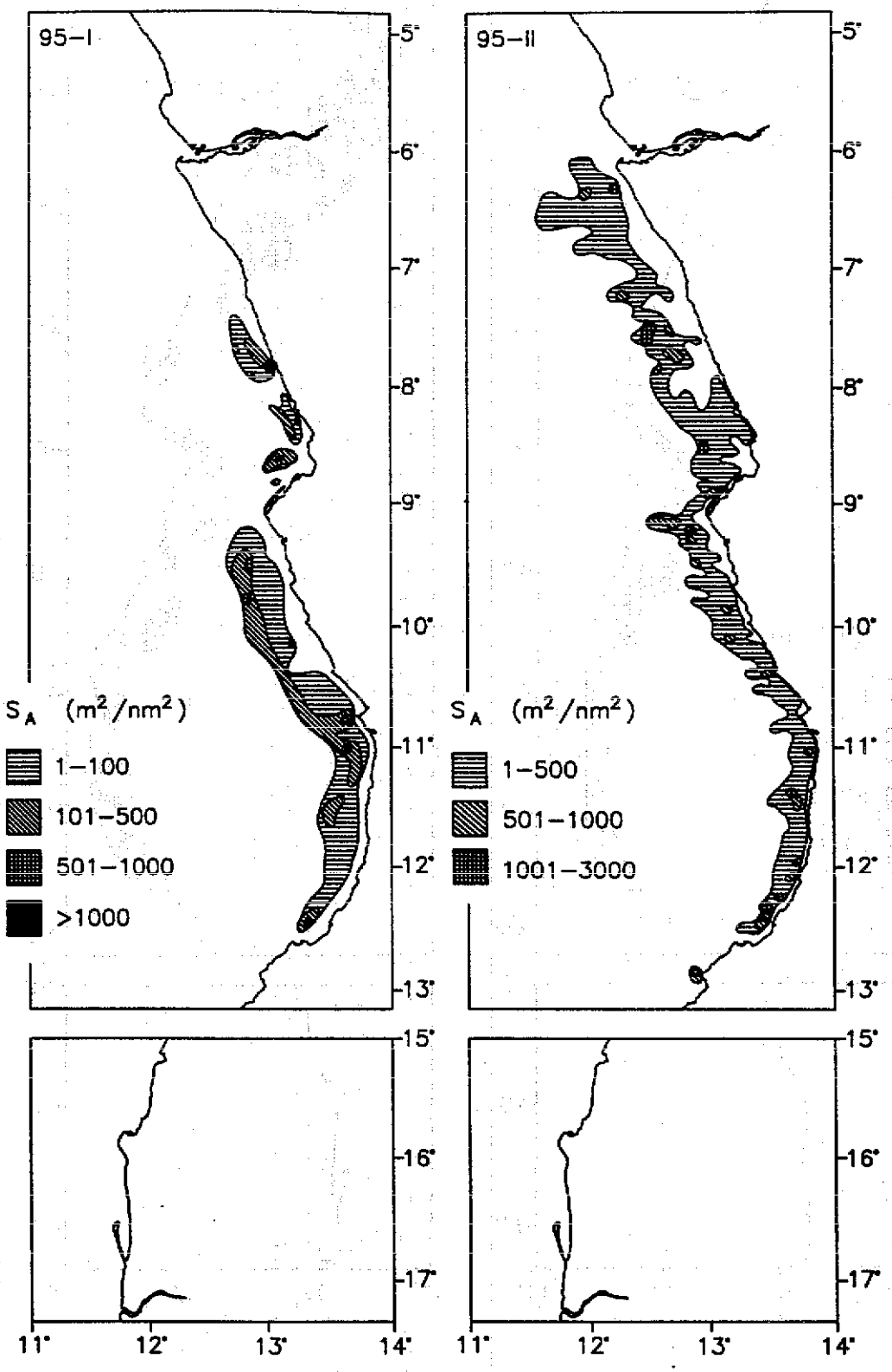


Figure 6. Distribution of acoustic recordings of sardinella off Angola in the summer (I) and winter periode (II) in 1995.

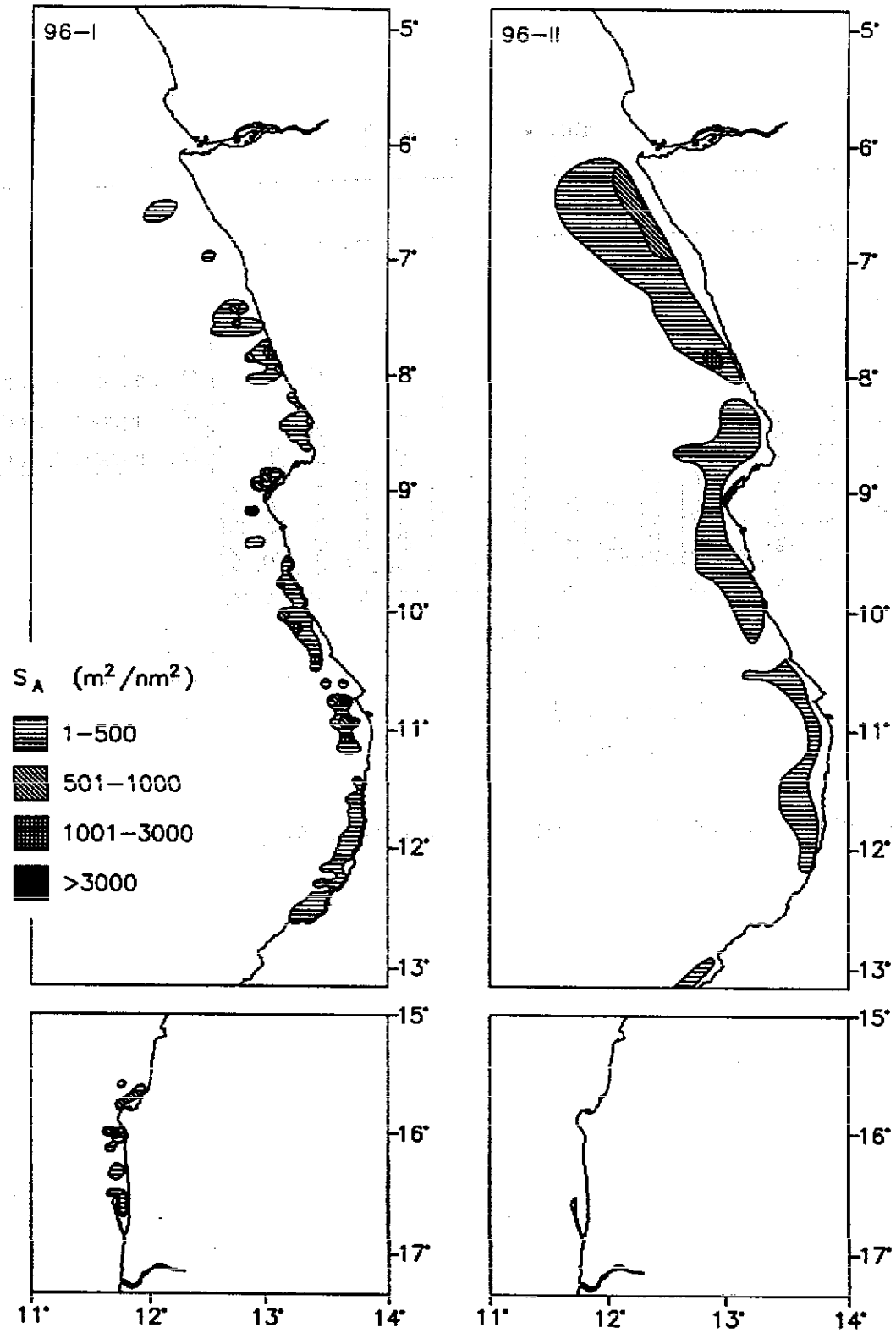
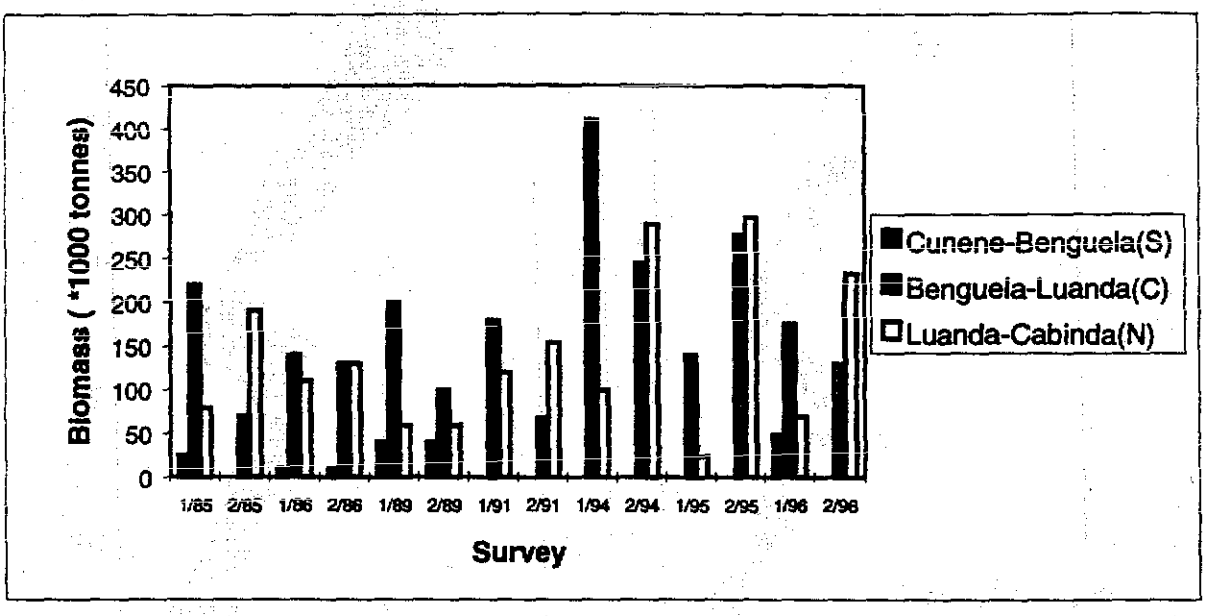


Figure 7. Distribution of acoustic recordings of sardinella off Angola in the summer (I) and winter periode (II) in 1996.



1 = summer period
2 = winter period

Figure 8. Survey estimates for sardinella off Angola 1985-1996.