SEASONAL MOVEMENTS OF SARDINELLA OFF SIERRA LEONE [a)]

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Abstract :

Three species of sardinella (*S. aurita*, *S. maderensis* and *S. rouxi*) occur in the waters of Sierra Leone, West Africa. Previous publications suggest that these sardinella migrate part of the year to neighboring Guinea, thus being unavailable to craft fishing off Sierra Leone. Off Northwest Africa, the great change of sea surface (SST) temperature appears to be the main factor regulating fish migration; however, in Sierra Leone SST changes are small, thus there is not the same environmental signal for sardinella to move north- or southwards in order to remain within a given temperature range. Analysis of data from Russian research surveys undertaken during the years 1976 - 1990 off Sierra Leone reveals, on the other hand, a strong pattern of seasonal onshore - offshore abundance, which coincide with the alternance of the rainy and dry seasons. Decrease in salinity in the near-shore waters caused by fluvial run-offs is likely to be the main reason for sardinella to move to deeper offshore waters.

These findings have consequences for the management of the sardinella stocks off Sierra Leone, which may not be shared with neighboring countries, thus making their management less dependent of decisions taken outside of Sierra Leone.

Résumé :

Trois espèces de Sardinella (S. aurita, S. maderensis, S. rouxi) existent dans les eaux de Sierra Leone (Afrique de l'Ouest). Des travaux antérieurs suggèrent que les sardinelles migrent une partie de l'année en Guinée voisine., devenant donc indisponibles aux petites embarcations de pêche du Sierra Leone. Au large de la partie nord-ouest de l'Afrique, les changements considérables de

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température de la mer en surface (SST) parait être le facteur principal gouvernant la migration des poissons. Toutefois en Sierra Leone, les changements de SST sont faibles et donc il semble que les sardinelles ne reçoivent pas le même signal environnemental qui les fasse migrer vers le nord ou le sud pour rester dans les mêmes plages de température. L'analyse des données collectées par les croisières de recherche russes pendant les années 1976-1990 au large du Sierra Leone, montrent au contraire un clair schéma de répartition de l'abondance selon les saisons entre la zone du large et la zone côtière, qui coïncide avec l'alternance des saisons sèche et humide. L'abaissement de la salinité dans les eaux côtières , provoquée par la décharge des fleuves semble la cause probable du déplacement des sardinelles vers les eaux plus profondes du large.

Ces constations ont des conséquences pour la gestion des stocks de sardinelles du Sierra Leone, qui ne seraient donc pas partagés avec les pays voisins, et donc rendaient leur gestion moins dépendante de décisions prises à l'extérieur de ce pays.

1. Introduction

Sardinella form an important part of the Sierra Leonean fishery resources and are represented by three species: *Sardinella maderensis*, *S. aurita* and the less important *S. rouxi*. The artisanal fishery mainly exploits *Sardinella maderensis* which is caught with ring nets laid out from planked canoes in the shallow near-shore waters. Though reliable figures on total catch are not available, it is estimated that some 20,000 t of sardinellas are caught annually by the artisanal fishery. The industrial fishery operates further offshore and targets *S. aurita*, though *S. maderensis* and to a lesser extent *S. rouxi* are also found in the catch of pelagic trawls and purse seiners. Overall, the purse seiners operating in Sierra Leonean waters in 1991 reported a sardinella catch of 8,500 t (Department of Fisheries, unpublished data).

A review of the migration pattern of sardinella along the West African coast by Garcia (1982) suggested that *Sardinella maderensis* performs anti-clockwise migration along the coast of Sierra Leone and Guinea, which would make them largely unavailable to the fishery off Sierra Leone during the months of June to August. Garcia (1982) was less specific about the migrations of *S. aurita* and suggested two possible patterns for the stock occurring off Sierra Leone: i) it is part of a larger stock with a distribution ranging from Guinea Bissau to the Sierra Leonean/Liberian border in the south and ii) it represents a separate stock («Sherbro Stock»), with a northern limit in Guinean waters and a migration pattern similar to that of *S. maderensis*, the existence of which would require joint management between Sierra Leone and Guinea.

The aim of the present study is to test hypotheses derived from these proposed migration patterns, using data on the spatial distribution of *Sardinella* spp. in Sierra Leone waters generated during 14 years of Sierra Leone/USSR research surveys carried out between 1976 and 1990.

2. Material and Methods

Temperature

Monthly time-series of average sea surface temperature (SST) were extracted from COADS (Comprehensive Ocean-Atmosphere Data-Set) for the years 1950 to 1990, consisting of weather observations collected by merchant ships over the world oceans (Woodruff *et al.*, 1987). The extraction was made with the help of the database and software developed for the CEOS program (Bakun *et al.*, 1993) for the area along the West African coast from 22°N to 7°N (Fig. 1).

Abundance

Regular resource surveys of the Sierra Leonean stocks were carried out from 1976 to 1990 in the frameworth of an agreement between the Republic of Sierra Leone and the then USSR; the latter provided a research vessel, while the scientific crew was a joint Sierra Leone/USSR team. The surveys were carried out with both bottom and pelagic trawls; the bottom trawl hauls usually lasted for half an hour, while the pelagic hauls were of varying duration. Data recorded for each haul/station were: vessel's position, time and duration of fishing haul, and - for each species separately - total number, total weight, size range, sex, and maturity stage. The original data sheets were kept at the Institute of Marine Biology and Oceanography (IMBO) of Fourah Bay College, the University of Sierra Leone, Freetown.

A joint IMBO/ICLARM project was launched in 1991 to analyze these data, which were transferred into a relational database and a computer-based Low-level Geographic Information System (LL-GIS) called SIERRA (Vakily 1992).

The available relative abundance data for each species were grouped by season, as follows :

1.	January	-	March	Intermediate season, dry
2.	April	-	June	Hot season
3.	July	-	September	Rainy season
4.	October	-	December	Intermediate season, wet

Because the surveys were carried out with different gears, a direct use of catch per hour data as index of abundance would not have been appropriate. Thus, these data were standardized using the following procedure :

a) For each cruise, the data were grouped by gear (if more than one gear was used) and by species ;

b) In each gear/species group the range between 0.01 kg and the maximum catch per hour was divided into six classes of equal size, ranked from 1 to 6 ;

c) In each gear/species group, the individual catch per hour records were classified according to the grouping defined in (b) and the corresponding class rank assigned to the record ;

d) For each cruise, all stations where fishing took place but no sardinella catch was made were assigned a rank of zero;
e) For each sardinella species, date and geographical reference (latitude and longitude at start of the trawling station) were used to extract all records that fell within a defined season (irrespective of the year), and arrange them within a 15 by 15 nautical minutes grid;
f) For each season, the values obtained under (c) and (d) were averaged within each grid as defined in (e) to obtain a species-specific mean ranks, used here as index of relative abundance.

3. Results and Discussion

The mean annual sea surface temperature (SST) off Sierra Leone as derived from COADS (Fig. 2) is 27.7°C, the seasonal amplitude is small, less than 2°C. The annual cycle is characterized by a balanced semi-annual pattern, closely related to the alternating climatic influence from the North during winter and from the South during summer. Maximum values are observed in May and December and minimum values in February and August. The latter correspond to the prevalence of the Sahara-born «Harmatttan» wind and the height of the rainy season, respectively.

Figure 3 represents a time-latitude diagram of the mean annual cycle of SST along the West-African coast from 7°N up to 23°N, illustrating the prominent variation of SST at higher latitude compared to Sierra Leone (7°N to 9°N); also shown on Fig. 3 is the seasonal distribution of *Sardinella aurita* along the Senegalese/Mauritanian coast, based on data of Garcia (1982) and Cury & Fontana (1988). It depicts a migratory route that is closely linked to the annual SST cycle, and which results in *Sardinella aurita* being absent from certain part of the Senegalese/Mauritanian coast during at least part of the year.

If it is accepted that the migratory patterns of *S. aurita* off Senegal and Mauritania, where seasonal variation of SST are very large, are largely the result of attempts by the fish to remain within a range of preferred temperature (Longhurst and Pauly 1987), one can infer that the low amplitude of seasonal variation in SST off Sierra Leone would exerts little pressure on the local stock of *S. aurita* to undertake large migrations. This is exemplified by the straight line in Fig. 3 at 8°N latitude, representing the stationarity of *S. aurita* off Sierra Leone. This stationarity would not submit the fish to changes in SST larger than experienced by the migrating fish at higher latitudes.

S. maderensis is a coastal species occuring in a broad range of temperatures but sensitive to salinity change: it leaves the shore when salinity drops below 3.5 % (Postel 1960, Cury and Fontana 1988).

The coastal waters of Sierra Leone are divided into two distinct environments by Sherbro Island, 7°30"N, about mid-way between the Guinea and Liberian borders. The northern part represents a broad shelf, 40 to 70 miles wide; the major river systems of Sierra Leone discharge their waters into this area. During

the rainy season (July to September), about 250 cm of rain fall along the coast. The estuaries become diluted and extrude low salinity wedges which are held alongshore by strong southwesterly winds. During the dry season, especially when the «Harmattan» prevails, northeasterly winds push the low-salinity surface waters offshore, and this is replaced by higher salinity bottom waters, thus generating a small upwelling along the northern coast of Sierra Leone.

South of Sherbro Island, the shelf narrows down to around 30 km. It is less influenced by river discharge during the rainy season, as Sherbro Island forms a natural barrier against some of the freshwater outflow of the rivers further north. During the dry season, the strong Guinea current flowing southeast along the coast could be expected to generate a slight upwelling on its left (shore-ward) flank. Thus, it is not surprising that the analysis of the Sierra Leone/USSR survey data suggests two main, persistent areas of distribution for *S. maderensis* (Fig. 4): North of Freetown, close to the Guinea border and south of Sherbro Island. However, with the onset of the rains, the area of greater abundance of *S. maderensis* shifts from the coast towards the edge of the shelf, as illustrated in Fig 4. During January to March *S. maderensis* is evenly distributed throughout the shallow waters close to the shore, while in April to June, especially in the northern part of the Sierra Leone shelf, *S. maderensis* abundances are greater offshore. During the height of the rainy season, July to September, quite a number of grid squares along the 200/1000 m isobaths show an elevated density, indicative of the movement of *S. maderensis* to the edge of the shelf. At the end of the rainy season (October to December), the distribution reverts back to its normal with *S. maderensis* close to the shore.

It should be noted that the 15x15 nautical minutes squares of Sierra are too large to depict well inshore/offshore shifts of abundance in the southern part of Sierra Leone (south of Sherbro Island), where the shelf is only some 30 km wide, as one grid square can cover the whole area from the shallow waters to the 200 m isobath.

S. aurita generally prefers the deeper waters further offshore (Ben-Tuvia 1960, Cury and Fontana 1988). This is also apparent in the results of the Sierra Leone/USSR surveys, which show *S. aurita* to be more abundant in the deeper waters along the 40 to 200 m isobaths (Fig 5). The distribution differs from *S. maderensis* also in that *S. aurita* seems to be more restricted to the northern part of the Sierra Leonean shelf, being rarely found in large quantities south of Sherbro Island.

Similar to *S. maderensis*, the fairly broad distribution of *S. aurita* over the whole shelf area north of Sherbro Island during the dry season changes during the rainy season, when *S. aurita* is mostly found at the edge of the shelf, even though some substantial catches were also made in shallower waters along the Guinea border. After the rainy season (October to December) *S. aurita* moves closer inshore, especially south of Sherbro Island.

5. Conclusions

This investigation into the change in abundance of the two major *Sardinella* species off Sierra Leone found little evidence that these species migrates out of Sierra Leone waters during any part of the year.

On the other hand, our analysis of 14 year's worth of survey data reveals a strong pattern of inshore/offshore abundance shifts in close relation to the occurrence of the rainy season. From this we infer locally restricted migrations perpendicular to the coast, related to the avoidance of low salinity waters and the utilization of optimum feeding conditions during upwellings.

Though it can not be precluded that some of the sardinella in the northern part of the shelf near the northern border of Sierra Leone regularly move into Guinean waters and *vice versa*, this study does not support a migration pattern implying that the bulk of Sierra Leone's sardinella would migrate to Guinea (or Liberia) for a part of the year.

Notwithstanding that cooperation between neighbouring countries is generally advisable in marine resources management, its practical implementation has often proven difficult. The findings of the present study suggest that Sierra Leone can pursue the management of its sardinella stocks without having to give much consideration as to what is decided in the two neighboring countries.

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CAPTIONS OF FIGURES

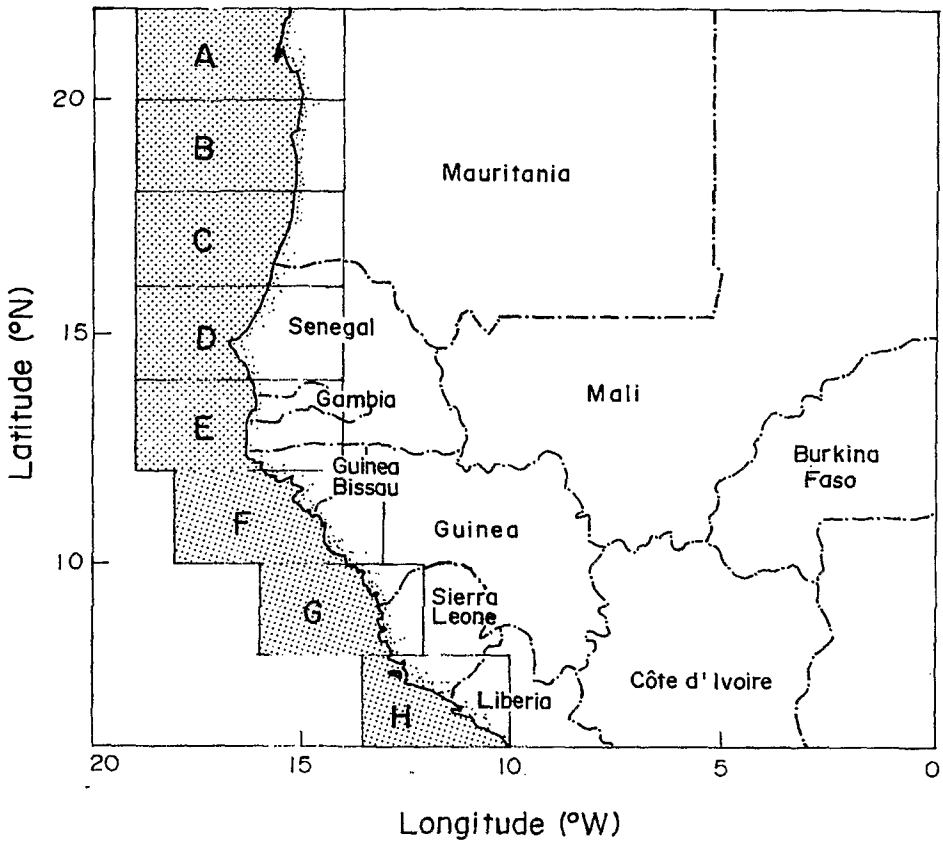
Figure 1 : Map of North Western Africa, showing the areas (A - H) used for aggregating the sea surface temperatures extracted from the COADS (courtesy of Dr. Claude Roy, ORSTOM).

Figure 2 : Mean annual cycle of sea surface temperature off Sierra Leone (7°N to 9°N and 11°W to 14°W), derived from the COADS, 1950 to 1990 (courtesy of Dr. Claude Roy, ORSTOM).

Figure 3 : Time-latitude diagram of the mean seasonal cycle of sea surface temperature along the Atlantic coast of Africa from 23°N to 7°N, based on data extracted from the COADS and averaged by month for the years 1950 to 1990 for the areas in Fig. 1. The seasonal distribution of *Sardinella aurita* off Senegal, described in Garcia (1982) and Cury and Fontana (1988), and off Sierra Leone, are superimposed.

Figure 4 : Distribution of *Sardinella maderensis* in Sierra Leone waters, averaged over three-months periods, from 1976 to 1990, based on standardized catch-per-effort data from successive Sierra Leone/USSR research surveys.

Figure 5 : Distribution of *Sardinella aurita* in Sierra Leone waters, averaged over three-months periods, from 1976 to 1990, based on standardized catch-per-effort data from successive Sierra Leone/USSR research surveys.



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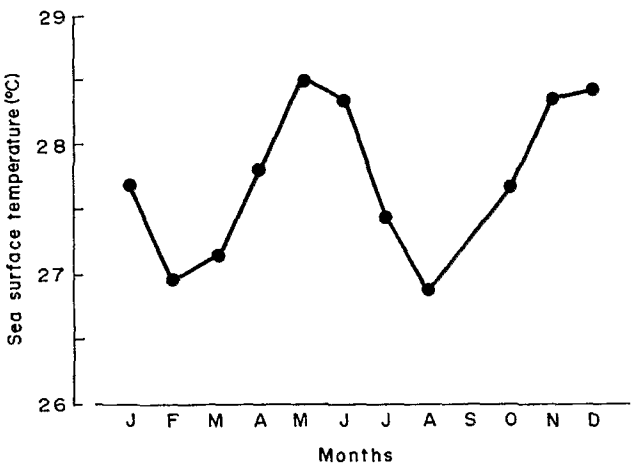

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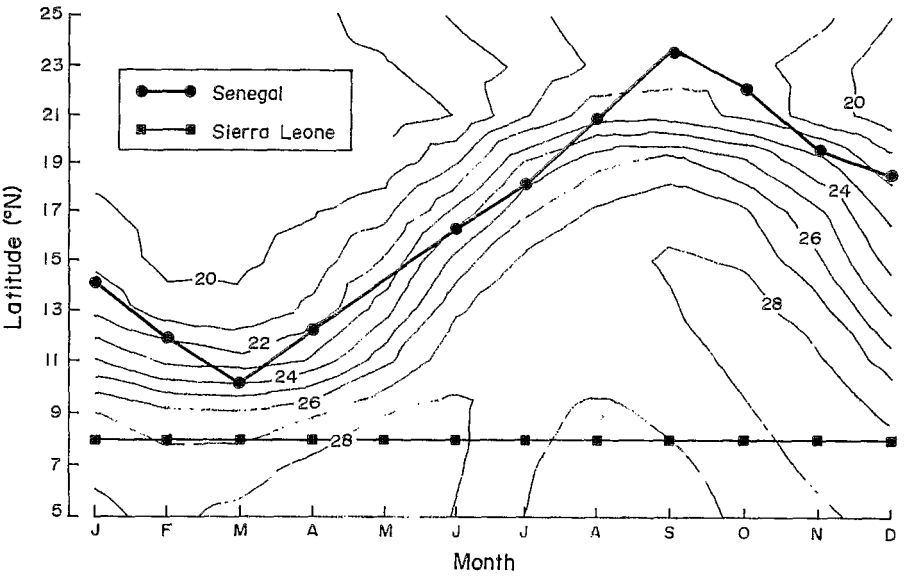

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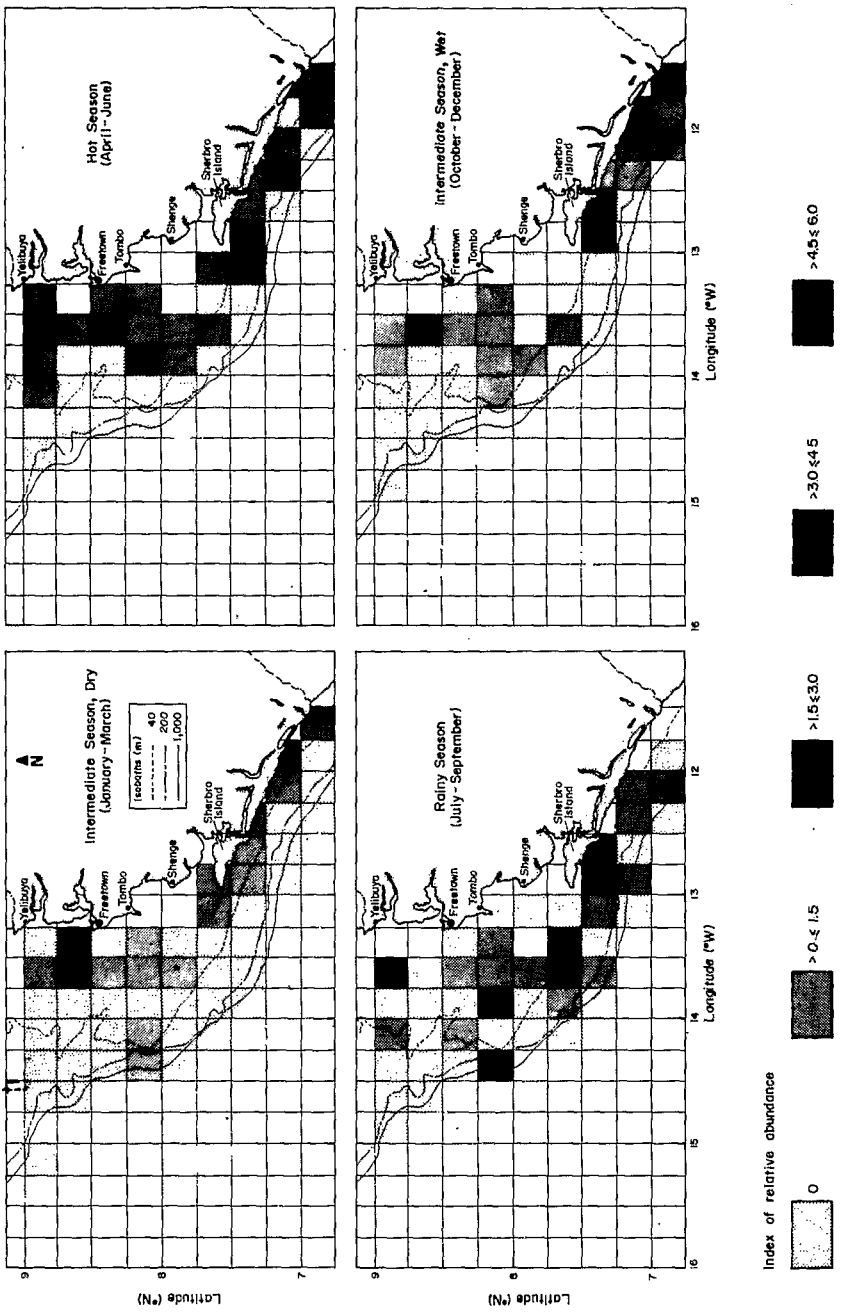

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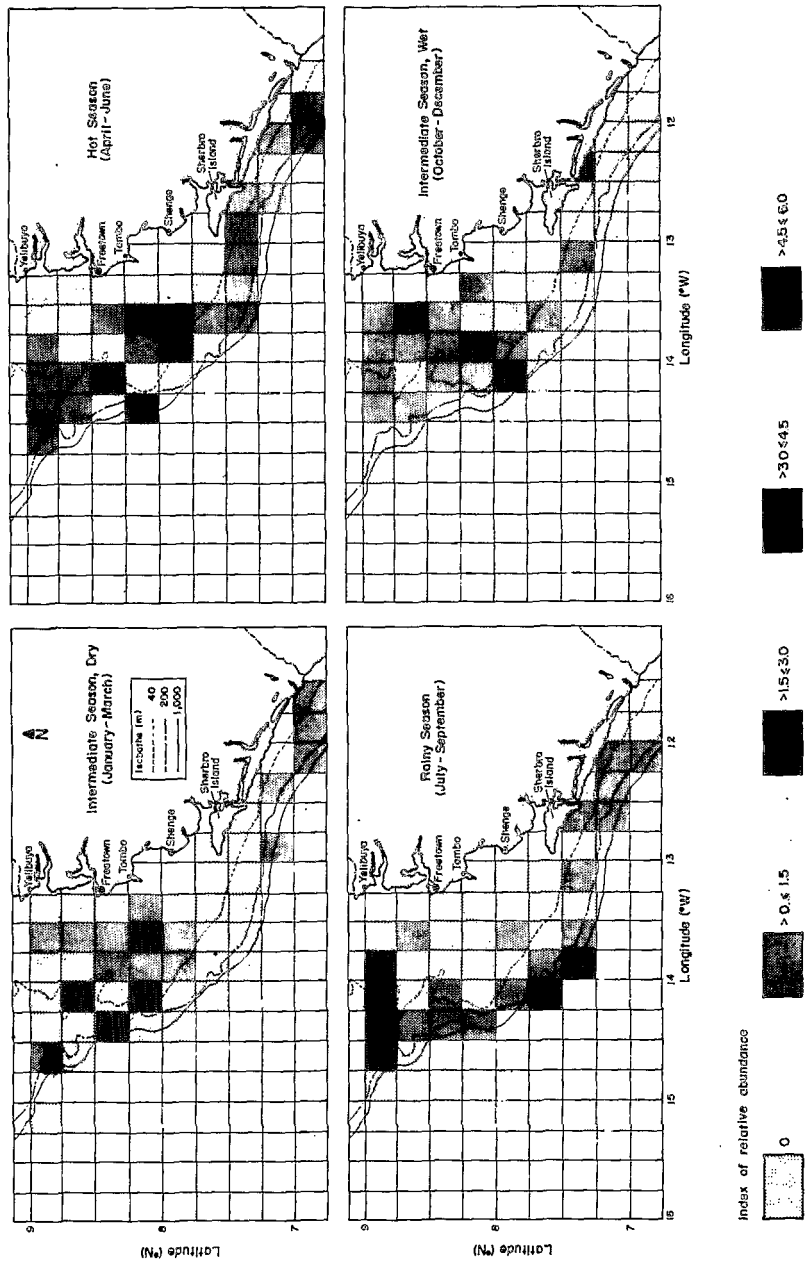

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