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PURSE SEINE TUNA FISHING AND ENVIRONMENTAL CONDITIONS IN THE SOMALI BASIN (0°-12°N , 43°E-60°E) AT THE CESSATION OF THE SOUTHWEST MONSOON

by

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INTRODUCTION

The effect of environmental process on tuna availability is being more and more considered in current population dynamics studies. Dynamic changes of oceanographic parameters could sometimes explain high variability in population abundance which is not predicted by production models. For instance, in Eastern Atlantic, during 1984 first half-year, abnormal high heat content of the surface layers and deep thermocline are now considered as a major cause of the drastic decline of purse seine catch rates, since few concentrations of tuna were sighted in the usual fishing grounds (FONTENEAU, comm. pers.).

With respect to tuna population, we could consider the environmental changes are likely to affect recruitment, availability and vulnerability to the fishing gears. Strong winds induce a mixing of the surface layers that disperse the planktonic preys, a basic food for juveniles tuna. In the Pacific Ocean, FORSBERG and MILLER (1978) evidenced a reciprocal relationship between the mixing index (cube of surface wind speed) and the cohort strength of skipjack tuna. In the other hand, El Nino event seems to induce a positive effect on larvae survival in the Eastern Pacific Ocean. High recruitment levels were observed in 1971, 1974, 1978 and 1985, while El Nino situations had occured 2 years before (IATTC, 1987). Beside the possible stock - recruitment relationships, variations in availability and vulnerability of tuna schools can be related with the current oceanic conditions, which is the purpose of this paper.

We analyse the fishing success recorded by purse seiners during the cessation of the southwest monsoon, in the Somali Basin, according to wind and temperature patterns observed in the fishery. Additional parameters measured during a recent cruise provide an general description of the hydrological conditions promoting concentration of tuna in this area.

1 - PHYSICAL AND BIO-CHEMICAL ENVIRONMENT

In Indian ocean, the Somali basin is the area where the stronger variability of oceanic parameters can be observed between the two main seasons, the northeast and the southwest monsoons. The former takes place from December to March, the latter from June to September. Therefore this region is of prime interest to study the effect of environmental conditions on biological production.

Several oceanographic cruises were carried out in the Somali basin in the past years. The major contributions are given by the International Indian Ocean Expedition (1964), the Global Atmosphere Research Programme (1979) and SINODE cruises (still on progress). The latest campaigns considered were made by two French vessels, a purse seiner MASCAROI (15-22 September 1987) and the R/V ALIS which completed the INDOTHON 01 cruise (1-17 October 1987). Main objectives of this cruise were to mark off the spread of waters upwelled along the Somali coast during the 3 previous months and to compare the fishing success of the purse seiners with the hydrological patterns. Complementary temperature measurements made in the area were provided by the TOGA subsurface data centre settled in Brest, France.

1.1 - General conditions

During the southwest monsoon, strong winds blow in the Western Indian ocean (speed over 20 knots). Along Somali coast, the wind stress induces an intense upwelling. That oceanic response is very quick at the onset of the monsoon; the sea surface temperature (SST) pattern is modified within one week. The lowest temperature recorded range from 13° to 17°C indicating these waters are upwelled from 100 to 200 m depth. The upwelling shows greater extension along the coast in two areas, 4°-5°N and 10°N (fig.1) where the surface currents are deviated offshore and create two anticyclonic gyres (fig. 2). The northern gyre is found between the two upwelled cold patches. The strong Somali current (up to 7 knots near Ras Asir) creates a sharp gradient of the geopotential topography from the shore to the open ocean. In July and August, along 10°N, the dynamic height increases as much as 50 cm within a short distance ,less than 600 nautical miles (WYRTKI, 1971). As a comparison, normal situation in Pacific ocean is 65 cm between 80°W and 160°W (7200 nautical miles) along the Equator. By the end of the monsoon, the wind stress decreases and the upwelling weakens. However, the northern gyre is still observed until the beginning of the following northeast monsoon (BRUCE et al., 1981).

The surface circulation has a great effect on subsurface thermal structure. Due to a convergence, the mixed layer is thick (thermocline at 120 m depth) in the middle of the gyre and becomes more reduced at the boundary (40 to 50 m depth). In post-upwelling situation, the thermal structure undergo a great change. A monthly analysis made from August to November along 3 latitudinal belts (from 0° to 10° N) shows that both depth of mixed layer and depth of maximal thermal gradient drastically rise up in September and October, while occurs the wind relaxation (fig.3).

The nutrient and planktonic distributions are closely related with the upwelling activity. In 1979, maximum nitrate and chlorophylle-a contents were measured within the coastal cold patches. The greater development of total biomass including zooplankton was located on the south bound of the northern gyre. These various distributions are summarized in fig.4.

1.2 - Conditions met in September-October 1987

The two cruises considered took place during the cessation of the summer monsoon. A wind relaxation occured by the end of September south of 6°N but surface conditions were rather similar in the northern region. A clear evidence of a remaining upwelling activity at 11°N appears in fig.5, whereas the south patch (4°-5°N) had already disappeared. On the equator, high sst was measured (over 30°C). This observation was confirmed on TOGA biweekly analysis temperature maps and a 2°C positive anomaly was estimated. The northern gyre is well depicted by surface drift and topography of the 20°C isotherm (fig.6). The converging transport caused an intense deepening of the thermocline. An XBT section made between 12°N - 52°E and 10°S - 50°E (fig.7) shows the great variation of the depth of mixed layer at 10°N and 3°N, respectively north and south bounds of the gyre. Along the coast, salinity of the upwelled waters partially originating from intermediary antarctic waters was less than 35.4 ‰. Surface salinity increased drastically towards the east where it reached values in excess of 36.2 ‰, probably due to prevailing evaporation over rainfall in the Arabian Sea. Between 10°N and 12°N, a sharp saline gradient is associated with the thermal front caused by the upwelling (fig.8).

The highest dissolved oxygen levels (4.2 ml/l) and the lowest nitrate contents (<5 µatg/l) at 100 m depth were found in the gyre (fig.9). The piling up of surface waters induces a deepening of both oxycline and nitracline. Plumes with high nitrate contents (> 20 µatg/l) were observed east of the gyre (fig.10). Chlorophylle-a concentration remained below 0.8 mg/l in the whole area and no major gradient was noticeable, a consequence of the wide dispersion of phytoplanktonic cells by the currents during the monsoon. Bulk of zooplankton was concentrated in the gyre (average : 2.7 g.dry/m2 , in 0-200 m layer), which is similar to the patterns depicted in 1979. Oligotrophic conditions prevailed east and south of the surveyed area (fig.11).

2 - THE PURSE SEINE FISHING ACTIVITY

In the Somali basin, purse seine fishing activity starts by mid -August and lasts until November (fig.12). The catch rates recorded by the fleets are among the highest in the year (25 to 35 t/day, on a fornightly basis). Except during the latest fishing season (1987), the highest cpue are observed in October. 90% of the catch are made on drifting logs. The months of September and October represent 20% to 27% of the total catch of the year (i.e. more than 25 000 mt). The dominant species is skipjack tuna.

In purse seine tuna fishing, the wind is a severe limitation since handling the net in rough sea is tough and dangerous for the crew. We computed boat-day statistics (maximum catch, maximum number of sets, mean catch, mean number of sets) considering the whole fleet and compared them with regard to wind strength. Results in Table 1 show that the gross fishing activity explained by the catch and the number of sets globally decreases when the wind strengthens. With respect to the catch, a drop off occurs for wind in excess of 10 knots. The variance is strong in windy condition, that reflects more and more hazardous success is expected as the sea becomes rougher and rougher. During the cessation of the monsoon, the operational capability of the fleet is improving week after week.

3 - ANALYSIS OF CATCH RATES VERSUS SURFACE AND SUBSURFACE CONDITIONS

3.1 - Environmental parameters

We consider three parameters: surface wind speed, sea surface temperature and depth of thermocline. With respect to the two first ones, a common source of data is the message ships provided by merchant vessels through Global Telecommunication System (GTS). However, we prefered the similar data collected on board purse seiners because they show a better homogeneity and they depict quite accurately the surface conditions at the time and location of fishing operations. The records are made once or twice a day by each fishing vessel. Subsurface data come from XBT launches made by the purse seiners themselves and from a historic data collection based on several thousands of vertical profiles (XBT, CTD and others).

3.2 - Abundance and fishing success indices

Two major parameters are analysed : catch per set and catch per successful set. They reflect different aspects of the resource availability status :

- the catch per set is a gross index of the actual availability of tuna; it does not incluse the vulnerability of the schools to the gear since all sets are considered.
- the catch per successful set explains the school size or at least, the catchable part of the schools, and takes into account their vulnerability.

These factors are calculated for log-schools fishing activity which contribute to 90% of the total catch and also for both log and free-schools catch combined.

3.3 - General trend

The surface oceanic and fishing data are first distributed into 5° quadrangle / 2 weeks strata in order to obtain mean values for each parameter in each stratum.

A first glance at fig.13 points out 1)a reciprocal relationship between wind speed and SST at the cessation of the monsoon (the wind weakens and the SST increases as the upwelling disappears) and 2)non linearity between fishing and environmental parameters that reveal the concept of optimal environmental window promoting fishing success.

3.4 - Fishing success - surface conditions regression analysis

Because of non normal distributions and the use of semi - quantitative scale for the wind (Beaufort), Spearman rank correlation coefficients were choosen. The maximum yield (60 t/set) is recorded in the quadrangles no 7 and 8 where a higher upwelling intensity prevails during the monsoon (fig.14). The catch per set trend is very different from one quadrangle to another.

Two kinds of correlation are calculated: 1)direct correlations between fishing and surface parameters in the same space and time stratum and 2)cross correlations including a 2 weeks time lag between the variables in the same 5° quadrangle (i.e. SST and wind speed at fortnight Q versus catch rates at fortnight Q+1). Results are exhibited in Table 2.

Direct correlations lead to a single significant result between global catch per set (log-schools + free-schools) and SST. Catch per set is negatively related to the SST. All other combinations remain without any correlation. In the other hand, cross correlations are highly significant ($2.5\% < \alpha < 1\%$) with catch per set and catch per successful set. They indicate that burst of wind and surface cooling enhance the production 2 weeks later. Inversely, wind relaxation and associated surface heating are followed by a decrease of the available resource and the school size.

3.5 - Optimal environmental window of surface conditions for fishing success

A tridimensional representation of catch per set and catch per successful set (grouped into 10 t classes) versus wind speed and SST depicts an optimal range of surface conditions enclosing the maximum occurence of each yield class. The ridge extends between 25°C and 27°C in temperature and between 2 to 3 Beaufort in wind (fig.15).

Another delimitation of the optimal environmental window is shown in fig.16. The whole dotted area contains the catch per set values in excess of 40 t : this estimate of the maximum available resource narrows along the fishing season. The dark area includes the catch per successful set higher than 50 t. The concentration in large schools is mostly observed with SST ranging from 26°C to 27°C and wind strenght from 1 to 3 Beaufort (3 to 10 knots).

3.6 - Effect of subsurface conditions

We already pointed out that the peak catch rates in the whole area are recorded during September and October, when the variation of the depth of mixed layer and the depth of maximal thermal gradient in the thermocline is the strongest. Both factors undergo a drastic rising up to the surface which is likely to be related with the weakening of the convergent gyre at the beginning of the inter-monsoon.

Additional observations are to be noticed when comparing the fishing results obtained in September and October 1987 with the sub-surface hydrological features described during MASCAROI and INDOTHON 01 cruises. Catch per set are plotted by 30 nautical miles strata during 3 fortnights, from 16th of September until 31st of October (fig.17). The most productive grounds (catch/set > 100 t) are located between 3°N and 5°N, from 50°E to 54°E. The main bio-physical characteristics of this area are :

- a sharp rising up of thermocline from north to south, at the southern bound of the gyre (cf. fig.7); a stronger gradient was measured between 9°N and 10°N but unfortunately, has not been surveyed by the seiners ;
- high dissolved oxygen content (4 ml/l at 100 m depth - cf. fig.9) ;
- maximum zooplanktonic biomass in the layer 0-200 m which is the common feeding habitat of tuna (cf. fig.11).

Then, bulk of the vulnerable resource is concentrated in a boundary habitat where physical parameters vary greatly within rather short distance. Being aware of oxygen requirements of tuna (SHARP, 1979) and especially those of skipjack tuna (above 3 ml/l) that contributes to most of the catch, it is not surprising to record there greater catch rates than in ajacent waters. Currents dispersing the coastal phytoplanktonic blooms generated by the upwelling, and frontal system created on the bounds of the Somalian whirl promote the development of trophic chains.

CONCLUSION

This study highlights the positive effect of unstable environmental conditions on tuna concentration process and the fact that time lags must be considered to explain some part of the variability of catch from hydroclimatic evolution. Intensity of variations in oceanic properties by unit of time (i.e. derivative functions) seem appropriate to understand short term availability and vulnerability fluctuations of the resource.

The application of these findings can contribute to the delimitation of potential fishing grounds in an oceanic region. For example, in the Somali basin, it may be of great interest to monitor the surface parameters in real time by using satellite infra-red measurements (for SST) and data gathered by merchant ships and broadcasted through the GTS (for surface drift, wind and vertical thermal profiles). The combination of all these sources enables the estimation of the actual hydroclimatic context and the comparison with regard to the defined optimal environmental window. In final analysis, areas containing the best compromise between SST and wind speed can be identified and the information sent to the fleet.

However, several past experiments have shown that accurate prediction of tropical tuna fishing grounds still remains uncompleted. The proportion of variance not explained by models is important. Extensive researches on bio-chemical and physical environment of tuna must go forward to improve the actual knowledge, in order to have a better understanding of the complex processes leading to huge agregation of pelagic fishes in certain regions.

REFERENCES

BRUCE, J.G., M. FIEUX and J. GONELLA, 1981. A note on the continuance of the Somali eddy after the cessation of the southwest monsoon. Oceanol. Acta, 4(1): 7-9

FORSBERGH, E.D., and F.R. MILLER, 1978. Skipjack and the wind mixing index. Ann. Rep. IATTC : 5 p.

IATTC, 1987. Annual Report, 264 p.

SHARP, G. D., 1979. Areas of potentially successfull exploitation of tunas in the Indian Ocean with emphasis on surface methods. Rome, FAO, IOFC/DEV/79/47 : 55 p.

SWALLOW, J.C., et M. FIEUX, 1982. Historical evidence for two gyres in the Somali current. J. Mar. Res., 40 Suppl.: 747-55

WYRTKI, K., 1971. Oceanographic atlas of the International Indian Ocean Expedition. Washington, D.C., National Science Foundation, 531 p.

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Table 1 - Boat-day fishing statistics versus wind strength in the Somali basin, from August to October (1983-87).

WIND STRENGHT (Beaufort)	CATCH/BOAT-DAY			NO SETS/BOAT-DAY		
	MAX.	MEAN	ST.DEV	MAX.	MEAN	ST.DEV
1	110.3	53.4	17.5	2.1	1.5	0.3
2	83.9	50.3	14.9	2.2	1.5	0.3
3	90.0	45.4	26.7	1.8	1.3	0.5
4	57.8	34.8	19.5	1.5	1.3	0.1
5	57.5	41.2	23.0	1.0	1.0	0.0

Table 2 - Regression analysis between surface conditions and catch rates, in Somali basin (1983-86).
Spearman correlation coefficient.
Catch rate 1 : catch per set
Catch rate 2 : catch per successful set

a) direct correlations

		CATCH RATE 1	CATCH RATE 2
LOG CATCH	sst	- 0.281	- 0.228
	wind	0.247	0.178
ALL CATCH	sst	- 0.419 *	- 0.275
	wind	0.290	0.199

a) cross correlations

		CATCH RATE 1	CATCH RATE 2
LOG CATCH	sst	- 0.479 **	- 0.423 *
	wind	0.582 **	0.543 **
ALL CATCH	sst	- 0.462 *	- 0.399 *
	wind	0.517 **	0.530 **

Significance levels : (*) 2.5 % (**) < 1%

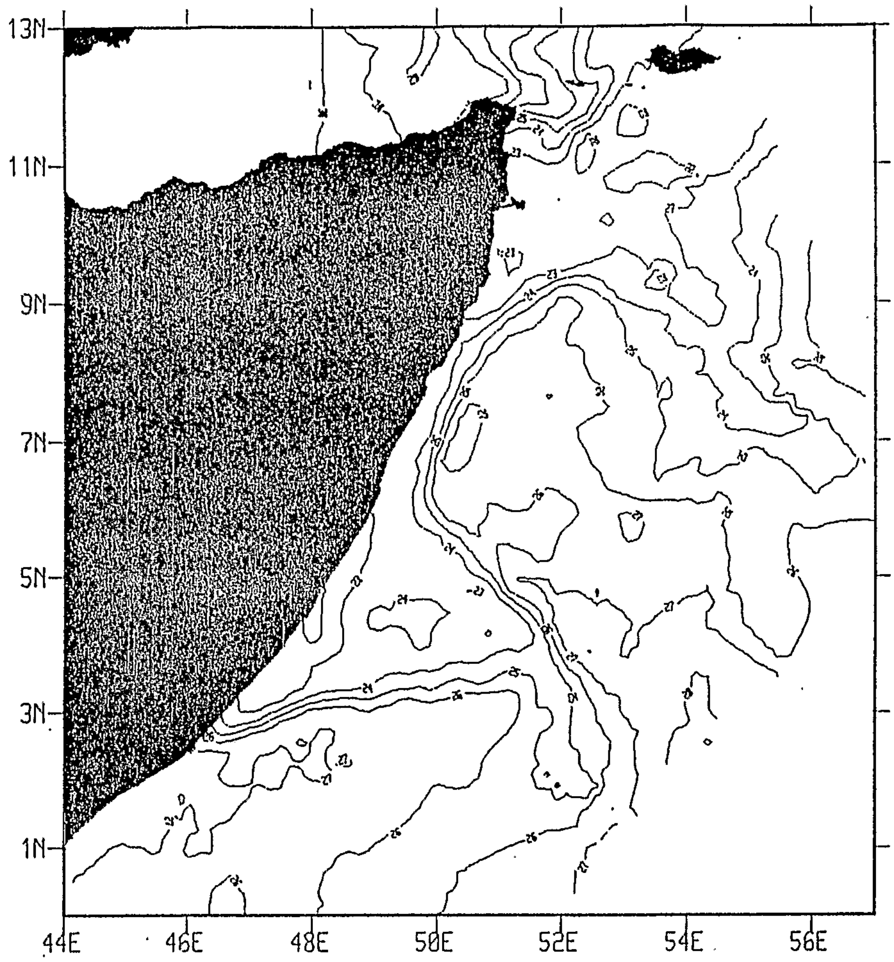


Fig.1 - Estimated SST off Somalia based on satellite infrared data (NOAA-9) and in situ measurements, from June 8 to 15, 1985.

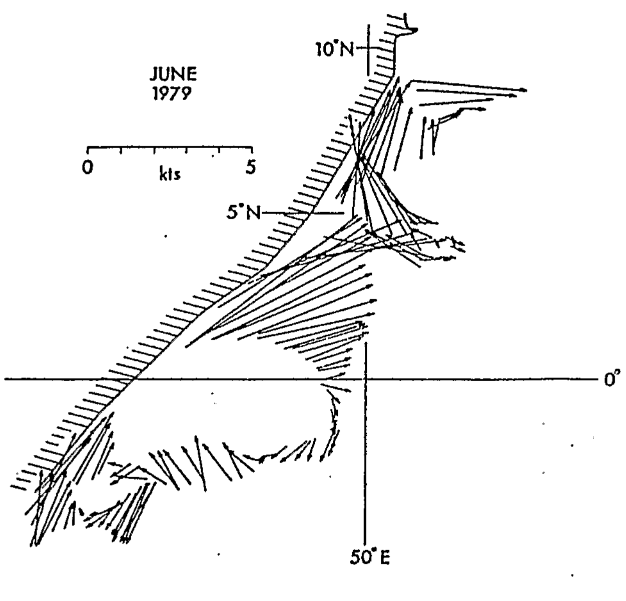


Fig.2 - Surface currents observed by the R.R.S. Discovery in the Somali basin in June 1979. The center of each arrow is at the midpoint of observations (from Swallow and Fieux, 1982).

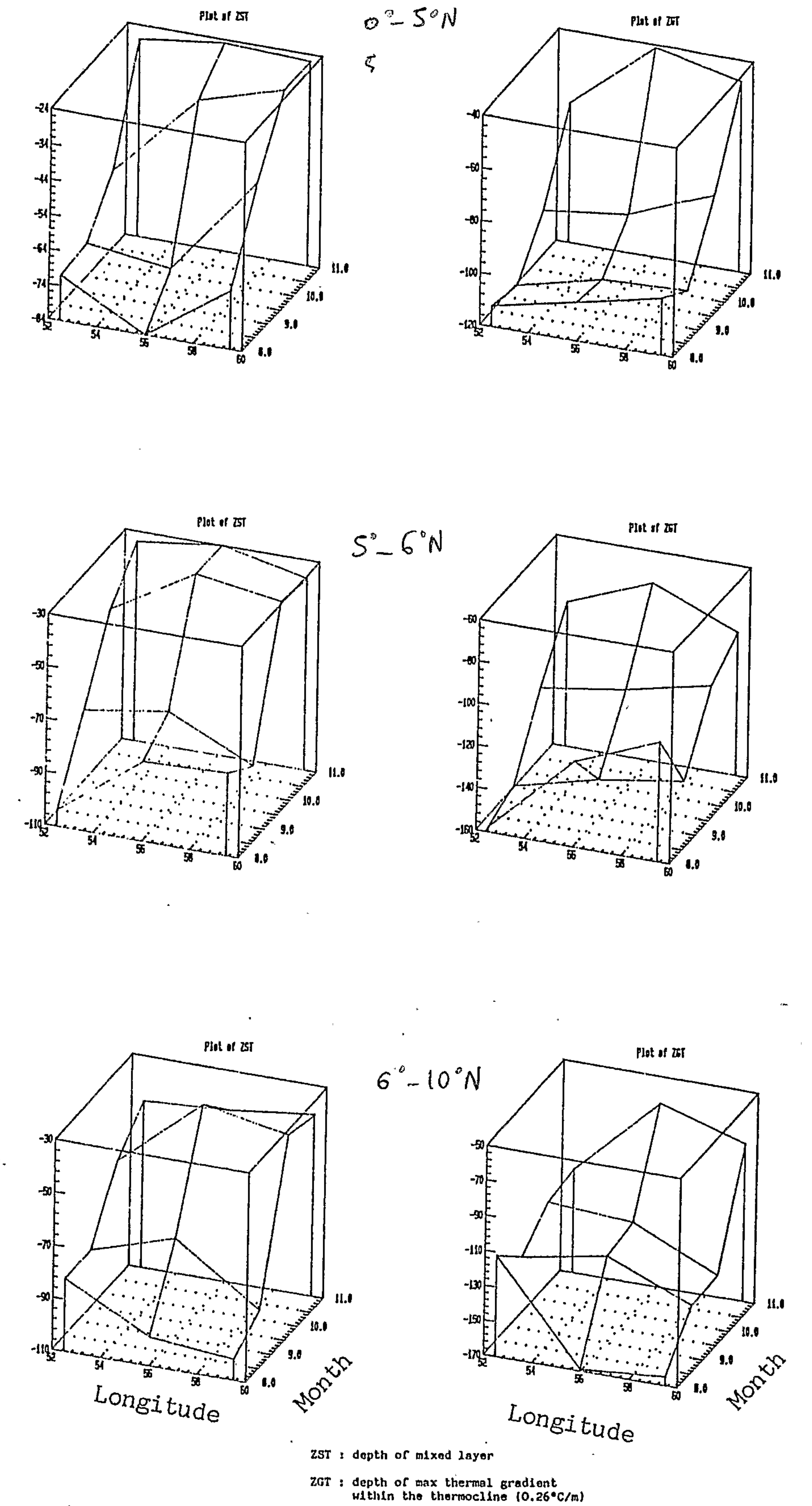


Fig.3 - Depth of mixed layer and depth of maximal thermal gradient variations from August to November, in the Somali basin.

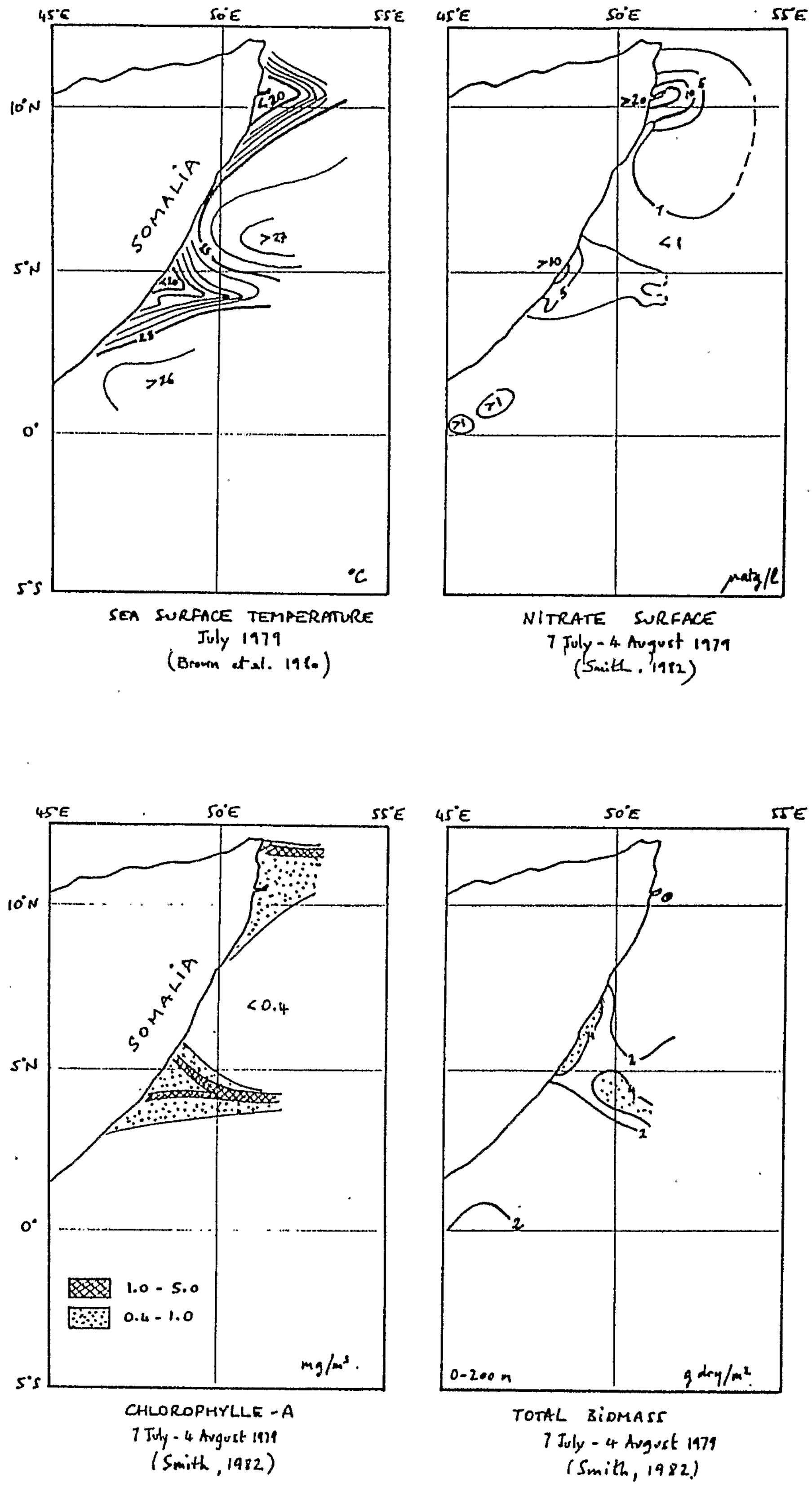
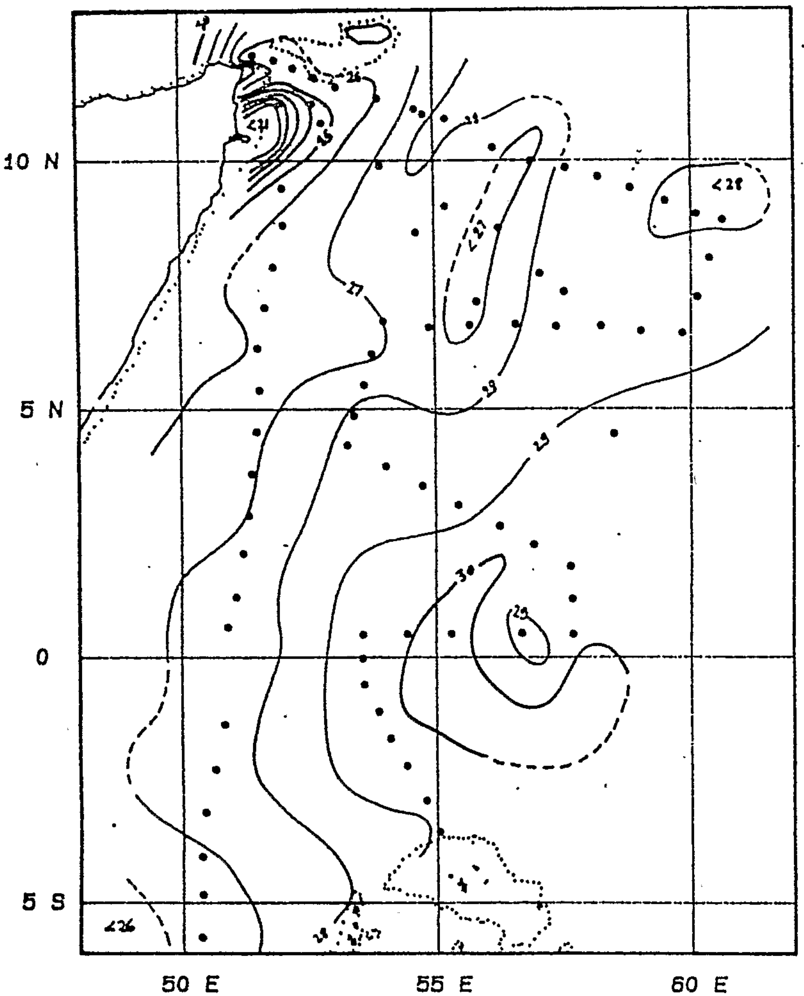


Fig.4 - Physical and bio-chemical characteristics of the Somalian upwelling.



ig.5 - SST (in °C) measured in September-October 1987 during MASCAROI and INDOTHON 01 cruises.

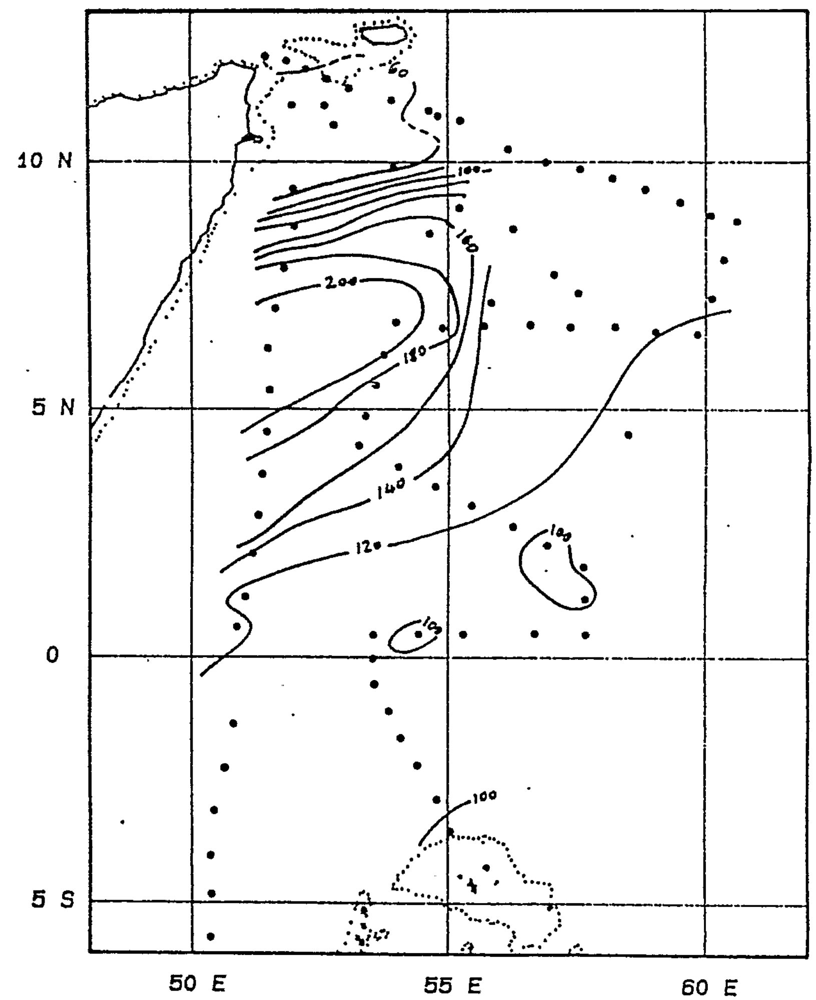


Fig.6 - Topography of 20°C isotherm in September-October 1987.

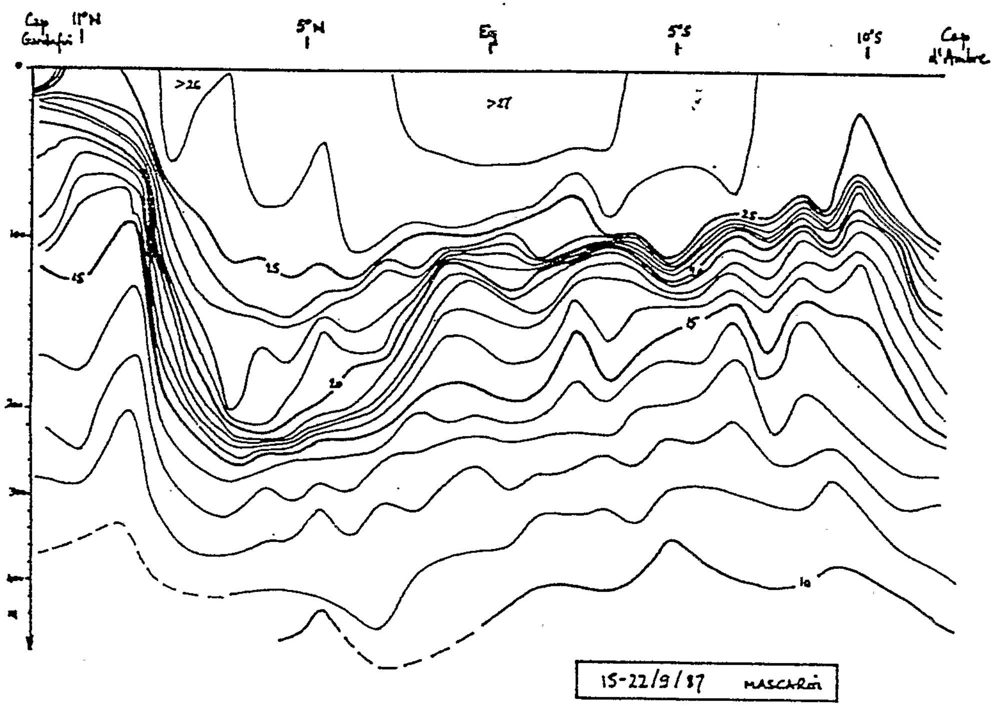


Fig.7 - North-south temperature section from Cape Gardafui (Somalia) to Cape Amber (Madagascar), between September 15 and 22, 1987 (MASCAROI cruise).

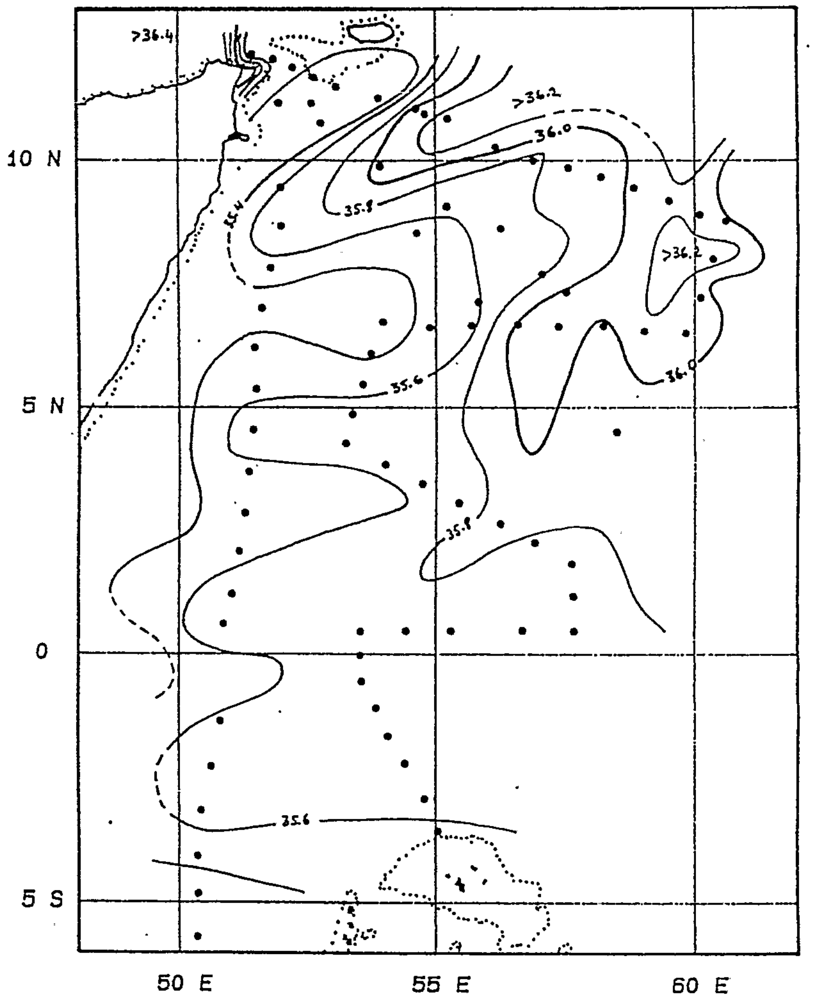


Fig.8 - Surface salinity (in part per thousands) measured in October 1987, during INDOTHON 01 cruise.

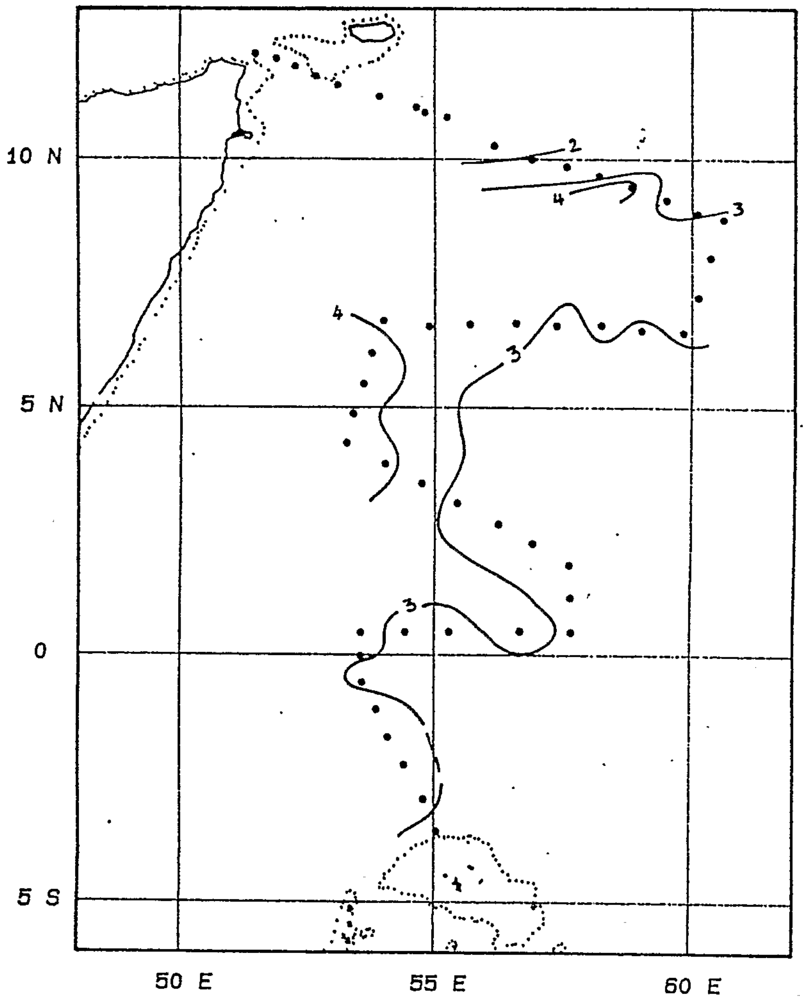


Fig.9 - Dissolved oxygen content (in ml/l) at 100 m depth measured in October 1987, during INDOTHON 01 cruise.

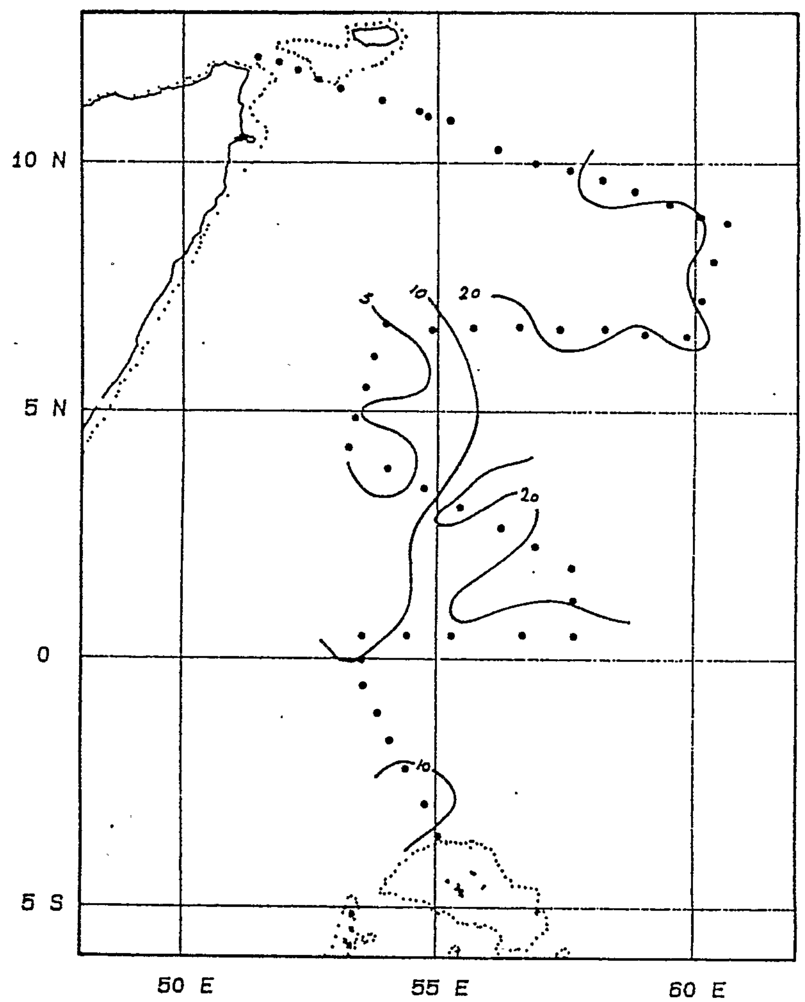


Fig.10 - Nitrate content (in µatg/l) at 100 m depth measured in October 1987, during INDOTHON 01 cruise.

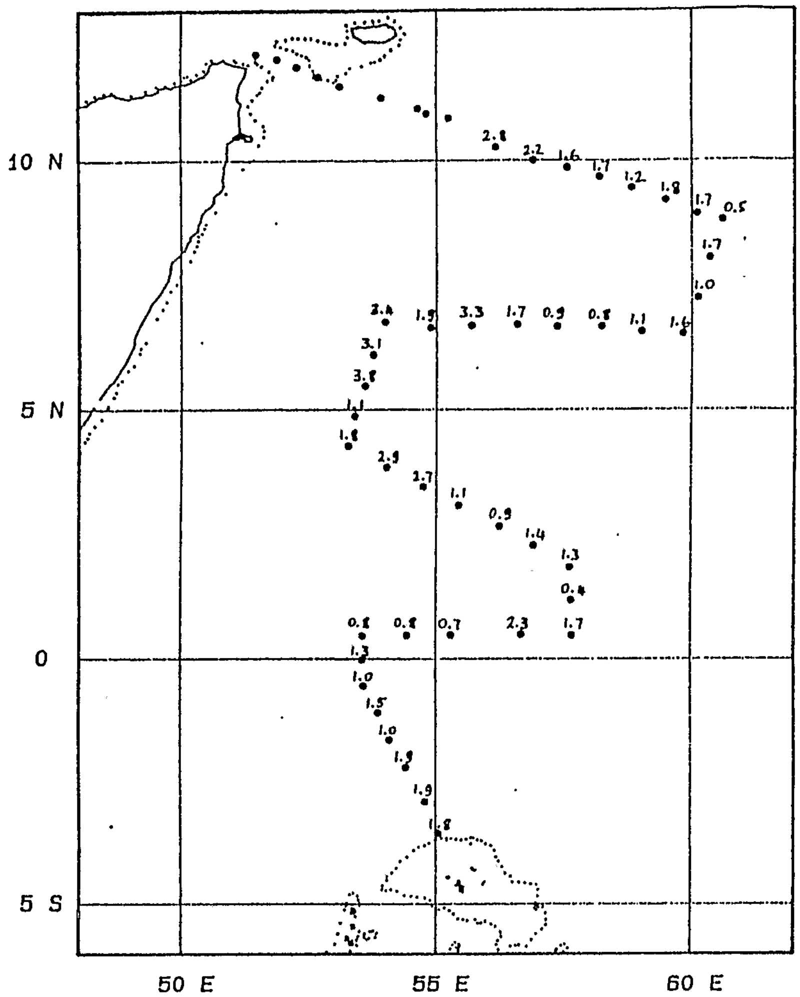


Fig.11 - Total biomass (in g.dry/m2) in the layer 0-200 m measured in October 1987, during INDOTHON 01 cruise.

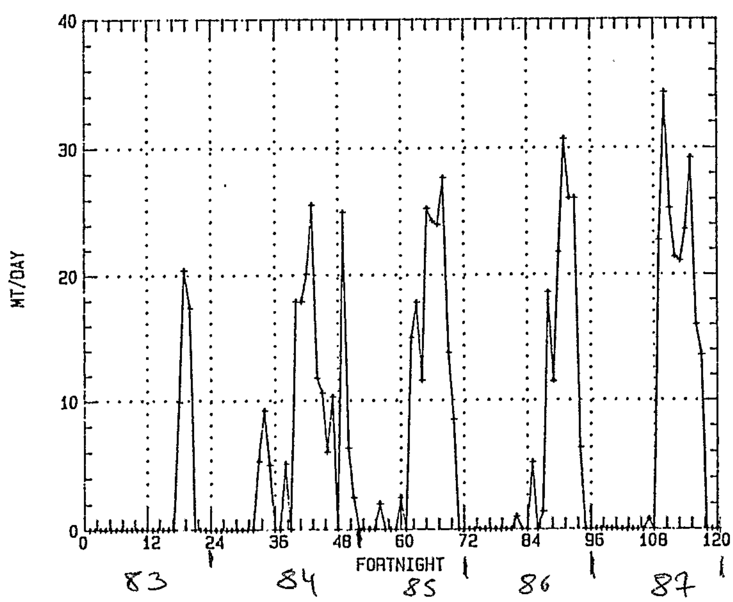


Fig.12 - Purse seine CPUE by fortnight (average 1983-1987) between 0°-8°N and 48°E-60°E.

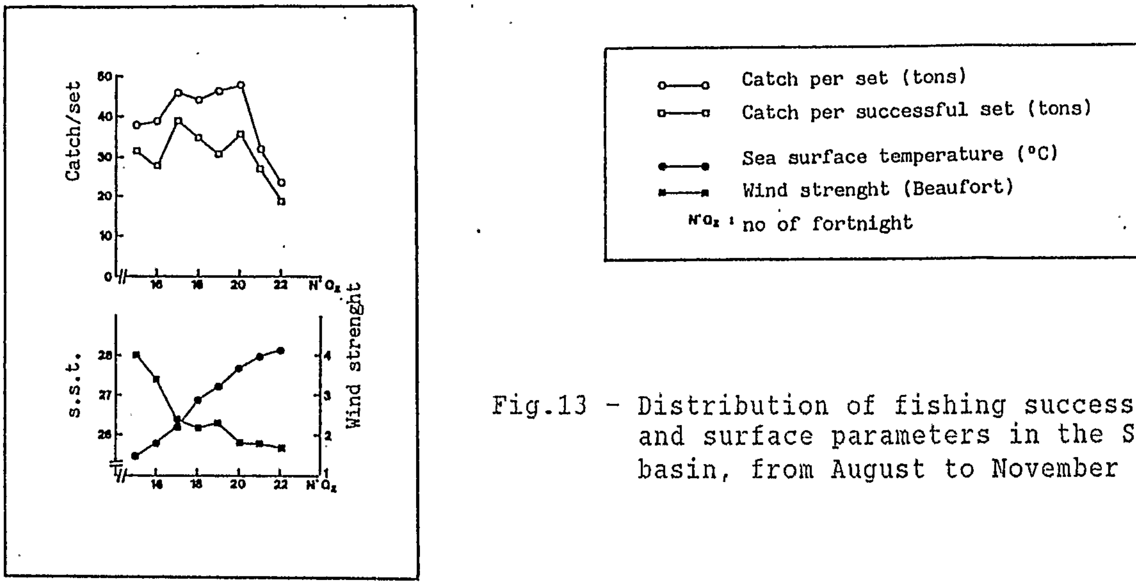


Fig.13 - Distribution of fishing success and surface parameters in the Somali basin, from August to November (1983-1987)

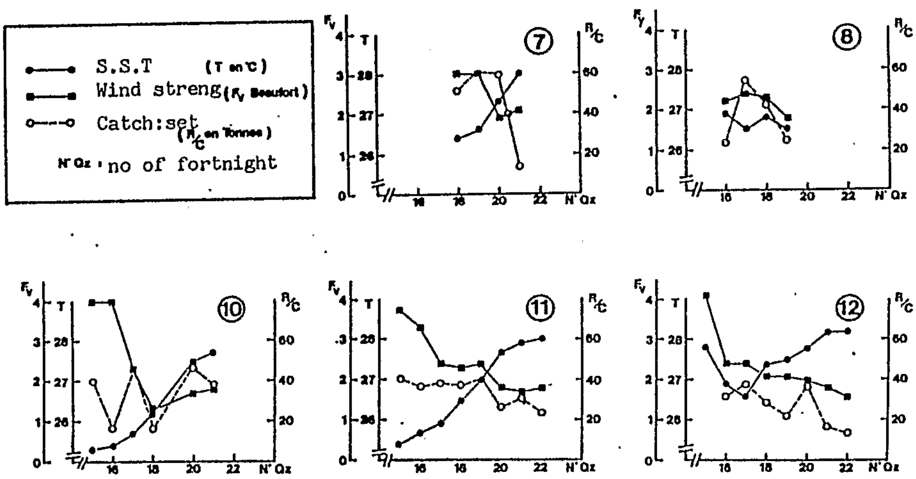
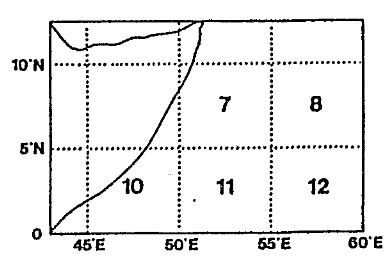


Fig.14 - Distribution of fishing success and surface parameters per 5° quadrangle in the Somali basin, from August to November (1983-1987).



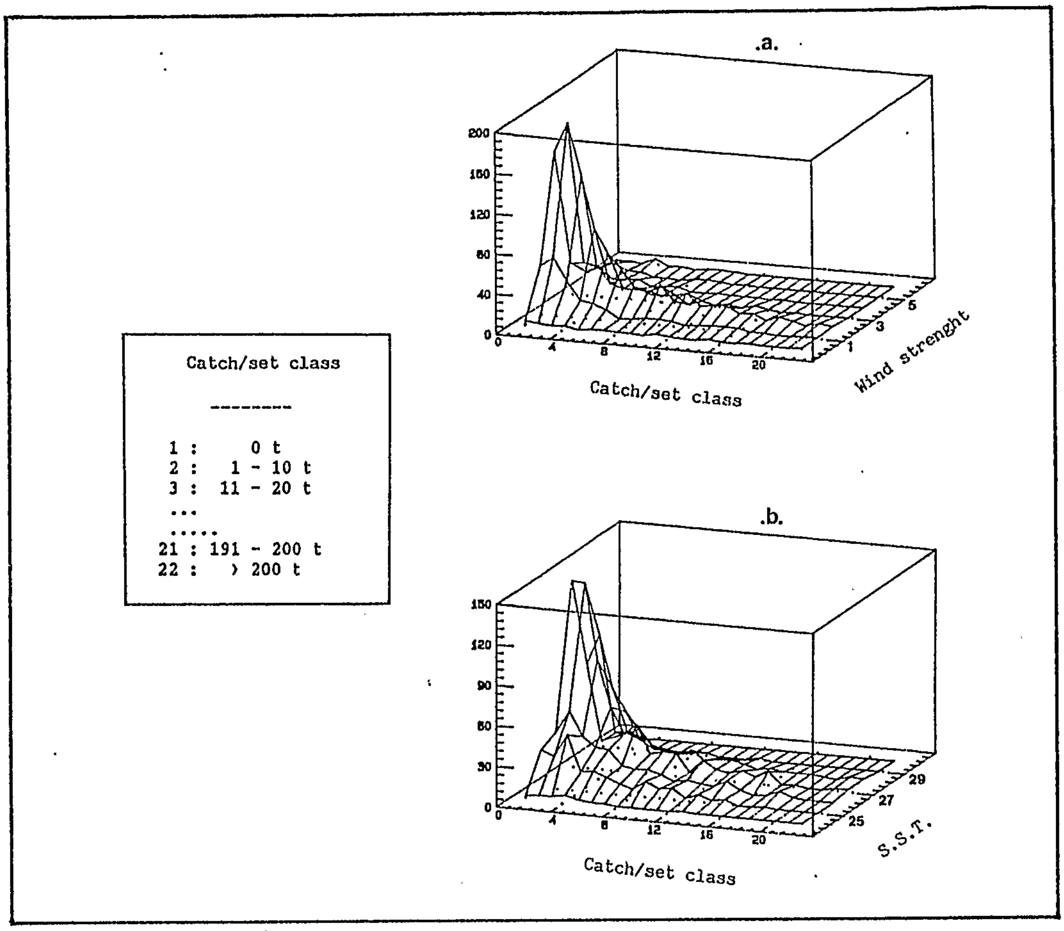


Fig.15 - Distribution of occurence of yield classes according to wind strenght (a) and SST (b).(1983-1987)

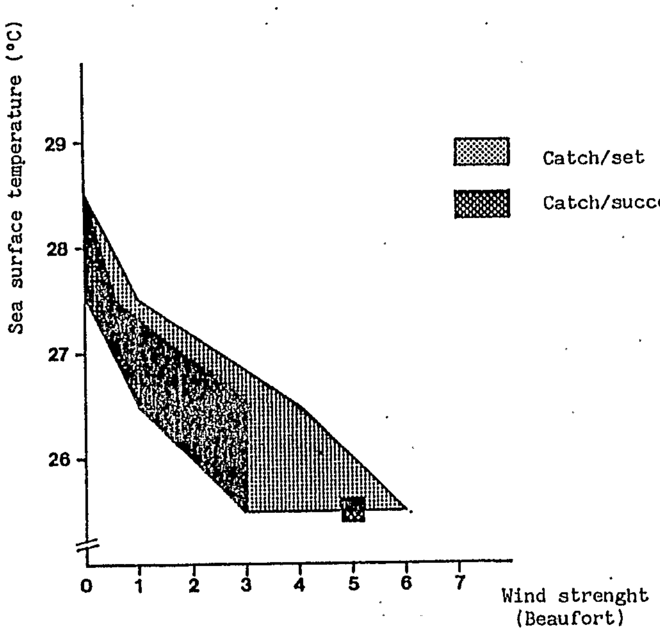
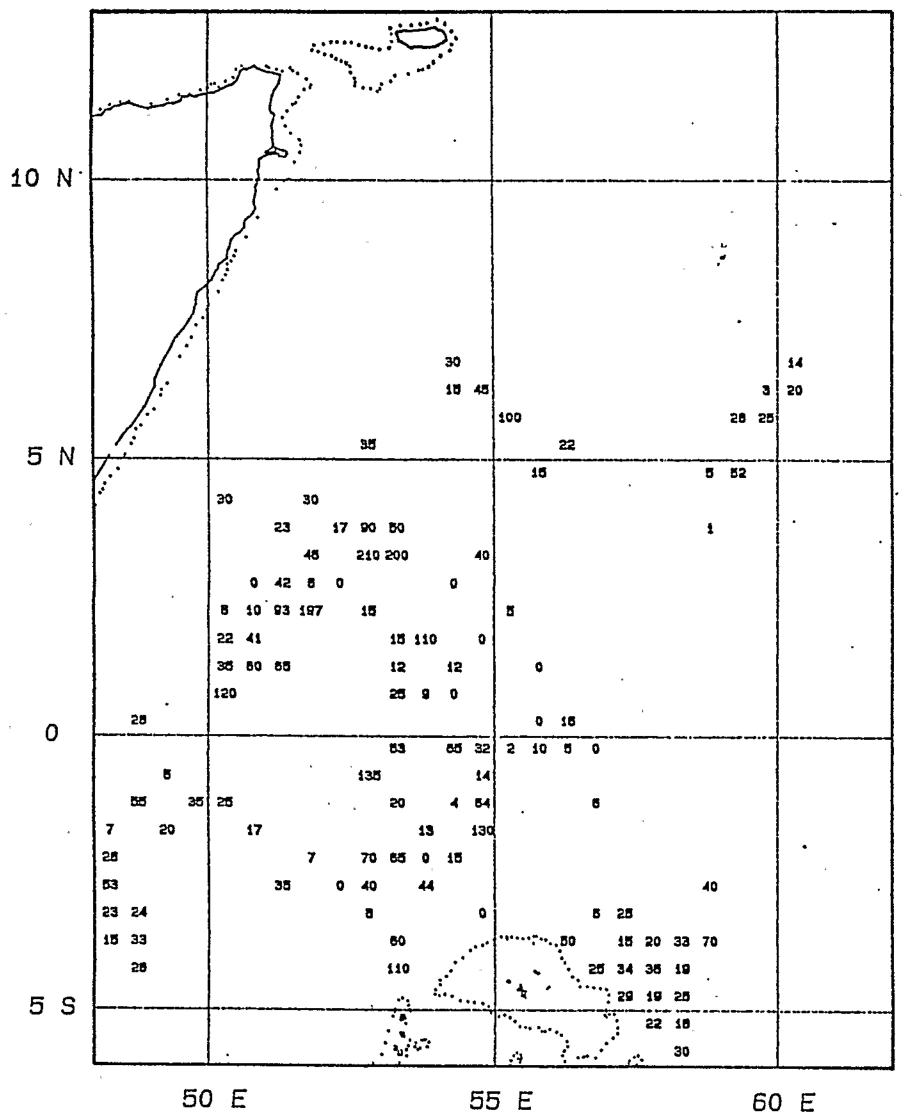
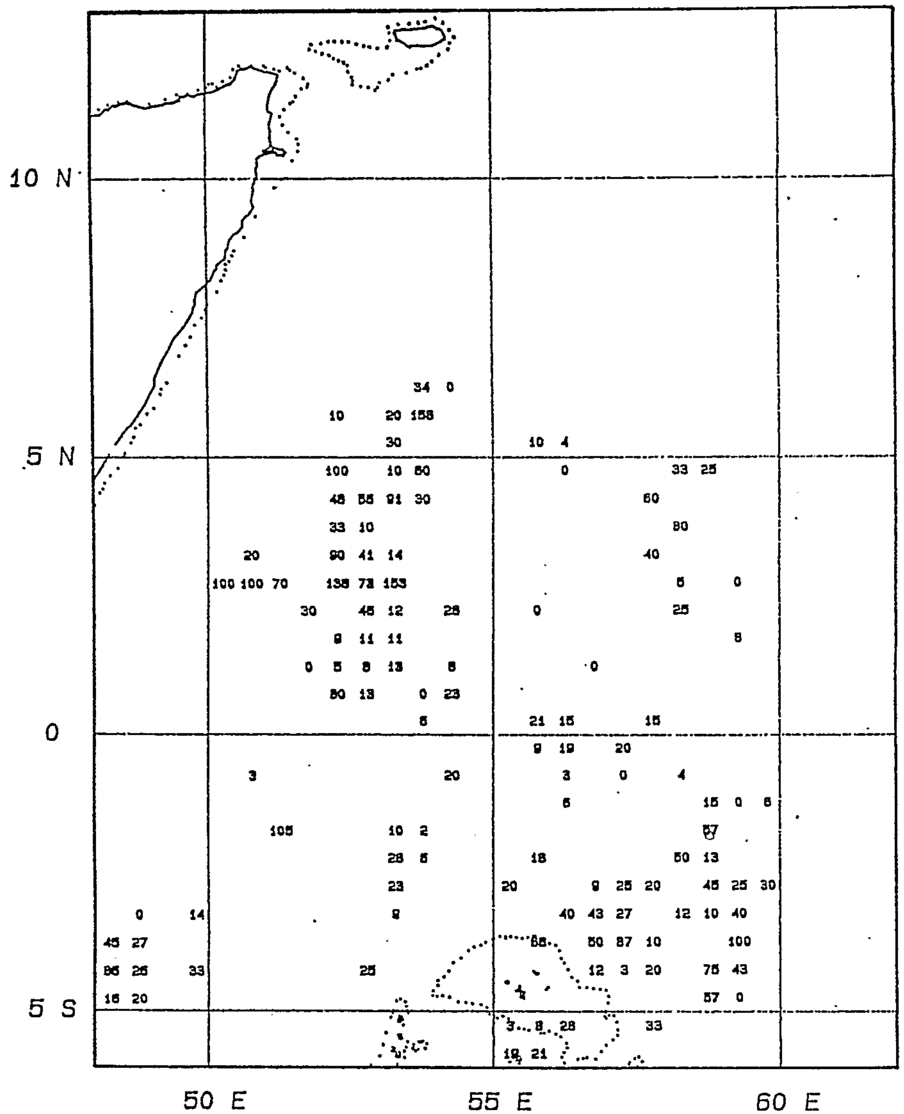


Fig.16 - Optimal environmental window of surface conditions containing the highest catch rates.



Total catch = 8848 t No of sets = 313 Catch/set = 28.2 t

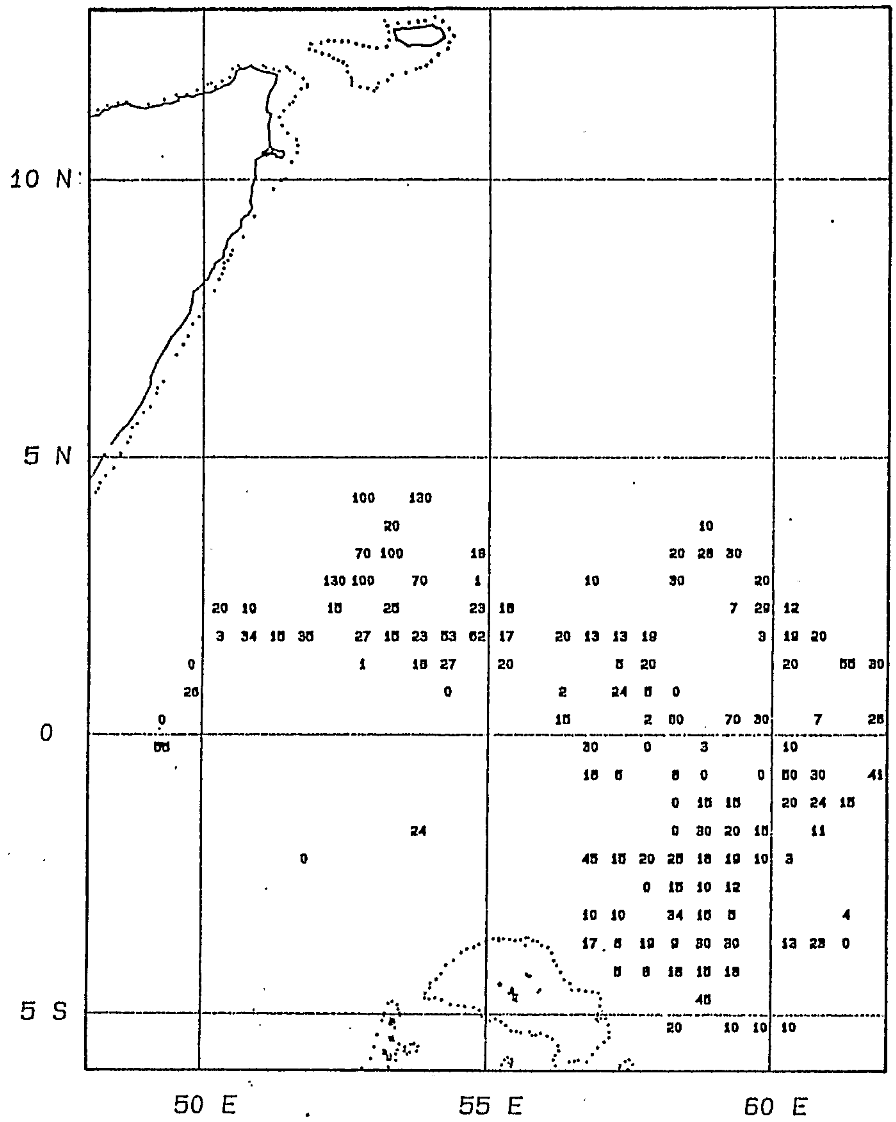
a) 16 to 30 September 1987



Total catch = 10257 t No of sets = 445 Catch/set = 23 t

b) 1 to 15 October 1987

Fig.17 - Catch per set (in tons) per 30 nautical miles area



Total catch = 7710 t   No of sets = 416   Catch/set = 18.5 t

c) 16 to 31 October 1987