Reports on surveys with the R/V Dr Fridtjof Nansen

A Survey on the Fish Resources at Sofala Bank - Mozambique

September 1982

Instituto de Invstigação Pesqueira - Maputo

Institute of Marine Research - Bergen

«Dr. Fridtjof Nansen»

The fishery research vessel «Dr. Fridtjof Nansen» belongs to the Norwegian Agency for Development Cooperation (NORAD). It was designed and built for scientific and exploratory investigations of fishery resources of developing countries, under a joint plan with the Fisheries Department of FAO based on a funding of operation to be shared by FAO and Norway.

REPORTS ON SURVEYS WITH THE R/V "DR. FRIDTJOF NANSEN"

A SURVEY ON THE FISH RESOURCES AT SOFALA BANK – MOZAMBIQUE

SEPTEMBER 1982

BY

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1. INTRODUCTION

From August 1977 to June 1978 the Norwegian research vessel "Dr. Fridtjof Nansen" surveyed the waters adjacent to Mozambique. The results from this investigation were reported by SÆTRE and SILVA (1979). The report dealt with the pelagic and demersal fish resources as well as the crustaceans. It also included a brief description of the most conspicuous hydrographic features and some comments on whales.

"Dr. Fridtjof Nansen" returned to Mozambican waters in October 1980 to carry out an investigation on the small pelagic fish and the shallow-water shrimp resources (BRINCA, REY, SILVA and SÆTRE, 1981).

According to an agreement between the government of the People's Republic of Mozambique and the United Nations Food and Agricultural Organization (FAO), "Dr. Fridtjof Nansen" returned to Mozambican waters in September 1982. During the period 1–30 September 1982 an investigation was carried out on the Sofala Bank area with the following objectives:

- to study the distribution and abundance of small pelagic fish,
- to study the distribution of shallow-water shrimps,
- to carry out oceanographic studies.

The program was executed by a joint team of Norwegian and Mozambican scientists.

2. METHODS

The R/V "Dr. Fridtjof Nansen" is a 150-foot stern trawler with a main engine of 1500 Hp. The vessel is equipped for acoustic surveying, bottom and pelagic trawling, hydrography and plankton observations.

The net used for bottom trawling was the shrimp trawl "Campelen Super" 1800 mesh with the following specifications:

30 m headline, 19 m ground rope, 40 mm mesh size in the body and 20 mm mesh size in the cod end. The trawl was without bobbins and equipped with a tickler chain. Bridles of 40 m gave it a horizontal opening of about 15 m and a vertical opening of about 5 m at a towing speed of 3 knots.

The 1600-mesh pelagic trawl had dimensions of 30 x 30 m around the trawl mouth. When fishing it was always equipped with a net sonde and the vertical opening was normally observed to be about 13 m. It was operated with 120 m bridles.

Nansen bottles were used for the oceanographic work. Temperature, salinity and dissolved oxygen were observed at standard depths to the bottom or maximum 500 m. The salinity samples were analysed aboard with an inductive salinometer. Dissolved oxygen was determined by the Winkler method.

The vessel was equipped with two echo sounders, one operating at 38 kHz and one at 120 kHz, connected to echo integrators. Settings and performance of the two acoustic systems appear in Annex I.

Echo integrator values were recorded for each nautical mile sailed and averages over 5 nautical miles were worked out and logged. The echo integrator reading (unit: mm/nautical mile) are relative measures proportional to fish density. This means that one unit of 1 mm/nautical mile represent a certain number of individual fish per square nautical mile of the species recorded. A conversion factor or density coefficient is needed for conversion from relative echo integrator values to absolute fish biomass.

Further details on biological methods are given in chapters 4 and 5. Fig. 1 shows the survey routes and the location of the stations. Annex II gives details on the fishing operation.

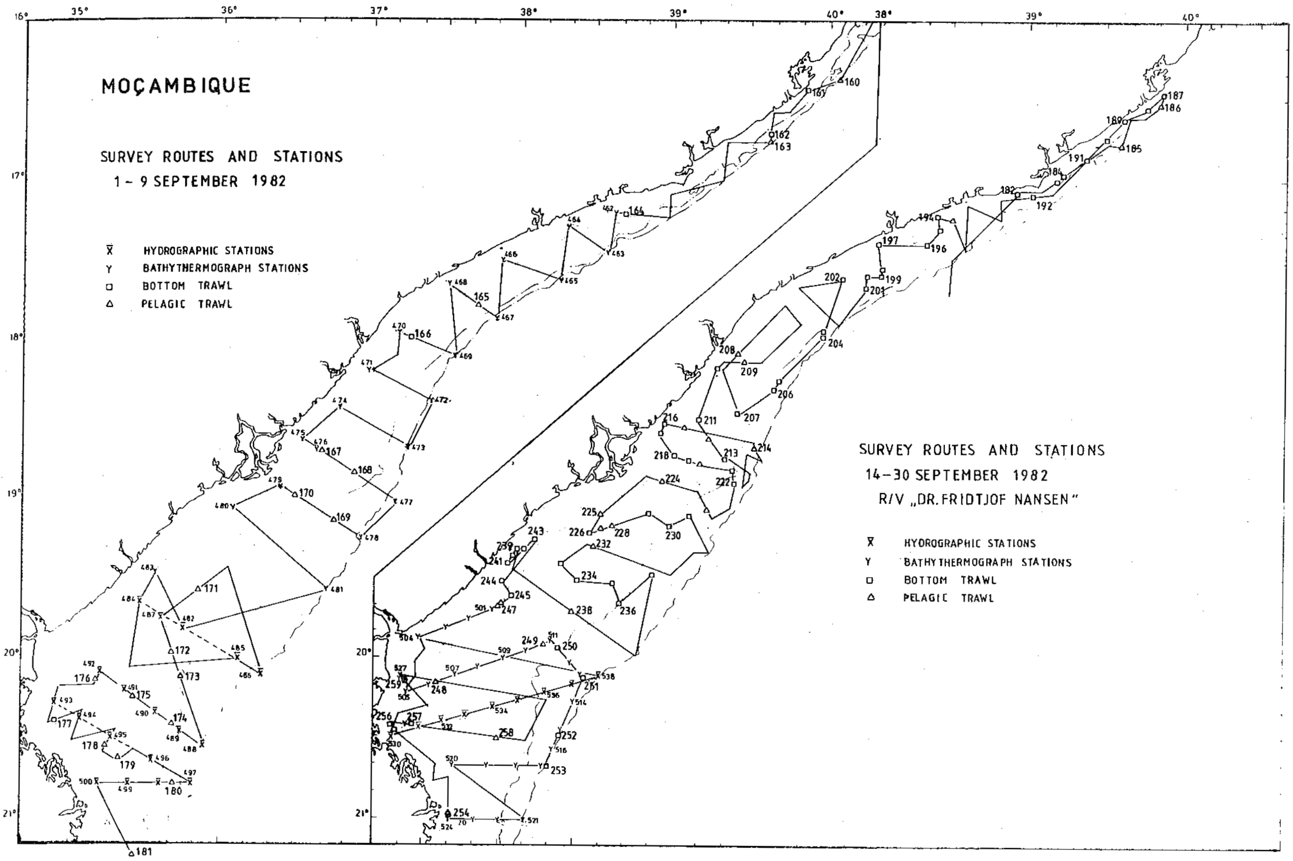

Fig. 1. Survey routes and stations.

3. HYDROGRAPHY

3.1 Introduction

Oceanographic research has been carried out in the Sofala Bank area since 1979 (BRINCA, SILVA and SILVA, 1981; BRINCA, REY, SILVA and SAETRE, 1981; BRINCA, BUDNITCHENKO, JORGE DA SILVA and SILVA, 1982). In every cruise a shelf area with high salinity (>35.4°/oo) water was found south of latitude 19°40'S, showing a positive gradient towards the coast. No explanation is so far given for the origin of this water.

The aim of the oceanographic investigations during this cruise was:

to map the distribution of high salinity water over the shelf south of latitude 19°40'S, and to gain insight into the process of its formation.

The following mechanisms are believed to be involved in the formation process:

- Flushing of salt from the mangrove area by the tide,

- Reduced circulation of the area by increased bottom friction.

- Reduced horizontal water exchange due to "trapping" of the near-shore water by the Zambezi outflow.

The coast of the Sofala Bank is rather flat with an almost continuous fringe of mangrove swamps extending from Angoche to the entrance of Bazaruto Bay. Mangroves are found either at the deltas and estuaries of the main rivers, or associated with minor rivers and small creeks. These only carry freshwater during the rain season. MACNAE (1968) reports the presence of extensive and dense mangrove forests to the north and south of Beira and in the deltas of the Zambezi and neighbouring rivers. According to this author, the mangroves encroach between successive cheniers and lows, these being covered with brackish water. This type of distribution can be clearly seen in aerial photography of the area.

South of Beira, however, a bare soil flat of varying width separates the mangrove forest from the characteristic terrestrial vegetation. This feature can easily be identified in the LANDSAT imagery of the area. The bare soil flat is likely to be caused by periodic inundation by sea water with the consequent increase in soil salinity. The inundated area amounts to about 1200 km^2. MACNAE (1968) reports that soil salinity can exceed $100^o/oo$ near Maputo.

According to the climatological data for the area the potential evapotranspiration tends to be higher than the rainfall (GONÇALVES, 1974). This tendency is enhanced during the dry semestre, from May to October. River runoff in Mozambique is clearly seasonal (SAETRE and JORGE DA SILVA, 1982). Two main rivers, Pungoé and Búzi outflow near Beira, and another impor-

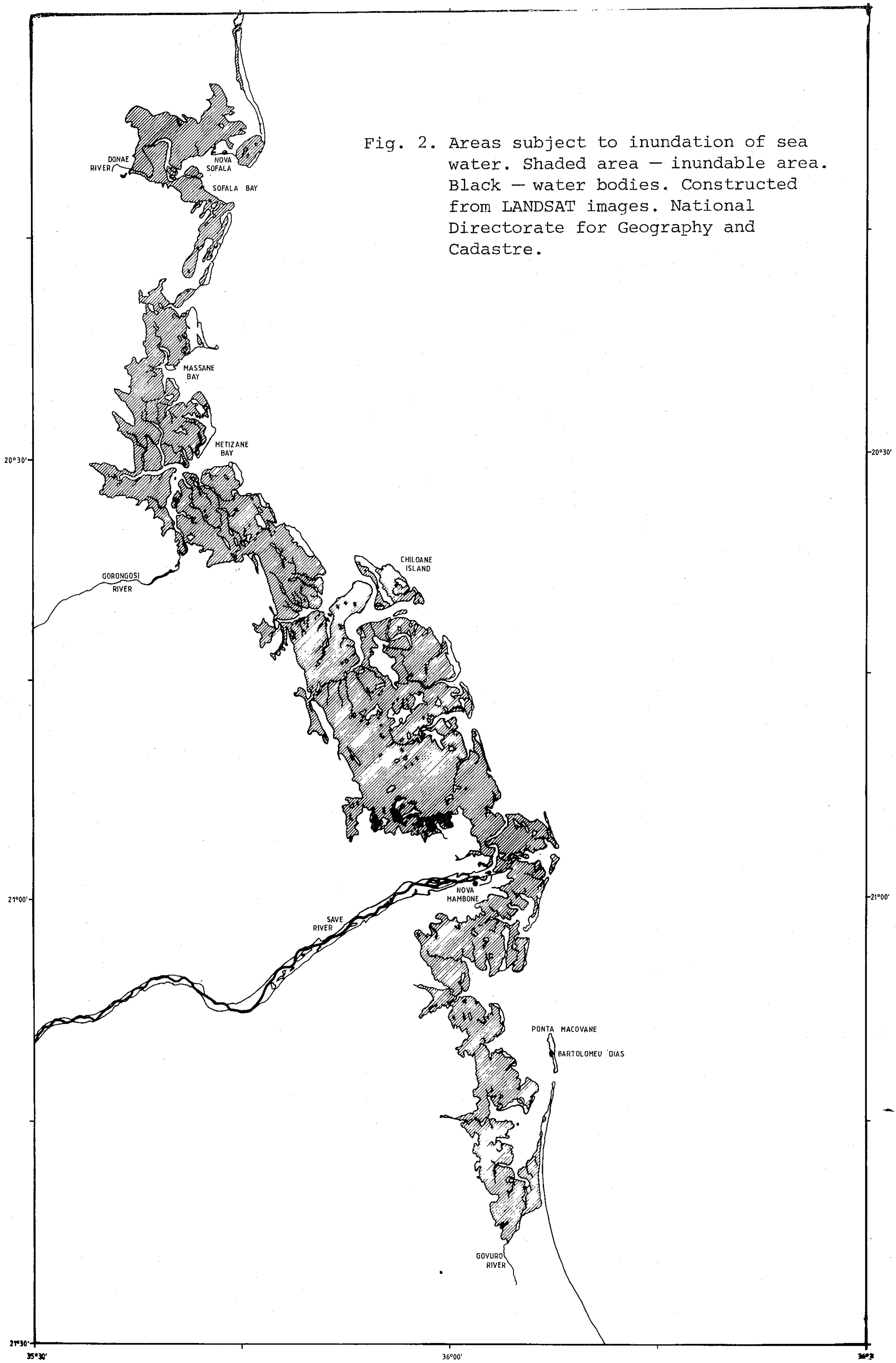

Fig. 2. Areas subject to inundation of sea water. Shaded area — inundable area. Black — water bodies. Constructed from LANDSAT images. National Directorate for Geography and Cadastre.

tant river, Save, outflows at approximately latitude 21°S. From May to November the runoff of Búzi and Pungoé rivers is about 20% of the annual average, while the corresponding value for the Save is only 1%.

Tides are semidiurnal in Mozambique with maximum amplitudes ranging from 3.5 m in the south to 4.2 m in the north. However, at Beira the mean high water level during springs is 6.4 m (TINLEY, 1971) and amplitudes may reach more than 6.5 m in extreme spring tides. Currents above 5 knots have been reported by ship masters and Beira harbour pilots. According to TINLEY (1971), the large tidal amplitudes in this area are due to the shallow and long continental shelf. The bottom has a strong undulating character, which is most likely due to sandwaves generated by strong tidal currents (SAETRE and PAULA E SILVA, 1979). This pattern is clear between the 10 m and the 50 m isobaths, and becomes perhaps more important in areas shallower than 30 m.

According to the tide tables for the ports of Mozambique, issued by the Portuguese Hydrographic Institute, forecasted tidal ranges for the periods of the oceanographic survey were:

6.0–4.5 m for 5–8 September 1982
0.8–4.3 m for 26–30 September 1982.

There is a tendency for a decrease in amplitude towards south, with the decrease in shelf width.

3.2 Results

Fig. 3 show the temperature distributions at the depth of water intake for engine cooling (ca. 4 m) for the two surveys made. Typically, they reveal the pattern of a warm oceanic current propagating southwards off the shelf. The surface temperature distribution in the southern part of the Sofala Bank, constructed on the basis of thermometer readings, show essentially the same pattern (Fig. 4A and 5).

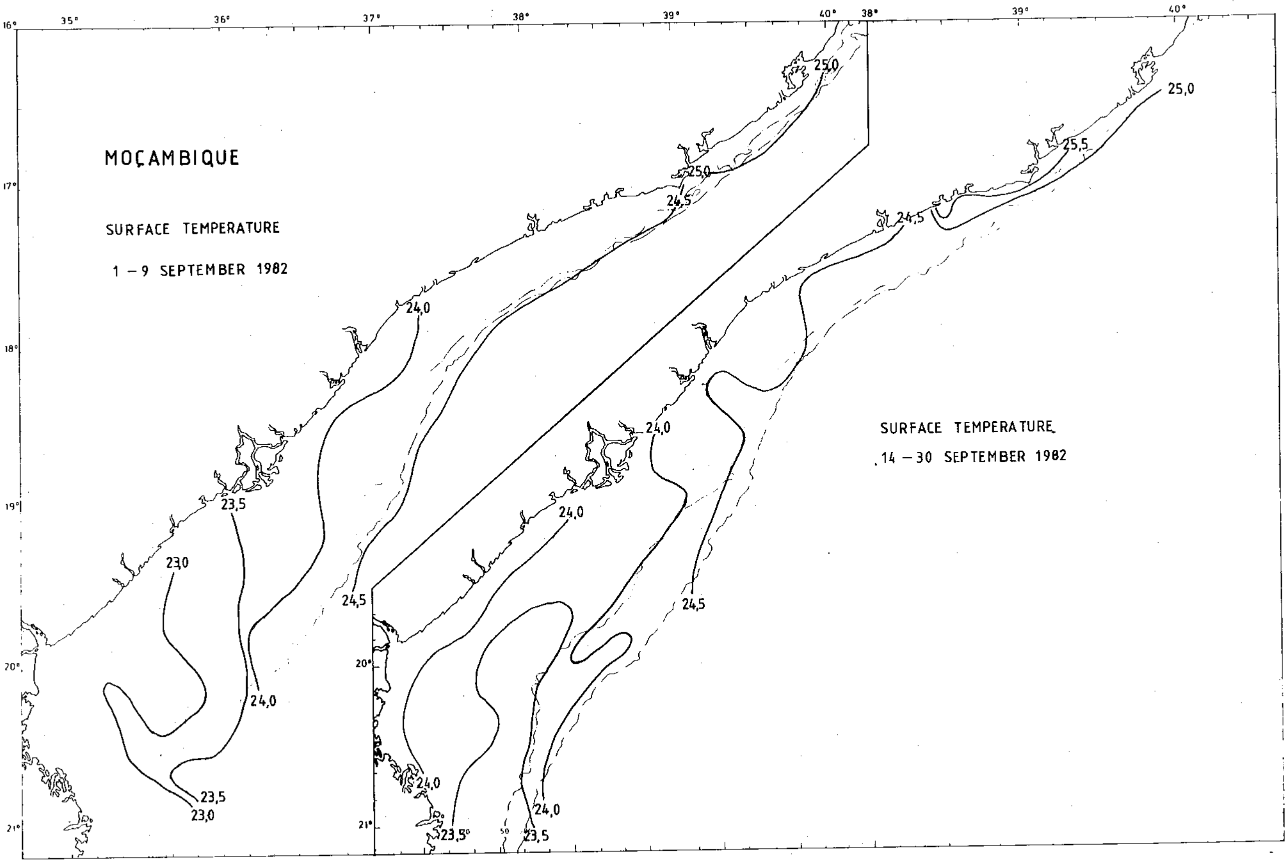

Fig. 3. Surface layer temperature distribution.

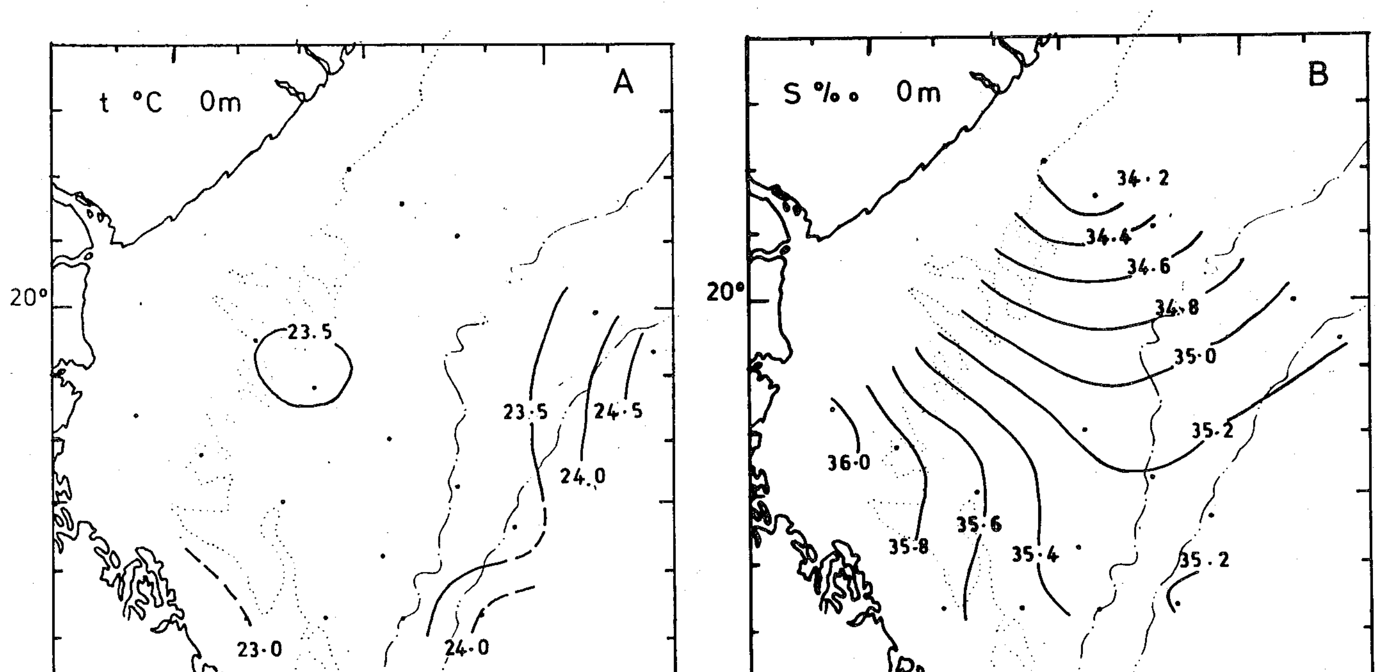

Fig. 4. Surface temperature (A) and salinity (B) 1-9 September 1982.

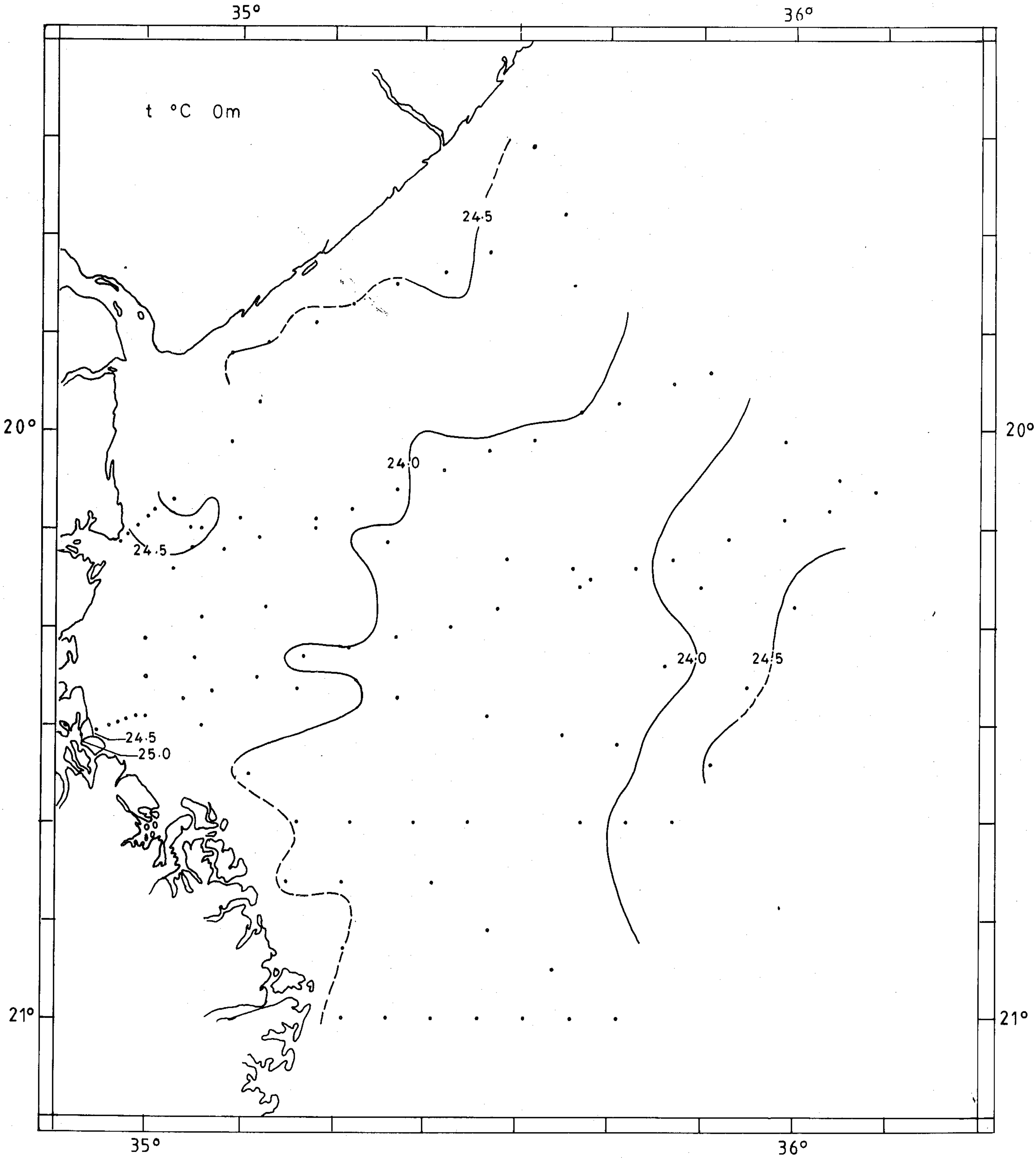

Fig. 5. Surface temperature distribution, 26–30 September 1982.

The surface salinity distributions in the southern Sofala Bank (Figs 4B and 6), reveal the interaction of two types of shelf water with oceanic water. At those latitudes the oceanic water ($t>24^{o}C$, S: 35.2–35.3^{o}/oo) is a mixture of Equatorial Surface Water and Subtropical Water (SAETRE and JORGE DA SILVA, 1982). The shelf water types can be distinguished in terms of salinity. Water with salinity below 35.0^{o}/oo, and showing values as low as 34.0^{o}/oo, is seen to propagate southwards. Its origin is related to the freshwater runoff of the main rivers: Pungoé, Búzi and Zambezi. The latter is most likely the main contributor. Closer to the western coast, and apparently propagating eastwards, it is clearly identifiable a water type with salinity above 35.4^{o}/oo, increasing to more than 37.2^{o}/oo near the shore. This water type will be furhter referred to as High Salinity Shelf Water (HSSW).

As seen from Fig. 6 a more or less zonal salinity front was present between latitudes 20^{o}00'S and 20^{o}10'S, extending from the coast to the low salinity tongue. The front separates the area of HSSW from another area that must be mainly influenced by the freshwater runoff. The analysis of sections I–IV (Fig. 7) reveals a quasi-homothermal and quasi-homohaline vertical structure over the shelf. For these reasons the second coverage was restricted to surface values except for one section.

Some unstability was present in section III (Fig. 7) with the highest salinity values being found at the top layer. Associated with the highest salinities, lowest temperature values reinforced the unstability. This feature was probably of very short-term duration and is likely to have been associated with strong tidal currents (forecasted tidal amplitudes at Beira during the section: 5.3–5.6 m).

Section V (Fig. 8) carried out during the second coverage, shows the characteristic shape of a brackish water plume embeded in water of higher salinity. Oceanic water was present to the east of the plume, while to the west HSSW showed a positive salinity gradient towards the coast. No signs of unstability

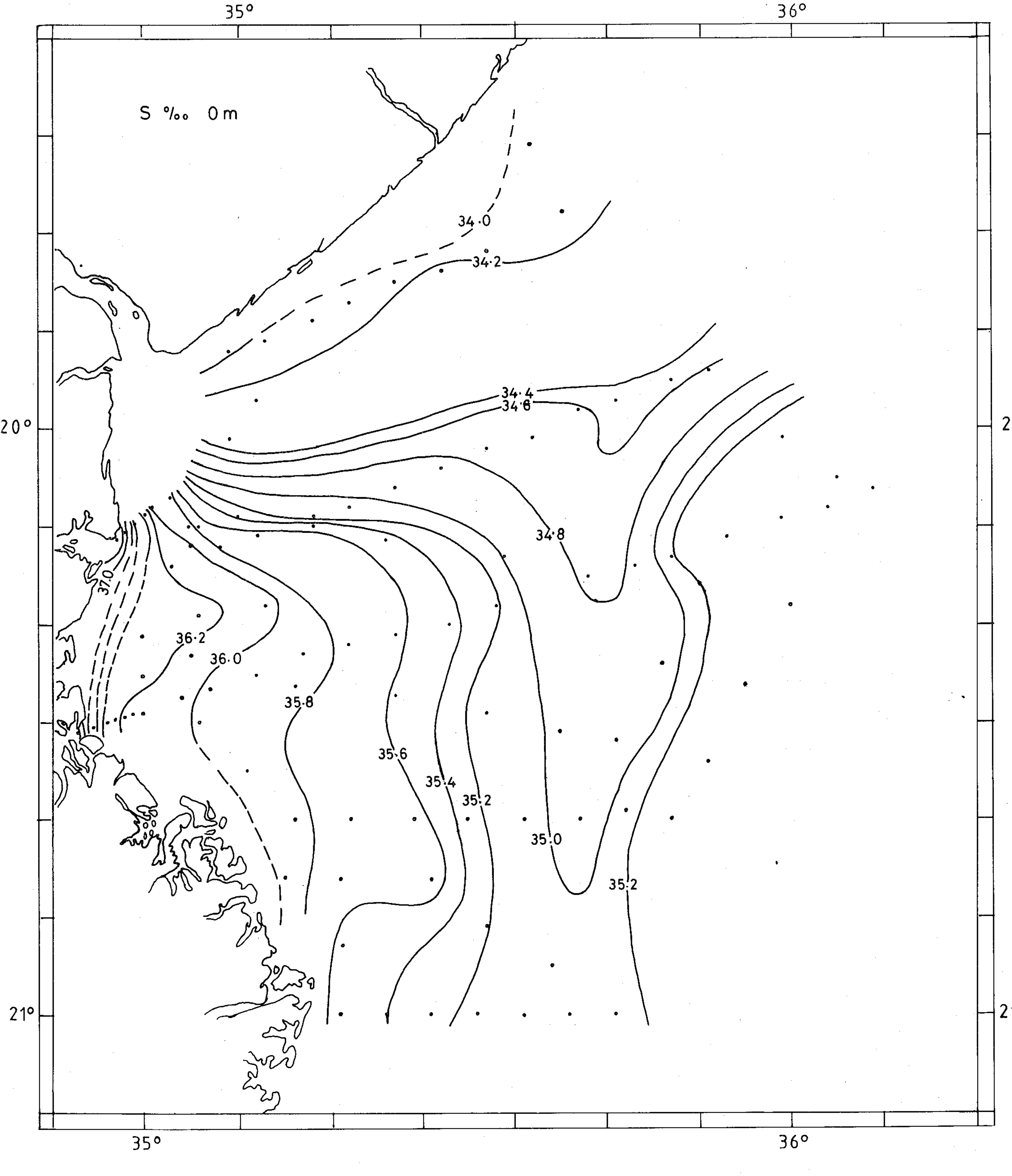

Fig. 6. Surface salinity distribution, 26—30 September 1982.

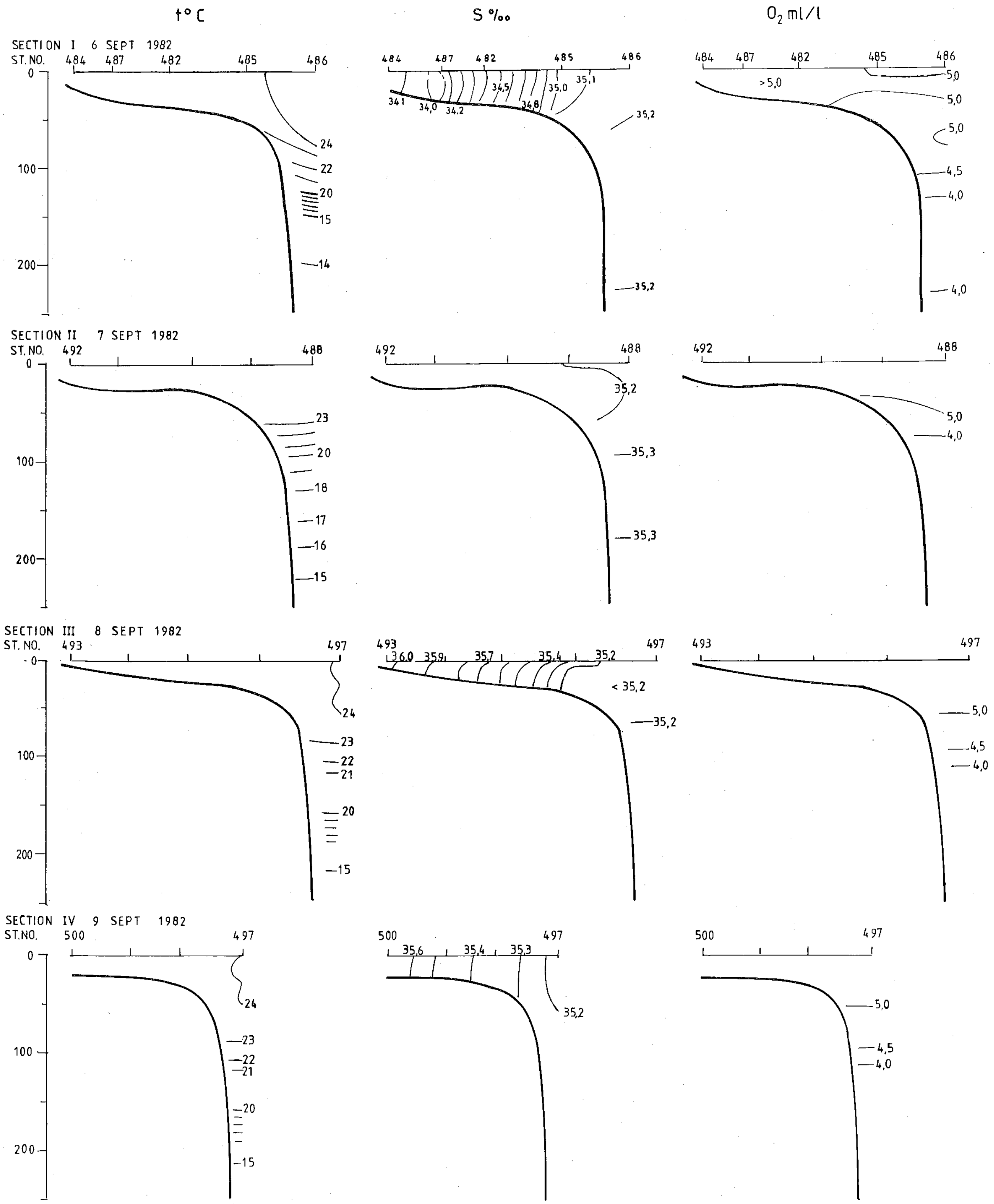

Fig. 7. Vertical distribution of temperature, salinity and oxygen in Section I–IV (Fig. 1).

vi) no water transport into or out from the distribution area of HSSW except for the strictly necessary to compensate the volume loss due to evaporation in the mangrove area.

vii) the salinity of in-flowing water is, at any time, equal to the mean salinity value of the HSSW,

then, for an evaporation area of 1,200 km^2 and a constant volume of 65 km^3 over the shelf, the mean salinity would have increased by $0.4^{o}/oo$ from May to October originating a final value of $34.4^{o}/oo$. Even if the initial salinity in late April was $35^{o}/oo$, which could eventually be the case in a very dry year, the final salinity, all other conditions kept constant, would have been less than $35.5^{o}/oo$.

The mean salinity of the HSSW that can be worked out on a two-dimensional basis from section V (Fig. 8) is $35.83^{o}/oo$. This may be an over-estimation for the total area, when the distribution shown in Fig. 6 is considered. A more realistic value would probably be about $35.7^{o}/oo$.

The comparison of this value to those calculated above through a very simple process, clearly points to the conclusion that the occurrence of HSSW cannot be justified only in terms of evapotranspiration in the mangrove area. However, assumptions iv) and vi) are obviously not compatible, at least during the dry season when evaporation is greater than rainfall.

Rearranging the assumptions to more average values;

i) runoff of Save river: 0.07 km^3 (May—October)

ii) rainfall: 150 mm (May—October)

iii) potential evapotranspiration: 650 mm (May—October)

iv) rainfall and evaporation over the sea similar to the land values

v) as before

vi) water transport into the area just compensates the volume loss due to all evaporative processes

vii) as before,

the final mean salinity in late October would now be 36.04^{o}/oo, with 35.71^{o}/oo in late September. The water volume necessary to compensate for the losses due to evaporation in six months would be 3.92 km^3 which correspond to a transport volume into the area of 2.5 x 10^{-4} Sv.

The calculated salinity for late September is quite similar to the value estimated on the basis of the salinity distribution in section V (Fig. 8). This suggests that assumption vi) must be essentially valid. Actually, if one should account for large volume transports through the area, a much longer period would be necessary for the observed salinity to be attained.

The calculated values also suggest that the whole system must be highly labile. Small changes in the evaporation and the rainfall, quite expectable from year to year, would cause important changes in the final salinity value. Changes are also to be expected in the initial salinity which depend on the intensity of the rain season and of river flood peaks. An interannual component should thus be expected in the intensity of the phenomenon, although it seems possible that it will occur every year during the dry season.

Summing up, and having in mind all the limitations of the above calculations, it seems clear that the mangrove area alone cannot be responsible for the production of such a huge volume of water with increased salinity as the one observed. Some stagnant eddy has to be postulated. It might be caused by the combined action of the southgoing oceanic current, the current induced by river runoff and increased bottom stress due to the strong undulating character of the bottom. Tidal effects, instead of destroying the structure of the eddy, must protect it while promoting, at the same time, inundation of the mangrove areas where water is evaporated and the salt is flushed back to sea.

The possible ecological consequences of such a feature are yet unknown. It should be reminded, however, that important concentrations of anchovy and juvenile fish of several species have been observed in the area. Bigger pelagic fishes like tuna, spanish mackerel and barracuda have also been detected, and sometimes provided good catches in trawl stations.

A substantial amount of research is yet to be carried out before any comprehensive model can be put forward to explain the origin, evolution, distribution and propagation of the High Salinity Shelf Water. A much better knowledge is required of the processes that affect the Sofala Bank as a whole before attempting the in-depth analysis of particular features. It is considered particularly important:

i) to study the time variability of the offshore processes and their influence over the shelf;

ii) to conduct direct current measurements over the shelf;

iii) to acquire good quality data on rainfall and evaporation both over land and sea areas;

iv) to obtain an accurate knowledge of the river runoff in the whole area;

v) to obtain good systematic records on sea level in the area.

4. FISH

4.1 Species composition and distribution

Table 1 gives the number of trawl stations at Sofala Bank during the period 1–30 September 1982 split into depth zones and areas. Table 2 shows the average catch rates with shrimp trawl at different depth zones and areas. As can be seen, the pelagic fish dominated the catches, except in Area B at depths more than 45 m and at depth less than 25 m. The maximum average

Table 1. Number of trawl stations at Sofala Bank.

Bottom depth (m) / Area	<25	25–45	>45
A North of 17°30'			
Bottom trawl	15	1	0
Pelagic trawl	3	0	2
B 17°30'–19°00'			
Bottom trawl	8	8	4
Pelagic trawl	6	4	1
C South of 19°00'			
Bottom trawl	14	4	7
Pelagic trawl	7	15	2

Table 2. Composition of catch with shrimp trawl ($kg \cdot h^{-1}$) at Sofala Bank for different depth zones.

Area	A North of 17°30'	B 17°30'–19°00'			C South of 19°00'		
Depth	< 25 m	< 25 m	25–45 m	> 45 m	< 25 m	25–45 m	> 45 m
Pelagic fish	129.7	51.2	382.5	39.2	202.2	212.0	21.4
Demersal fish	65.0	76.4	119.3	86.8	33.6	28.3	21.5
Sharks/Rays	1.9	1.1	3.2	2.7	9.1	-	-
Crustaceans	10.9	20.4	11.1	3.6	8.1	2.0	0.6
Molluscs	0.8	1.0	3.5	2.7	0.8	8.2	1.4
Total	208.3	150.2	519.6	135.0	253.8	250.5	44.9

catch rate, 519.6 kg/h, was obtained in Area B at depths between 25 and 45 m. The maximum catch rate was 2170 kg/h with *Leiognathus elongatus* and *Decapterus macrosoma* as the dominated species. In Area A *Sardinella fimbriata* contributed significantly to the catches when the catch rates were high.

Table 3 gives the species composition of the shrimp trawl catches split into depth zones and areas.

Area A (North of 17°30'S)

The catches of pelagic fish in this area was dominated by the Clupeida family (Table 3) with *Sardinella fimbriata* and *Sardinella longiceps* as the most important species. Significant contribution also came from *Secutor incidiator* and *Trichiurus lepturus*. *Thryssa vitrirostris* and *Pellona ditchela* made

Table 3. Species composition from shrimp trawl catches (kg·hr^{-1}) at different depth zones at Sofala Bank.

Area	A North of 17°30'	B 17°90'–19°00'			C south of 19°00'		
Depth	< 25 m	< 25 m	25–45 m	> 45 m	< 25 m	25–45 m	> 45 m
PELAGIC FISH							
ARIOMMIDAE – Driftfish	0.4	-	3.3	0.6	6.1	-	-
CARANGIDAE – Jack/Scad	5.5	3.6	138.3	28.9	22.1	140.8	13.4
CHIROCENTRIDAE – Wolf herring	0.3	-	0.2	-	0.3	-	-
CLUPEIDAE – Herring/Shad	55.7	16.8	12.0	1.6	80.7	1.1	0.4
ENGRAULIDAE – Anchovy	32.4	19.7	10.8	-	41.0	-	-
LEIOGNATHIDAE – Ponyfish	15.9	1.6	170.2	2.0	15.5	25.6	-
SCOMBRIDAE – Mackerel	5.1	1.6	25.3	5.0	13.8	43.9	7.3
SPHYRAENIDAE – Barracuda	0.4	-	20.9	1.0	16.6	0.6	0.3
TRICHIURIDAE – Hairtail	14.0	7.9	1.5	0.1	6.1	-	-
DEMERSAL FISH							
ACANTHURIDAE – Surgeon fish	-	-	3.9	-	-	-	-
ARIIDAE – Catfish	0.6	0.6	9.6	-	1.1	-	-
BALISTIDAE – Trigger fish	-	-	-	2.1	0.1	-	1.2
BOTHIDAE – Flounder	-	-	-	1.5	-	0.3	0.1
BREGMACEROTIDAE – Codlets	-	-	-	-	-	-	-
CYNOGLOSSIDAE – Tongue sole	2.4	5.3	0.3	-	+	0.1	-
DIODONTIDAE – Porcupine fish	-	-	0.3	-	-	-	0.1
DREPANIDAE – Concertinafish	0.5	-	-	-	0.1	-	-
ECHENEIDAE – Remoras	-	-	-	-	-	0.1	-
ELOPIDAE – Tenpounders	-	-	-	-	-	-	-
FISTULARIDAE – Pipefish	-	-	-	1.0	-	-	0.1
FORMIONIDAE – Black pomfret	1.5	-	0.5	-	3.6	-	-
GERREIDAE – Momarra	0.9	-	-	-	-	-	-
LABRIDAE – Wrasses	-	-	-	-	-	-	0.2
LETHRINIDAE – Scavenger	-	-	16.5	1.6	-	-	0.5
LOBOTIDAE – Tripletail	-	1.5	-	-	0.9	-	-
LUTJANIDAE – Snapper	-	-	4.7	-	-	-	1.8
MENIDAE – Moon fish	+	-	-	-	-	-	-
MONACANTHIDAE – Filefish	-	-	0.4	-	-	1.2	0.3
MUGILIDAE – Grey mullet	0.1	-	-	-	0.4	-	-
MULLIDAE – Goatfish	24.2	4.3	39.9	46.4	0.5	20.6	1.9
NEMIPTERIDAE – Threadfin bream	-	-	10.5	7.8	-	1.3	1.0
OSTRACIONTIDAE – Boxfish	-	-	0.9	-	-	-	-
PLATYCEPHAUDAE – Flathead	0.3	-	-	1.5	-	0.2	-
POLYNEMIDAE – Treadfin	8.1	9.9	3.5	-	0.7	-	-
PLEURONECTIDAE – Flounder	-	-	-	-	-	-	0.1
POMADASYIDAE – Grunt	4.7	3.8	12.1	9.0	6.0	-	5.9
PRIACANTHIDAE – Bigeye	-	-	-	5.2	-	1.9	0.3
PSETTODIDAE – Indian halibut	0.4	0.8	-	-	0.1	-	-
SCIAENIDAE – Croaker	10.9	58.1	1.5	-	13.9	-	-
SERRANIDAE – Sea basses	-	-	1.0	-	-	-	5.1
SILLAGINIDAE – Smelts	0.1	0.4	-	-	-	-	-
SPARIDAE – Seabream	-	-	3.5	5.6	-	-	0.8
SYNODONTIDAE – Lizard fish	0.1	0.2	2.9	4.6	0.9	2.4	0.6
TETRADONTIDAE – Puffer fish	-	-	0.8	-	+	0.2	1.5
THERAPONIDAE – Tiger perch	10.2	0.5	6.5	-	5.3	-	-
TRIGLIDAE – Searobin	-	-	-	0.5	-	-	-
SHARK/RAY							
CARCHARHINIDAE – Requiem shark	-	0.5	-	-	1.3	-	-
SPHYRNIDAE – Hammerhead shark	-	-	0.7	2.7	5.3	-	-
SHARK, unidentified	1.2	-	2.5	-	1.7	-	-
DASYATIDAE – Stingray	-	0.6	-	-	0.8	-	-
RHINOBATIDAE – Guitar fish	-	-	-	-	-	-	-
RAY, unidentified	0.7	-	-	-	-	-	-
CRUSTACEA							
CARIDAE	5.4	3.6	-	-	0.1	-	-
DECAPODA	0.2	1.6	4.5	1.2	0.9	1.5	0.4
PENAEIDAE	5.1	15.0	3.2	0.1	6.3	-	+
SCYLLARIDAE	-	0.2	2.7	-	0.3	0.5	0.2
STOMATOPODA	0.2	-	0.7	2.3	0.5	+	-
MOLLUSCA	0.8	1.1	3.5	2.7	0.8	8.2	1.4

approximately equal contribution to the catches. The goatfish Upeneus vittatus was the most important of the demersal species.

Area B ($17^{\circ}30'$–$19^{\circ}00'$S)

At depths shallower than 25 m Thryssa vitrirostris and Pellona ditchela dominated the catches of pelagic fish with approximately equal contribution. Between 25 and 45 m the most abundant pelagic species were Decapterus macrosoma and Leiognathus elongatus while at depths deeper than 45 m Decapterus russellii contributed most. Of the typical demersal fish the goatfish (Mullidae) and the croaker (Scianidae) were the most abundant.

Area C (South of $19^{\circ}00'$S)

Also in this area the Pellona ditchela dominated the catches with shrimp trawl at depths shallower than 25 m. Between 25 and 45 the Decapterus spp. were the most important. Of the typical demersal fish the goatfish (Mullidae) seems to be the most abundant.

Fig. 9 shows the distribution of the different pelagic regimes. The figure is a synopsis of all the trawl catches together with the acoustic recordings. In the northern area mainly sardinella (S. sirm, S. longiceps) and the ponyfish (Secutor incidiator) are found together with minor amounts of Pellona ditchela and Thryssa vitrirostris. Along the coast at depths shallower than 25 m Pellona ditchela and Thryssa vitrirostris dominates with minor contribution from Trichiurus lepterus and partly Hilsa kelee in the most nearshore area.

From about $17^{\circ}30'$S and further south at depths between about 30 and 100 m the scad (Decapterus spp.) and mackerel (Rastrelliger kanagurta) was observed. The anchovy (Stolephorus spp.) was found south of about $18^{\circ}30'$S at bottom depths between 20 and 50 m.

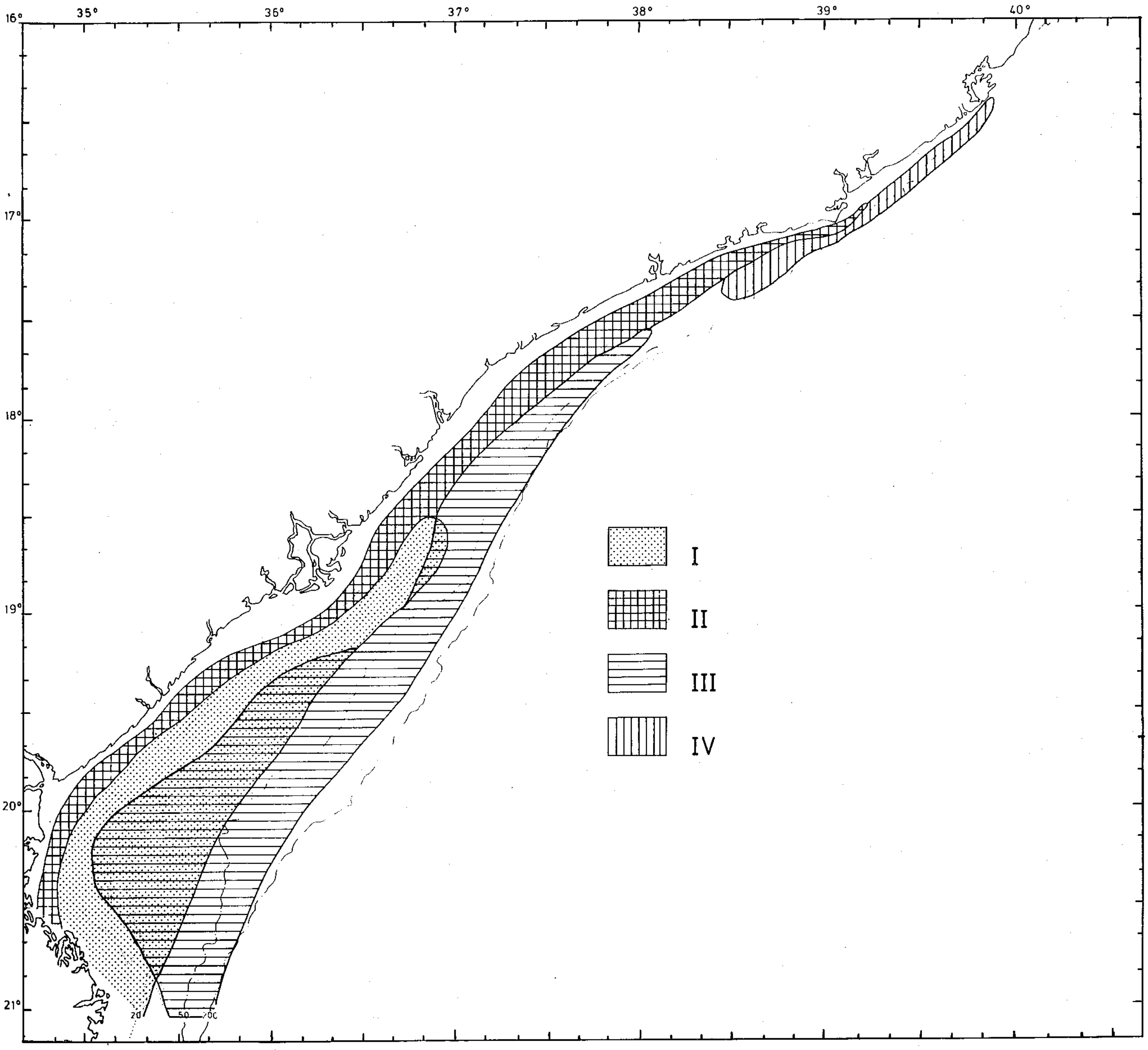

Fig. 9. Distribution of the different pelagic regimes. Main species: I) Stolephorus spp., II) Thryssa vitrirostris, Pellona ditchela, III) Decapterus spp., Rastrelliger kanagurta, IV) Sardinella spp., Secutor incidiator.

Fig. 10 shows some typical recordings of anchovy (Stolephorus sp.). During day time it forms small schools in mid-water while during night it is more scattered in the whole water column. Also the ponyfish (Leiognathidae) might be observed in mid-water during day time (Fig. 11) when most of the other pelagic species are found close to the bottom (e.g. Fig. 12).

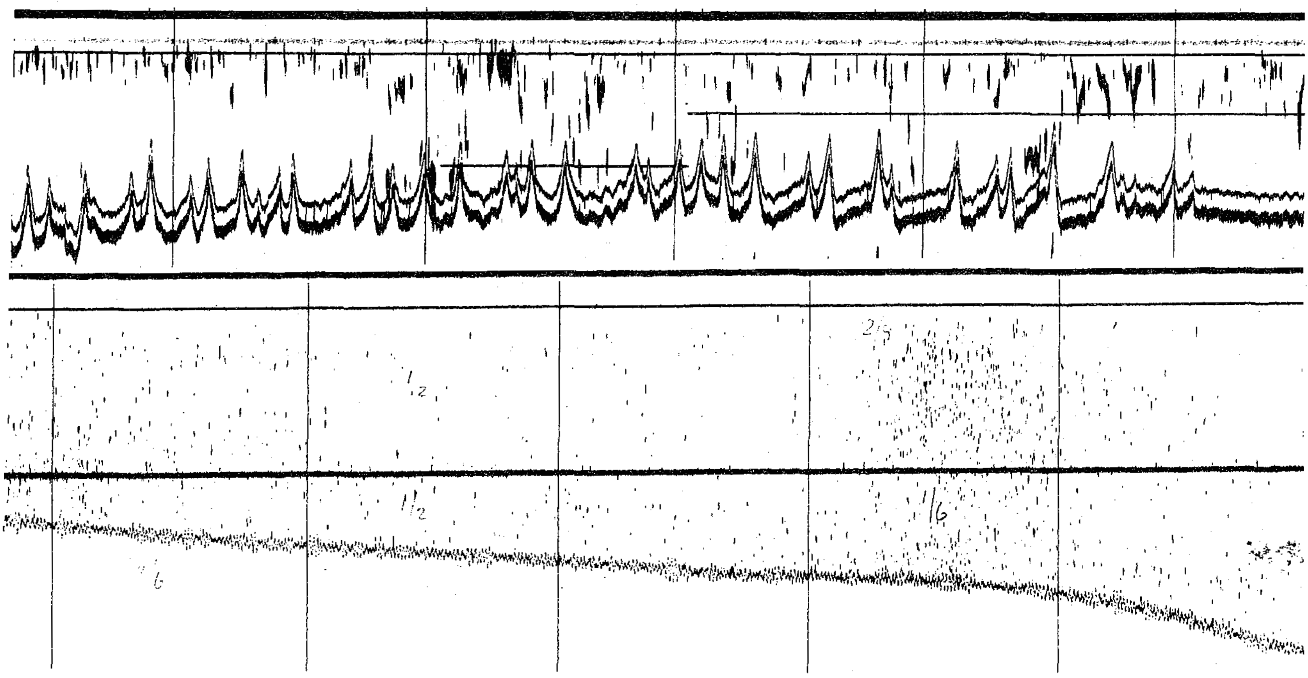

Fig. 10. Typical echo recordings of Stolephorus spp. Upper: Day recordings
Lower: Night recordings.

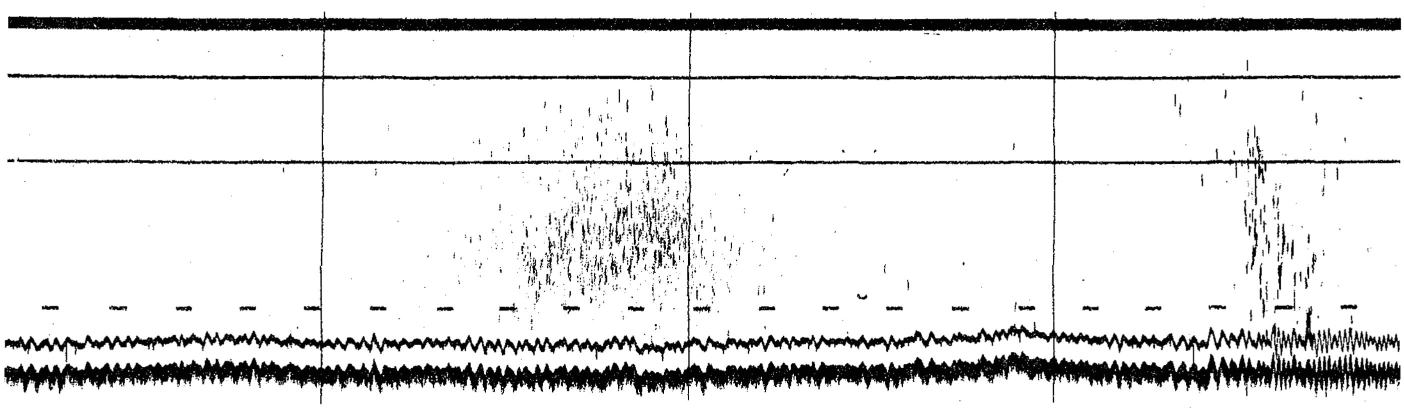

Fig. 11. Day recording of ponyfish (Leiognathidae).

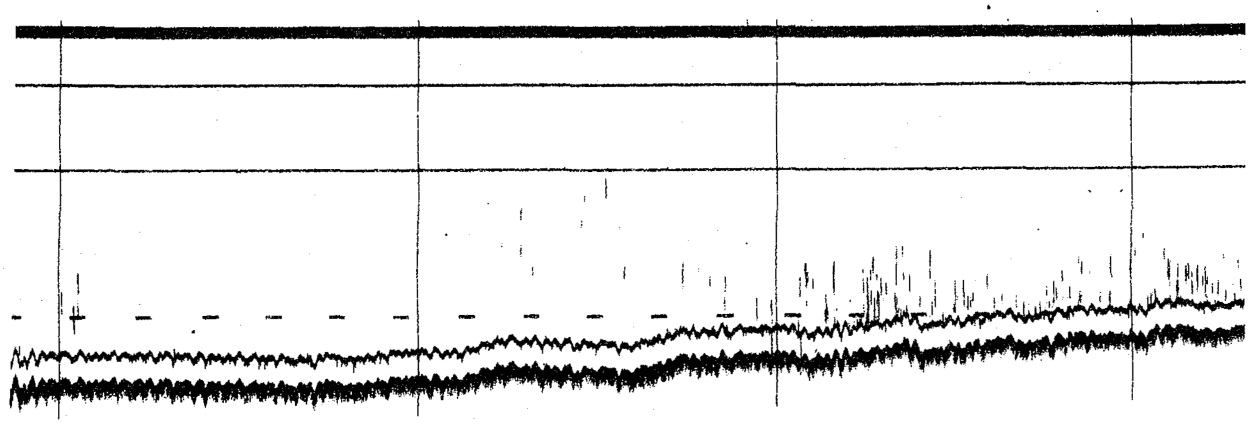

Fig. 12. Day recording of Pellona ditchela and Thryssa vitrirostris.

4.2 Abundance

Demersal fish

If the average fish density is known for a given area, the size of the demersal stock may be calculated. Crude estimates for the demersal stock of Sofala Bank for the depth zone 10–50 m have previously been calculated to 110–120,000 tonnes (SÆTRE and SILVA, 1979, BRINCA et al. 1981). By comparing the catch rates by similar trawls from October-November 1980 and September 1982 (Table 4) it seems quite clear that there have been a decrease in catch rates of demersal fish from 1980 to 1982. The decrease is most marked in Area C (South of 19°00'S) which is also the largest area.

Table 4. Catch rates of demersal and pelagic fish ($kg \cdot h^{-1}$) in shrimptrawl at Sofala Bank – Oct.–Nov. 1980 and Sept. 1982. Number of hauls in brackets.

AREA	A (North of 17°30'S)		B (17°30'–19°00'S)		C (South of 19°00'S)	
	Oct.–Nov. 1980	Sep. 1982	Oct.–Nov. 1980	Sep. 1982	Oct.–Nov. 1980	Sep. 1982
Depths < 25 m	(27)	(15)	(21)	(8)	(17)	(14)
Demersal fish	90.3	65.5	84.8	76.4	177.7	33.6
Pelagic fish	78.5	129.7	109.7	51.2	312.4	202.2
25 – 45 m			(11)	(8)	(9)	(4)
Demersal fish			128.7	119.3	99.9	28.4
Pelagic fish			161.1	382.5	48.3	212.0
> 45 m			(6)	(4)	(8)	(7)
Demersal fish			54.5	86.8	79.3	21.5
Pelagic fish			200.4	39.2	43.4	21.4

Even though the "swept area" method is uncertain, the decrease in catch rate seem to be significant and the further development should be closely followed.

Pelagic fish

The acoustic abundance estimate was calculated by the equation

$$B = C \cdot \overline{M} \cdot A$$

where B is the pelagic fish biomass, C is a conversion coefficient, $\overline{M}$ is the average integrator reading, and A the corresponding area. The value for C was calculated according to

$$C = \frac{13.6}{17} \cdot \overline{l}$$

where $\overline{l}$ is the average length of the dominant species in the area. The calculations were carried out separately for the four areas in Fig. 1 and the results appear in Table 5. The total pelagic stock of Sofala Bank by these calculation amounts to about 200,000 tonnes or about 130,000 tonnes if the anchovy (*Stolephorus* spp.) is excluded.

Table 5. Calculations of pelagic fish stock at Sofala Bank by the acoustic method.

AREA	The main species	Mean length	C-value	Acoustic estimate (tonnes)
I	*Stolephorus* spp.	7.0 cm	5.6	70213
II	*Thryssa vitrirostris*, *Pellona ditchela*	13.5 cm	10.8	22810
III	*Decapterus* spp., *Rastrelliger kanagurta*	17.0 cm	13.6	94017
IV	*Sardinella* spp., *Secutor incidiator*	15.0 cm	12.0	13740

For the same period in 1977 SÆTRE and SILVA (1979) reached 123,000 tonnes excluding the anchovy while BRINCA *et al*. (1981) for September-October 1980 estimated the pelagic stock excluding the anchovy (*Stolephorus* spp.) to about 120,000 tonnes. The stock of anchovy (*Stolephorus* spp.) seems to vary, maybe with a factor of ten during a year (SÆTRE and SILVA, 1979). Interannual variations in stock size is probably also significant. For the rest of pelagic stock all the acoustic estimates have reached values of 120–140,000 tonnes (SÆTRE and SILVA, 1979, BRINCA *et al*., 1981).

4.3 Biological Characteristics

Methodology of data analysis

For the analysis of biological data, mainly for length composition of fish species, the covered area of Sofala Bank was divided in the same strata considered for the shrimp coverage. Additionally, an eight stratum was taken into account for data analysis of Stolephorus buccaneeri and Decapterus russellii. It coincides with the untrawlable area, in the south of Sofala Bank.

Whenever data was scarce or no evident difference was present, two or more strata were pulled together. Also, the sub-strata in each stratum were sometimes mixed or other sub-divisions considered. Following SÆTRE and SILVA (1979)'s methodology, the buccaneer anchovy was considered separately from the rest of Engraulidae and Clupeidae families. Length compositions of pelagic fish caught by both pelagic and bottom trawls were considered separately.

With the purpose of easing the graphical representation of the maturity stages, the stage I was joint to stage II and the stage III to stage IV.

Gonadosomatic index (GSI) expressed as the percentual relation between the gonad weight (GW) and the total weight (TW):

$$GSI = 100 \times \frac{GW}{TW}$$

was estimated for each specimen.

The size at first maturity was studied for D. russellii and P. ditchela. It is the size at which 50% of females or males are spawning (stage V). The percentage of spawning individuals for each length class was calculated and the points were graphically represented. The resulting curve was made by hand.

The length-weight relationship was studied for some pelagic species and the logaritmically transformed data fitted to a functional linear regression:

$$\log W = \log u + v \log L$$

where W is the total weight in grams and L is the length in centimeters.

Some otoliths of juveniles D. russellii were collected and preserved dried in paper envelopes. They were prepared for the study of age determination by daily growth rings (Pannella, 1974). A growth curve based on otolith readings was fitted according to the conventional methods (BEVERTON and HOLT, 1957).

Pelagic Fish

Anchovies

Only one species of anchovies, the buccaneer anchovy, Stolephorus buccaneeri was represented in the pelagic trawl catches. The samples cover an area from the mouth of Zambezi river (latitude 18°50'S) to the south of Beira (latitude 20°58'S), at depths of 19 to 45 meters.

Total length of 768 individuals caught in 11 pelagic hauls was measured and the mean size determined to 5.8 cm. One main mode at 4.5 cm is distinct and the fish are ranging from 2.5 to 10.0 cm long (Fig. 13).

According to SÆTRE and SILVA (1979) this species has different behaviour during day-time and night-time. So, they form schools in the mid-water during day-time, while they are dispersed in the water column during night-time. For this reason, samples taken during day-time and night-time were treated separately.

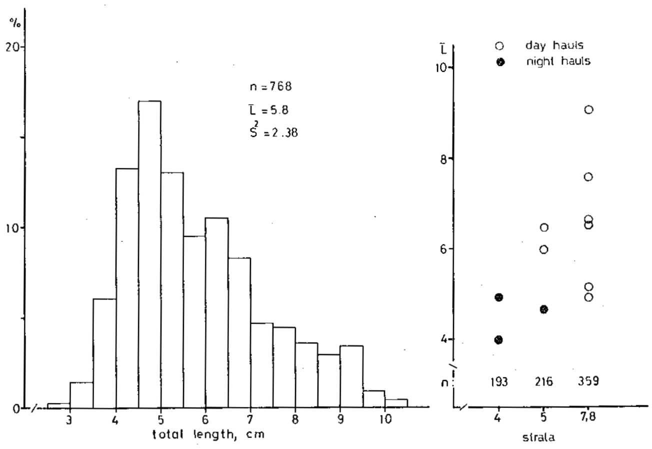

Fig. 13. Length distribution of Stolephorus buccaneeri (left) and mean length from day and night haul by strata (right).

Mean sizes of each sample were plotted against strata (Fig. 13). It seems that the fish increase in size as they come to the south. A particular feature was, however, denoted in the stratum 8 (untrawlable area): north of latitude 20°30'S the mean size found for 184 individuals was 6.7 cm, while south of this latitude the mean size decreased to 5.0 cm in 118 individuals analysed.

Comparison of day and night samples was only possible in one stratum (no. 5) where both were available. The individuals taken from the day hauls show a very low mean size ($\bar{L}$ = 4.67 cm) comparing to those from the night hauls ($\bar{L}$ = 6.20 cm) (Fig. 14).

Gonads of a few individuals were taken for sex and maturity stages analysis. The number of males is slightly bigger than the females, and the sex ratio is 1: 1.1. The females were dominant only in one station, at 31 m depth, where 83.3% of females were found in spawning. Table 6 indicates the relative percentage for each maturity stage for males and females separately. High values were found for stages V and III for females, while stages II, III and V were more important for males.

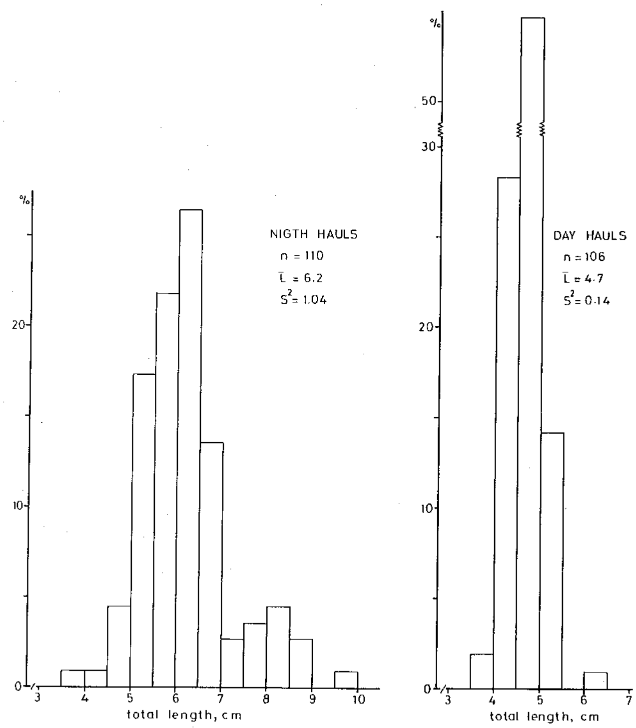

Fig. 14. Length distribution of Stolephorus buccaneeri from night hauls (left) and day hauls (right).

Table 6. Relative frequencies (%) of maturity stages for males and females of S. buccaneeri.

MATURITY STAGES		I	II	III	IV	V	VI	n
♀♀	n	1	4	21	2	25	3	56
	%	1.8	7.1	37.5	3.6	44.6	5.4	
♂♂	n	1	21	20	2	19	-	63
	%	1.6	33.3	31.7	3.2	30.2		
JUVENILES								7

Gonads appear in the pre-spawning stage at 5.5 cm long in males while in females they were found only with 6.0 cm long. For both sexes fish with 6.5 cm long appear to be in spawning reaching the highest percentage at 7.5 cm long (Fig. 15).

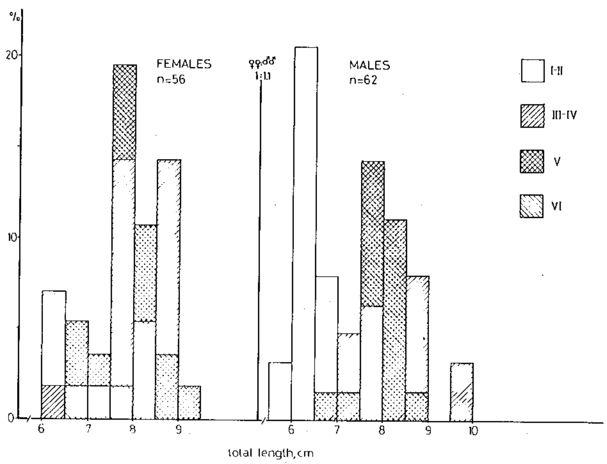

Fig. 15. Relative frequencies (%) of maturity stages by length classes for Stolephorus buccaneeri.

Table 8. Relative frequencies (%) of maturity stages of D. russellii taken from bottom hauls.

MATURITY STAGES		I	II	III	IV	V	VI	N
♀♀	n	2	4	20	71	143	2	242
	%	0.8	1.7	8.3	29.3	59.1	0.8	
♂♂	n	-	22	20	3	126	-	171
	%		12.9	11.7	1.8	73.7		
JUVENILES								126

Gonads of 867 individuals were extracted and the sex and maturity stages determined. Juvenile fish dominated in the pelagic trawl samples and 57.1% of females were at stage II. The highest percentages of males were found at stages V and II (Table 7). Different results were got for bottom trawl samples (Table 8): females dominated in the catches and the highest percentages of males and females were found at stage V (spawning).

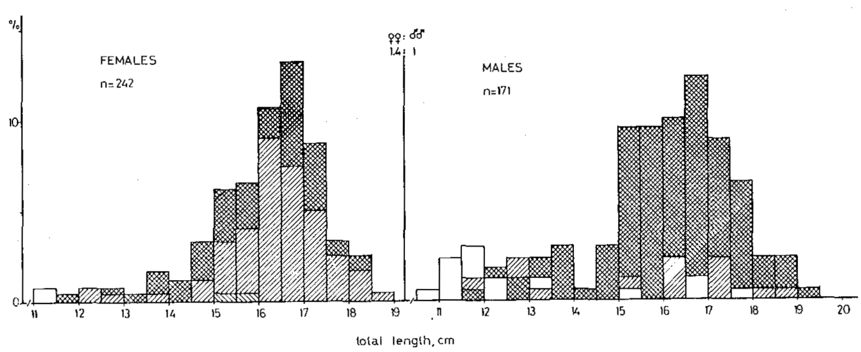

Fig. 19. Relative frequencies (%) of maturity stages by length classes for Decapterus russellii.

For both females and males the highest numbers of individuals in spawning were found at 16.5 cm long (Fig. 19) but males start the spawning activity earlier than females. This feature is very clear in Fig. 20 where the size at first maturity is represented for both females and males, respectively. It was found that 50% of females are in spawning between 13–14 cm long, while males reach their first maturity at sizes 12–13 cm.

Females in spawning activity were found only in the area south of Quelimane. North of this area fish were still at stages III and IV. The same pattern was seen in the cruise conducted by

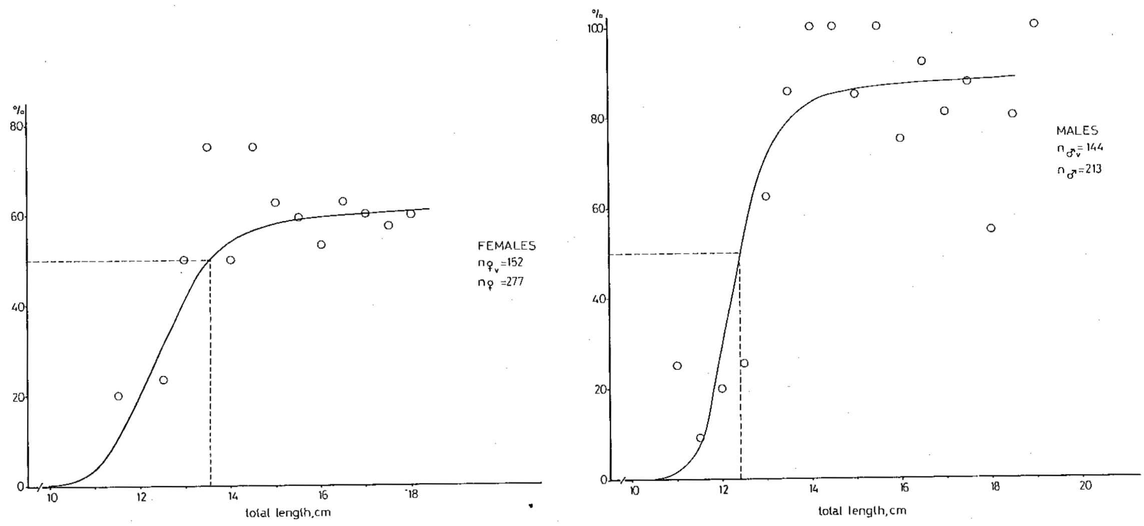

Fig. 20. Size at first maturity for Decapterus russellii.

"Pantikapey" during July-August 1981. Again spawning females were found at depths from 19 to 54 meters, and no concentrations of spawners in deeper waters were present, according to SÆTRE and SILVA (1979).

Juvenile fish were mainly caught in the southern part of Sofala Bank and the smallest specimens were found in the stratum 8 (untrawlable area).

Gonadosomatic indexes of both females and males were estimated for 151 and 110 individuals, respectively. The values obtained were:

Females: $n = 151$
$\overline{GSI} = 2.995$
$s = 2.2259$

Males: $n = 110$
$\overline{GSI} = 1.509$
$s = 1.0584$

These values are very similar to those obtained in 1980 and 1981 for the same period, of the samples taken from the commercial catches (GJØSÆTER and SOUSA, 1983).

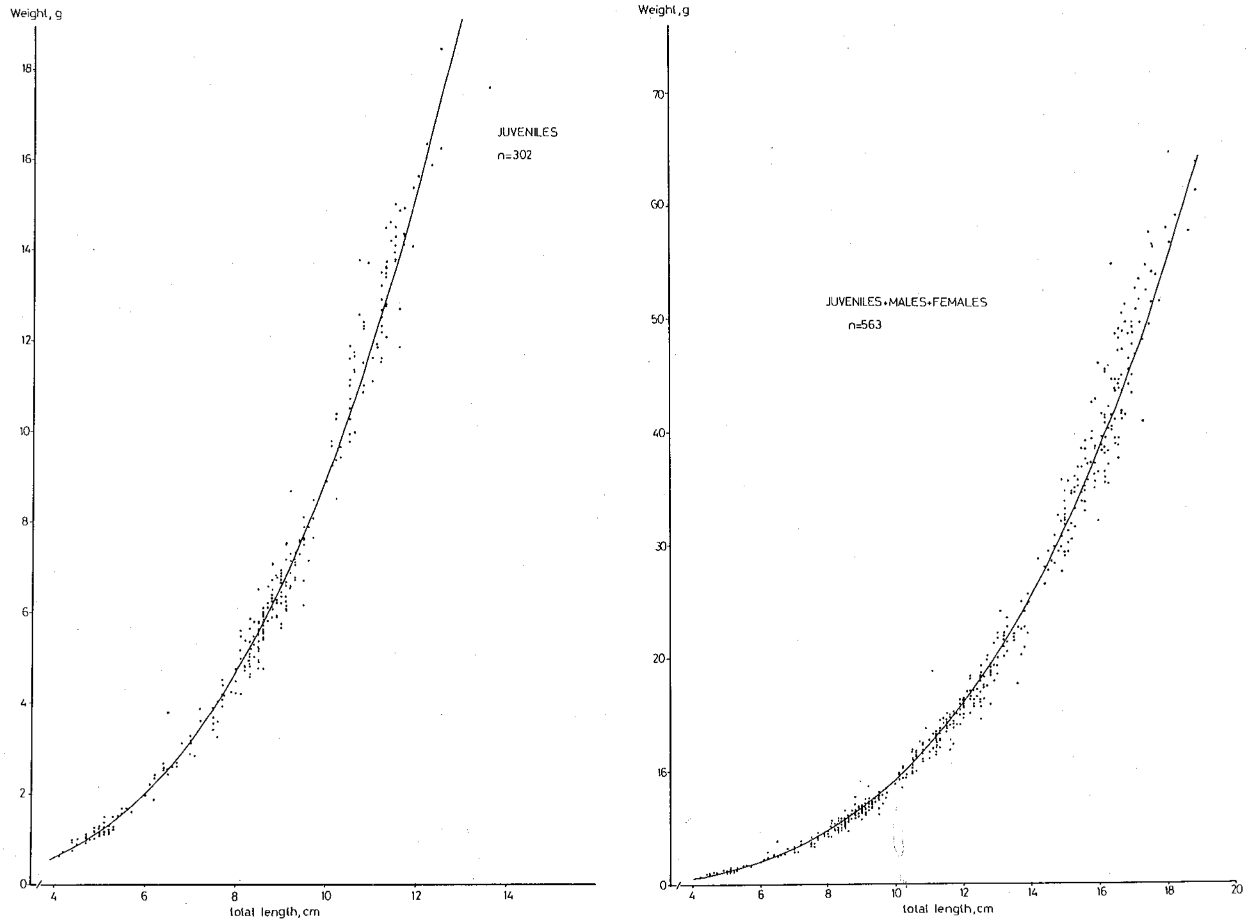

Fig. 21. Length-weight relationship of <u>Decapterus russellii</u>.

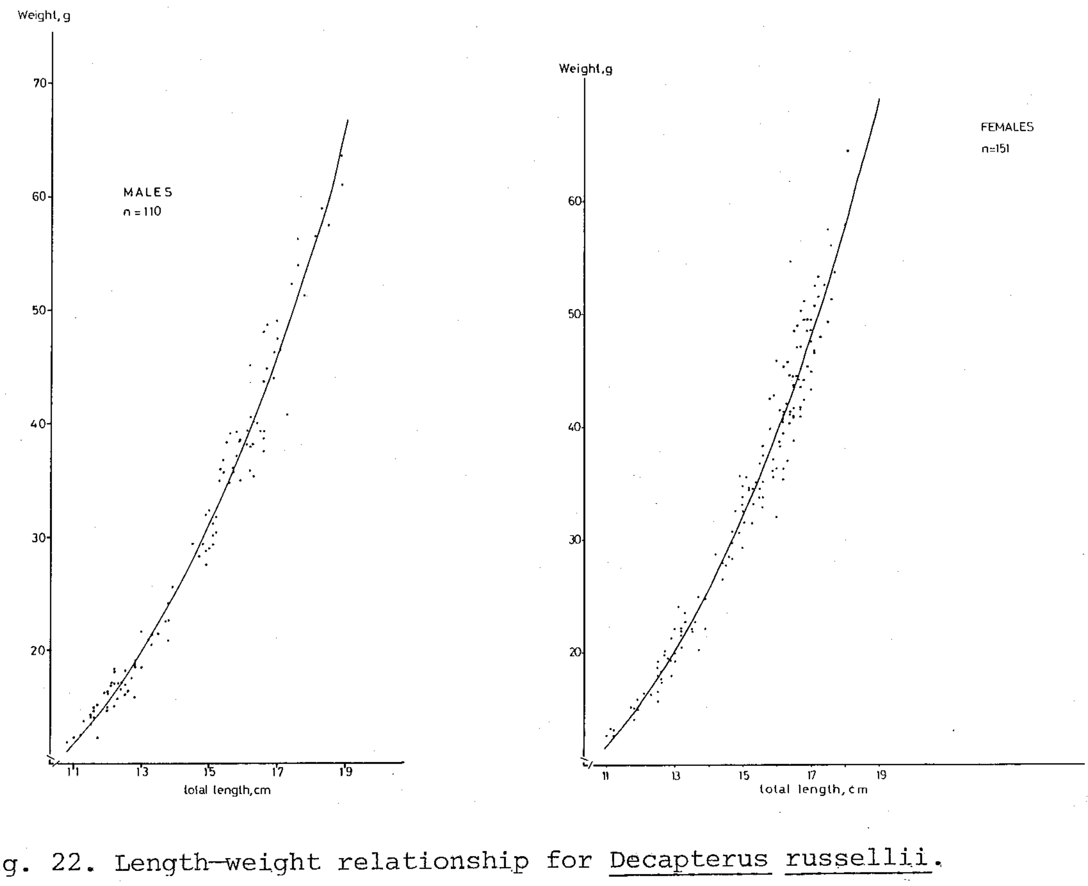

Fig. 22. Length-weight relationship for <u>Decapterus russellii</u>.

Length-weight relationships for juveniles, males and females separately and for all of them together were studied and graphically represented in Figs. 21–22.

The results are as follows:

Juveniles: $n = 302$
$\log W = 2.93\,823 \log L - 1.98471$
$r = 0{,}99509$

Females: $n = 151$
$\log W = 3.23275 \log L - 2.29684$
$r = 0.98477$

Males: $n = 110$
$\log W = 3.12075 \log L - 2.17831$
$r = 0.98977$

Total: $n = 563$
$\log W = 3.02614 \log L - 2.06296$
$r = 0.99743$

The results obtained for males and females are very similar. However, from 13–14 cm long females appear to be, for the same length, heavier than males.

Some otoliths were extracted during the cruise and a total of 62 of them were used for age determination. They belong to fish ranging from 4.2 to 13.0 cm long. Based on the otolith readings the following growth equation was derived:

$$L_t = 22.0 \quad (1 - e^{-0.6423 \ (t - 0.14)}$$

where k and t_o are annual values (Fig. 23).

The validity of this proceduce rests on the assumption that the rings laid in the otoliths are formed daily.

Using the same method, Gjøsæter and Sousa (in press) reached to the following equation:

$$L_t = 24.8 \ (1 - e^{-0.56 \ (t + 0.1)}$$

for otoliths of fish ranging from 13.4 to 18.6 cm long.

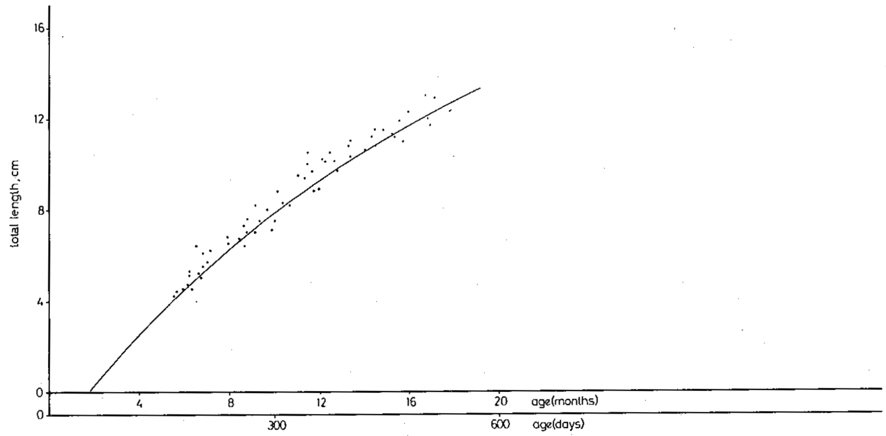

Fig. 23. Growth curve of Decapterus russellii.

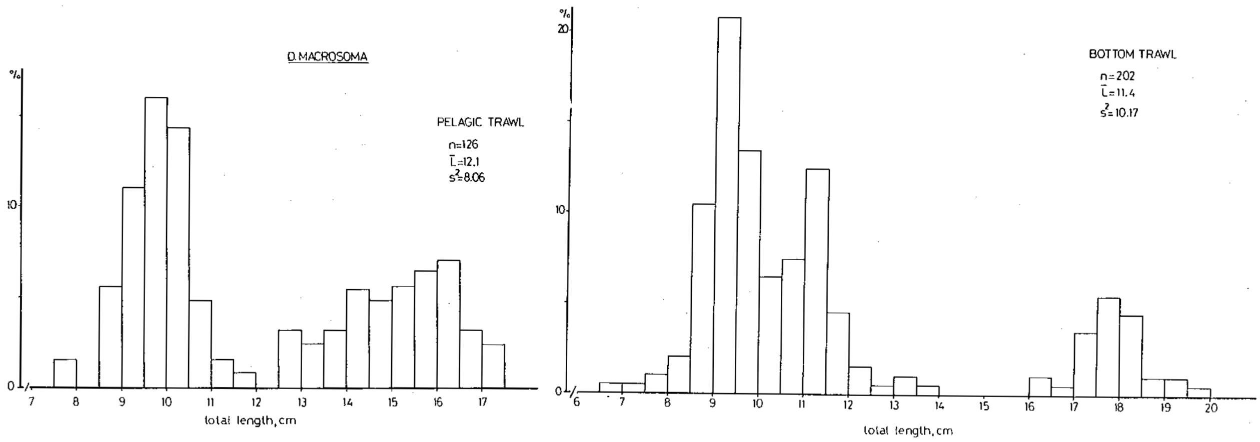

Fig. 24. Length distribution of Decapterus macrosoma from pelagic and bottom trawl.

A few specimens of D. macrosoma were measured and the length composition determined (Fig. 24). Samples taken from pelagic and bottom trawls seem to be similar, although a bit higher mean length was observed in the pelagic trawl samples. This feature, which is the opposite of what was found in D. russellii, seems to be related to the behaviour of this species. In fact, it was observed that the round scad has an avoidance capacity bigger than the layang scad, so that they can easily run away from the pelagic trawl, specially the bigger ones. The same doesn't happen to the layang scad where the big fish are also well represented in the pelagic trawl samples. This explanation should, therefore, be furtherly confirmed.

A few gonads were extracted in two stations close to Quelimane. Males dominated in the samples, representing 85.7% of all individuals sampled. The gonads were mainly found in stage III.

The malabar cavalla, Carangoides malabaricus was caught along the area covered at depths between 9 and 68 meters, and was caught by both pelagic and bottom trawls.

A total of 141 and 80 individuals were measured taken from bottom and pelagic hauls respectively. As the number of fish measured from pelagic trawl samples was scarce, only the length distribution of bottom trawl samples was represented (Fig. 25).

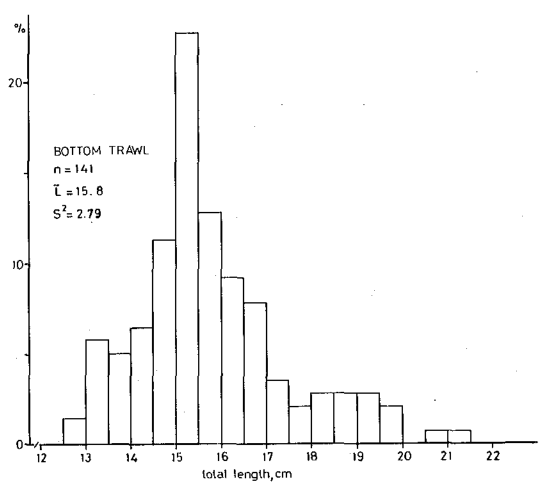

Fig. 25. Length distribution of Carangoides malabaricus from bottom trawl catches.

A few other carangids were measured but no analysis were done due to scarce information. They were, therefore, included in the Appendix III.

Sardines

This group, together with thryssas which were here included, was the best represented in the catches along the area covered, at depths from 9 to 30 meters. They were caught by both pelagic and

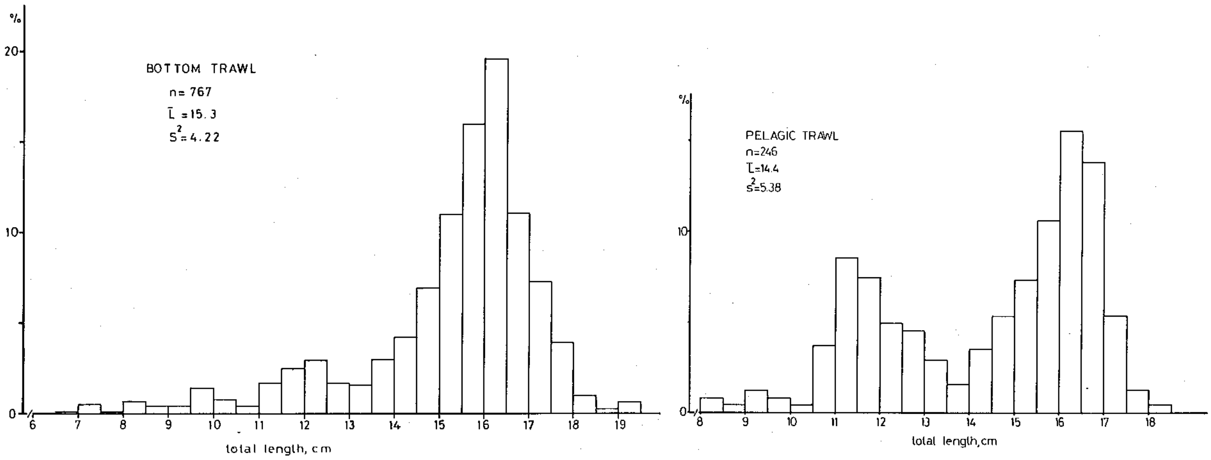

Fig. 26. Length distribution of Pellona ditchela from bottom and pelagic trawl.

bottom trawls. Special attention was paid to Indian pellona, Pellona ditchela and the orangemouth thryssa, Thryssa vitrirostris.

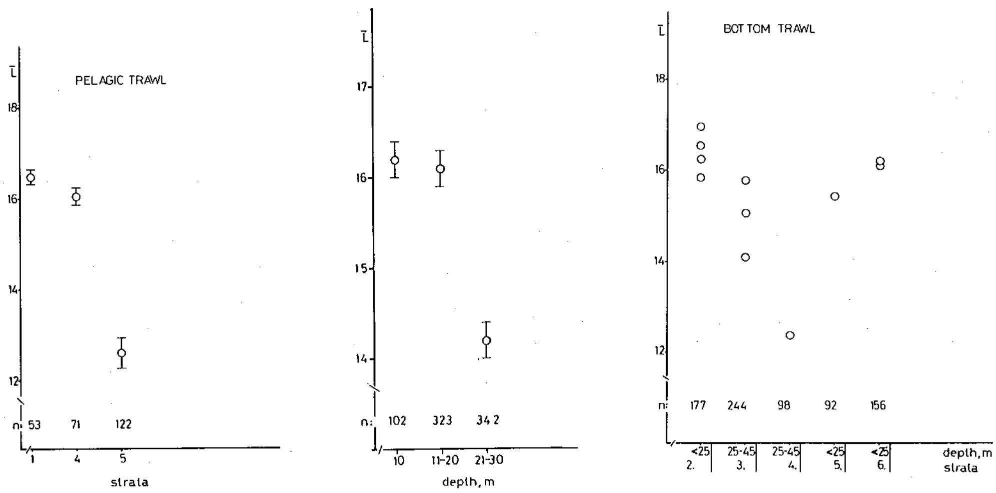

Fig. 27. Mean lengths of Pellona ditchela by strata (left), by depth (middle) and by strata and sub-strata from bottom trawl (right).

Total length was measured in 1013 individuals of P. ditchela taken from 15 pelagic and bottom hauls. Figures 26–27 refer to length distributions and mean lengths determined. Samples taken from pelagic hauls show a length distribution with two distinct modes, of fish ranging from 8 to 18 cm long and a mean length a bit smaller than the ones got from bottom hauls (Fig. 26).

A reduction in the mean length from the north to the south of Sofala Bank was observed in the pelagic trawl samples (Fig. 27). This trend should, however, be confirmed later with the collection of more information from pelagic trawls.

Mean lengths from bottom trawl samples were plotted against strata (Fig. 27). The smallest individuals were found in strata 3 and 4 at depths of 25–45 meters. A more distinct feature is, however, observed when the mean lengths are plotted against depth ranges (Fig. 27). A reduction in the mean length is seen as the depth range increases.

Table 9. Relative frequencies (%) of maturity stages of *P. ditchela* taken from bottom hauls.

MATURITY STAGES		I	II	III	IV	V	VI	N
♀♀	n	-	33	16	8	87	5	149
	%		22.1	10.7	5.4	58.4	3.4	
♂♂	n	1	25	32	7	105	2	172
	%	0.6	14.5	18.6	4.1	61.0	1.2	
JUVENILES								17

Some gonads of fish caught by bottom trawl were extracted for sex and maturity stages analysis. Males were more abundant than females in the proportion 1:0.9. High percentages of females and males were found in spawning (stage V), representing 58.4% and 61.0%, respectively (Table 9). The highest numbers of females and males in spawning were seen at sizes of 15.0 and 15.5 cm, respectively (Fig. 28).

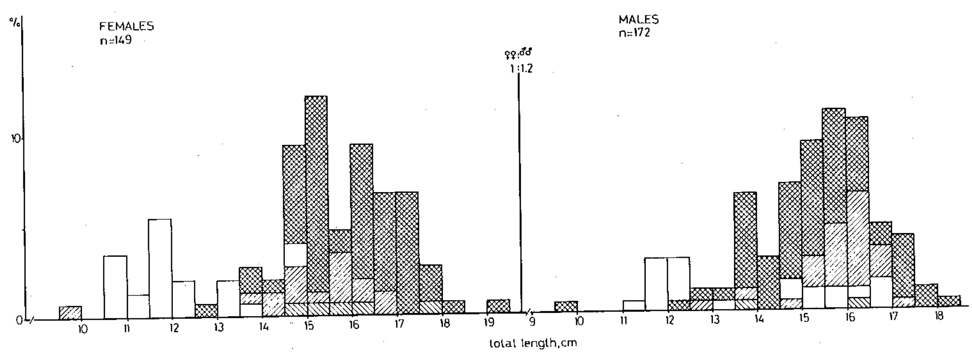

Fig. 28. Relative frequency (%) og maturity stages by length classes for *Pellona ditchela*.

It was found that the highest percentages of spawning females were at depths between 15 and 20 meters, while a reduced number was seen at depths below 20 meters. Females reach their size of first maturity between 13 and 14 cm long (Fig. 29). Males seem to reach earlier than females the size at first maturity but further confirmation should be done.

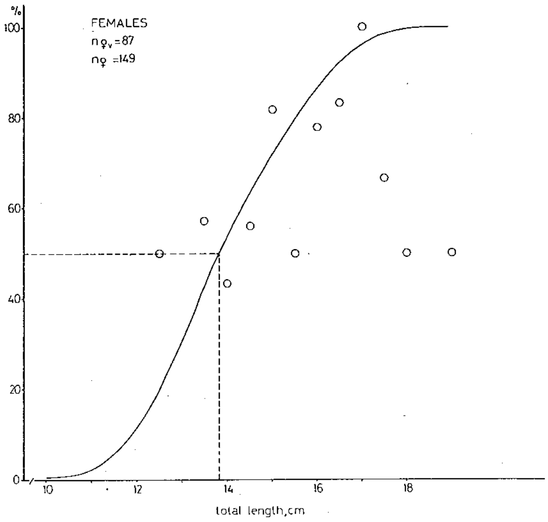

Fig. 29. Size of first maturity for females of Pellona ditchela.

Gonadosomatic index was estimated for both females and males and the results were:

Females: $n = 119$

$\overline{GSI} = 1.92$

$s = 1.358$

Males: $n = 81$

$\overline{GSI} = 1.45$

$s = 0.832$

The length-weight relationship was studied for a total of 221 individuals, where males, females and juveniles were considered all together (Fig. 30). The equation was:

$$\log W = 2.98988 \log L - 2.13667$$
$$r = 0.99015$$

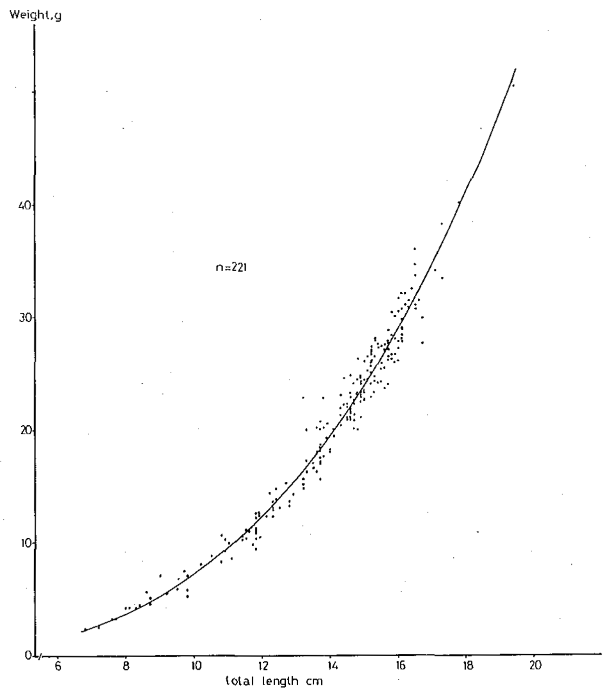

Fig. 30. Length-weight relationship of Pellona ditchela.

Total length was measured in a total of 1678 individuals of T. vitrirostris collected in 17 bottom hauls and 3 pelagic hauls. Once more samples from pelagic trawl show a lower mean length and the smallest fish are better represented in this distribution comparing to bottom trawl length composition (Figs. 31 and 32).

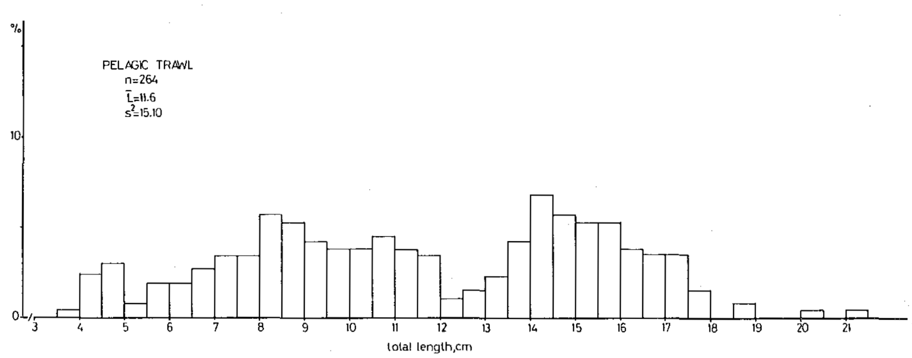

Fig. 31. Length distribution of Thryssa vitrirostris from pelagic trawl.

This species has a particular distribution by strata. So, the smallest mean sizes were found at strata 3 and 4, from Pebane to the mouth of Zambezi river (Fig. 32). No special feature was observed by depth ranges.

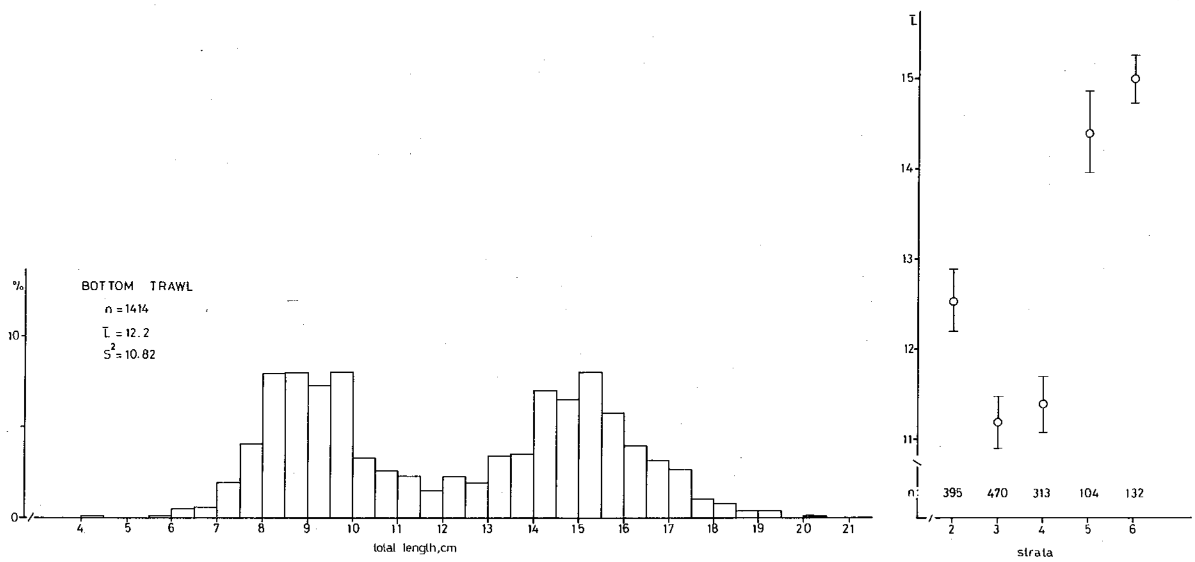

Fig. 32. Length frequency (left) and mean length (right) of Thryssa vitrirostris from bottom trawl catches.

In a total of 434 individuals caught by bottom trawl gonads were extracted for sex and maturity stages analysis. Females were mainly at stages II and III while males appeared mainly at stages I, V (spawning) and III (Table 10). Highest percentages of juveniles were found close to Pebane and Quelimane, where males in spawning were also concentrated. Females and males spawners were observed from the size of 12.5 cm long, reaching at 15.0 cm the highest percentage in males (Fig. 33). Males were more abundant than females in a proportion 1:1.2.

Table 10. Relative frequencies (%) of maturity stages of T. vitrirostris taken from bottom hauls.

MATURITY STAGES		I	II	III	IV	V	VI	N
♀♀	n	-	33	44	12	15	-	104
	%		31.7	42.3	11.5	14.4	-	
♂♂	n	42	1	33	14	35	3	128
	%	32.8	0.8	25.8	10.9	27.3	2.3	
JUVENILES								202

Gonadosomatic index was estimated for males and females, separately. The results were:

Females: $n = 93$

$\overline{GSI} = 1.26$

$s = 1.042$

Males: $n = 104$

$\overline{GSI} = 0.62$

$s = 0.450$

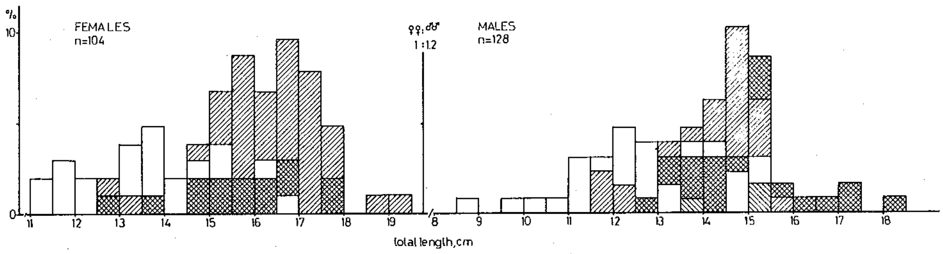

Fig. 33. Relative frequency (%) of maturity stages by length classes for <u>Thryssa vitrirostris</u> (For symbols see Fig. 15).

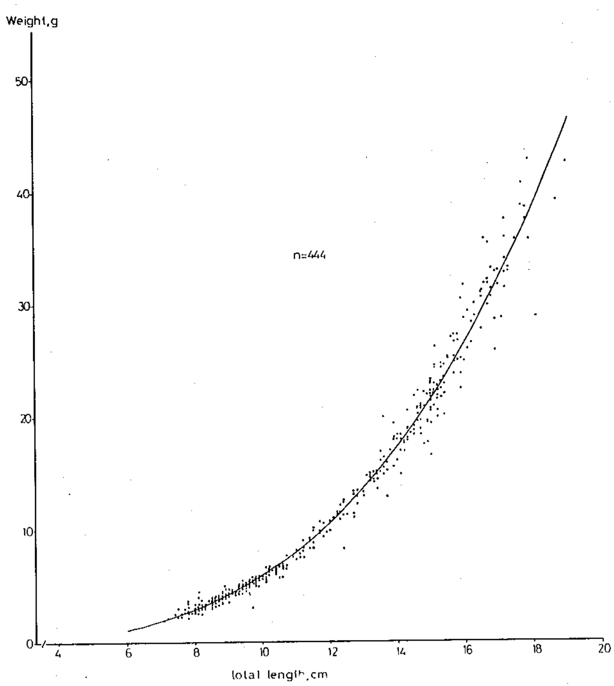

Fig. 34. Length-weight relationship for <u>Thryssa vitrirostris</u>.

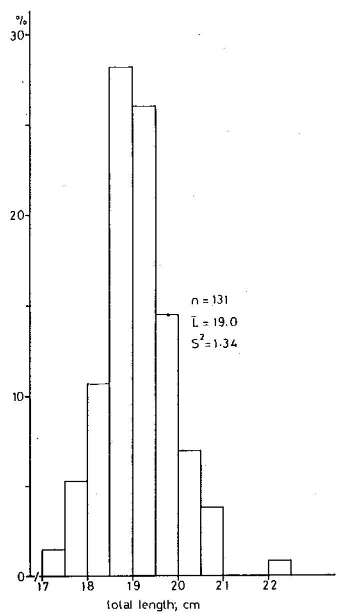

Fig. 35. Length distribution of <u>Hilsa kelee</u>.

Length-weight relationship was studied for a total of 424 individuals where males, females and juveniles were considered all together (Fig. 34). The resulting equation was:

$$\log W = 3.17151 \log L - 2.39863$$
$$r = 0.99204$$

In a few stations, at depths of 13 to 23 meters, some specimens of Hilsa kelee occurred in the catches. They were all measured and the gonads extracted. Fish were of big sizes, with a mean length of 19.0 cm. The length composition is represented in Fig. 35. The males dominated in the samples in a proportion of 1:0.6. A high percentage of fish – 91% were at spawning.

Some other sardines were also measured, but due to scarce information no analysis was made and the recorded data were included in Appendix III.

Ponyfishes

The main species of this group were: Leiognathus equulus, L. elongatus and Secutor insidiator. They occurred at depths of 9 to 68 meters along the coast.

Length composition was determined for 302 individuals of L. equulus caught in 6 bottom hauls (Fig. 36). The mean length was 12.3 cm. Smallest individuals were found close to the mouth of Zambezi river (st. 221).

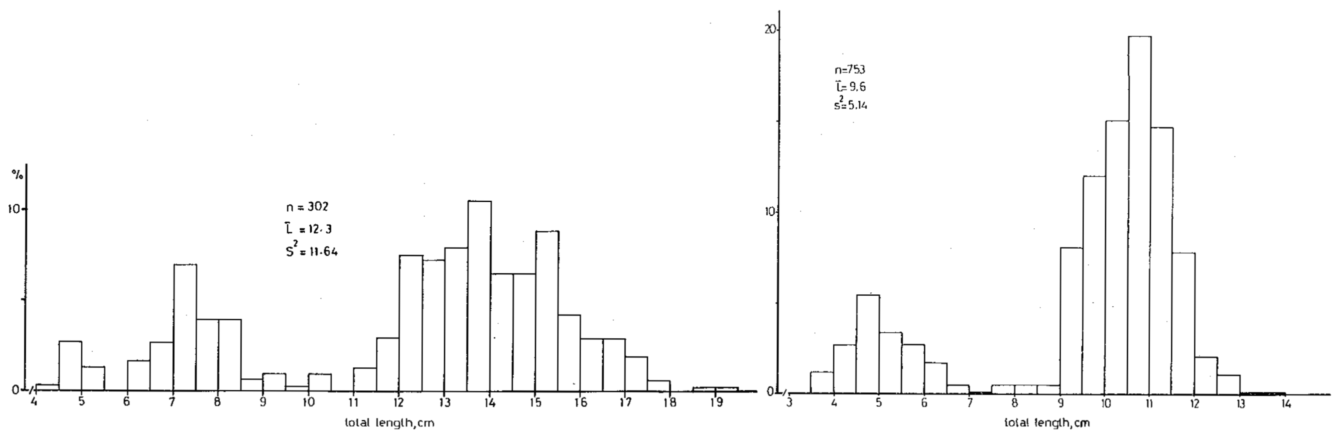

Fig. 36. Length frequencies of Leiognathus equulus (left) and Secutor incidiator (right) from bottom trawl catches.

A total of 50 gonads were analysed from fish caught in one station close to Beira (st. 257) and 50% of gonads were found to be in stage V (spawning) and others were mature.

Samples of S. insidator were collected in 12 bottom hauls and 753 individuals were measured. The length composition (Fig. 36) shows two main modes and the sizes ranging from 3.5 to 13.5 cm long. The smallest fish were caught close to Zambezi river (st. 221) where the mean length was 5.0 cm.

Mackerels

Two main species belong to this group, the Indian mackerel, Rastrelliger kanagurta and the Spanish mackerel, Scomberomorus commerson. Some biological data and material, namely length, sex maturity stages and otoliths were taken from the former one.

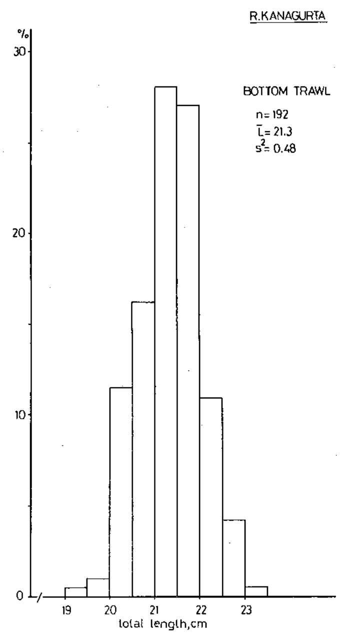

Fig. 37. Length frequency distribution of Rastrelliger kanagurta.

The Indian mackerel was caught by both pelagic and bottom trawls, dominating the juveniles in the pelagic trawl catches. Of 59 fish examined the sizes ranged from 4.5 to 18 cm long and the mean length was 7.7 cm. In the bottom trawl catches fish were mainly adults, of sizes between 19.0 and 23.0 cm long and a mean length of 21.3 cm (Fig. 37). Males were more abundant than females in a proportion of 1:0.8. Also a high number of males in

Croakers

Mainly three species were well represented in the catches Otolithes ruber, Johnius belangerii and J. dussumieri.

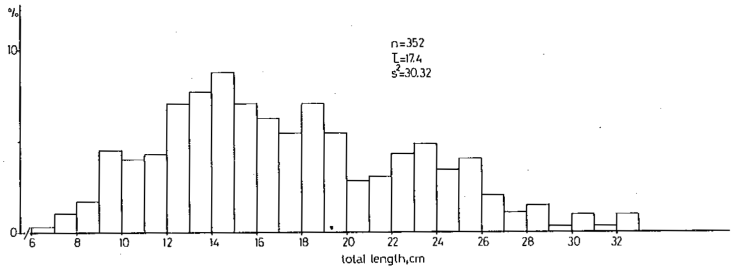

Fig. 40. Length frequency distribution of Otolithes ruber.

A total of 8 samples of O. ruber were collected from bottom hauls, covering the area north of the mouth of Zambezi river, at depths of 11 to 25 meters. For the whole area, a general length distribution was represented in Fig. 40, of fish ranging from 6 to 32 cm long and a mean length of 17.4 cm. However, fish caught at depths lower than 20 meters are mainly composed by small specimens, of mean length, $\bar{L}$ = 14.7 cm, while bigger fish prefer deeper waters, where the mean length was found to be $\bar{L}$ = 22.8 cm.

These observations are in good accordance with the results obtained during the cruise carried out by the vessel "Pantikapey" during June 1981 (SOUSA, 1982).

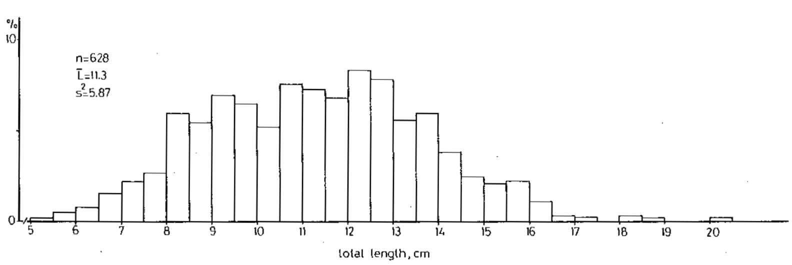

Fig. 41. Length frequency distribution of Johnius belangerii.

A few samples of the belanger's croaker, J. belangerii were collected of 6 bottom hauls, covering the strata 3, 4 and 6, at depths of 9 to 21 meters. For a total of 628 individuals, the mean length was 11.3 cm, of fish ranging from 5.0 to 20.0 cm long (Fig. 41). No differences were observed between the strata 3 and 4, where the mean length obtained was $\bar{L}$ = 10.96 cm, for 529 individuals.

A high value of mean length was, however, observed in the stratum 6, $\bar{L}$ = 13.01 cm, for 99 individuals.

Grunts

Two species of this group were mainly represented in the catches: Pomadasys hasta and P. maculatus.

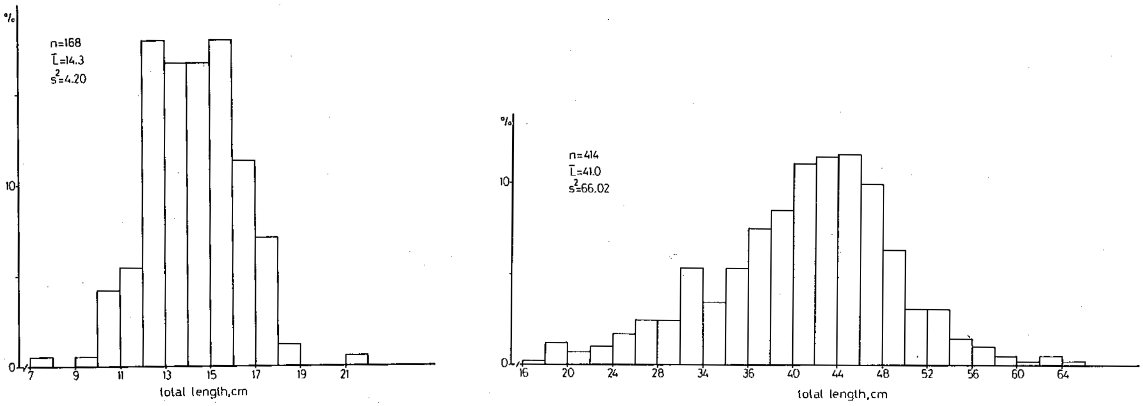

Fig. 42. Length frequencies of Pomadasys hasta (left) and Trichiurus lepturus (right).

A few individuals of P. maculatus were measured, taken from 4 bottom hauls and the length distribution determined (Fig. 42). No other analysis was done due to scarce data.

Recordings of length measurements of P. hasta is indicating in Appendix IV.

Hairtails

This group was represented by only one species, the largehead hairtail, Trichiurus lepturus, samples were taken from 6 bottom hauls, covering the strata 2 and 3, at depths of 16 to 29 meters.

For 414 individuals the length distribution was done, of fish ranging from 16.0 to 64.0 cm and a mean length of 41.0 cm (Fig. 42).

Some length measurements were recorded of fish belonging to the following families: Polynemidae, Teraponidae, Cynoglossidae, Lutianidae, Triglidae and Synodontidae.

Due to scarce data, the analysis were not done and the recordings were inserted in Appendix IV.

5. SHALLOW-WATER SHRIMP

5.1 Distribution and abundance

Bottom trawl surveys on shallow-water shrimp of Sofala Bank have been conducted for time to time since 1979. The frequency of these surveys has not been regular because it depends on the availability of foreign and national vessels; the use of different vessels with different gears and the lack of trawl comparison studies, does not allow that a principal objective – to monitor fluctuations in structure and size of shrimp population – be fulfilled.

Due to the level of exploitation of the resource, this objective should be the principal, which can only be achieved if:

- A vessel is available to cover regularly the area, with a standardized trawl gear and fishing method.

- A proper sampling design can give an objective measure of the precision of the abundance index.

Although the first condition will not be fulfilled in a near future, it is our objective to improve our understanding of the different sampling procedures used in bottom trawl monitoring surveys.

The main objective of the present survey was the training of the personnel in the application of stratified random sampling. According to GROSSLEIN (1980) and DOUBLEDAY (1981) this sampling design have great advantages for populations with a distribution similar to the shallow-water shrimp.

Routine data (carapace length, total length, sex and maturity stages) was recorded for Penaeus indicus and Metapenaeus monoceros. Samples of these two species were collected to record individual weight in the laboratory. On stations with shrimp catches, routine data (total length and sample weight) was recorded for the most important commercial fish species. Stratified random sampling was used according to the methodology included in GROSSLEIN (1980) and DOUBLEDAY (1981).

The definition of strata and sampling units, and the method of station selection are included in annex 5.

Figure 43 illustrates the stratification scheme and the station pattern obtained.

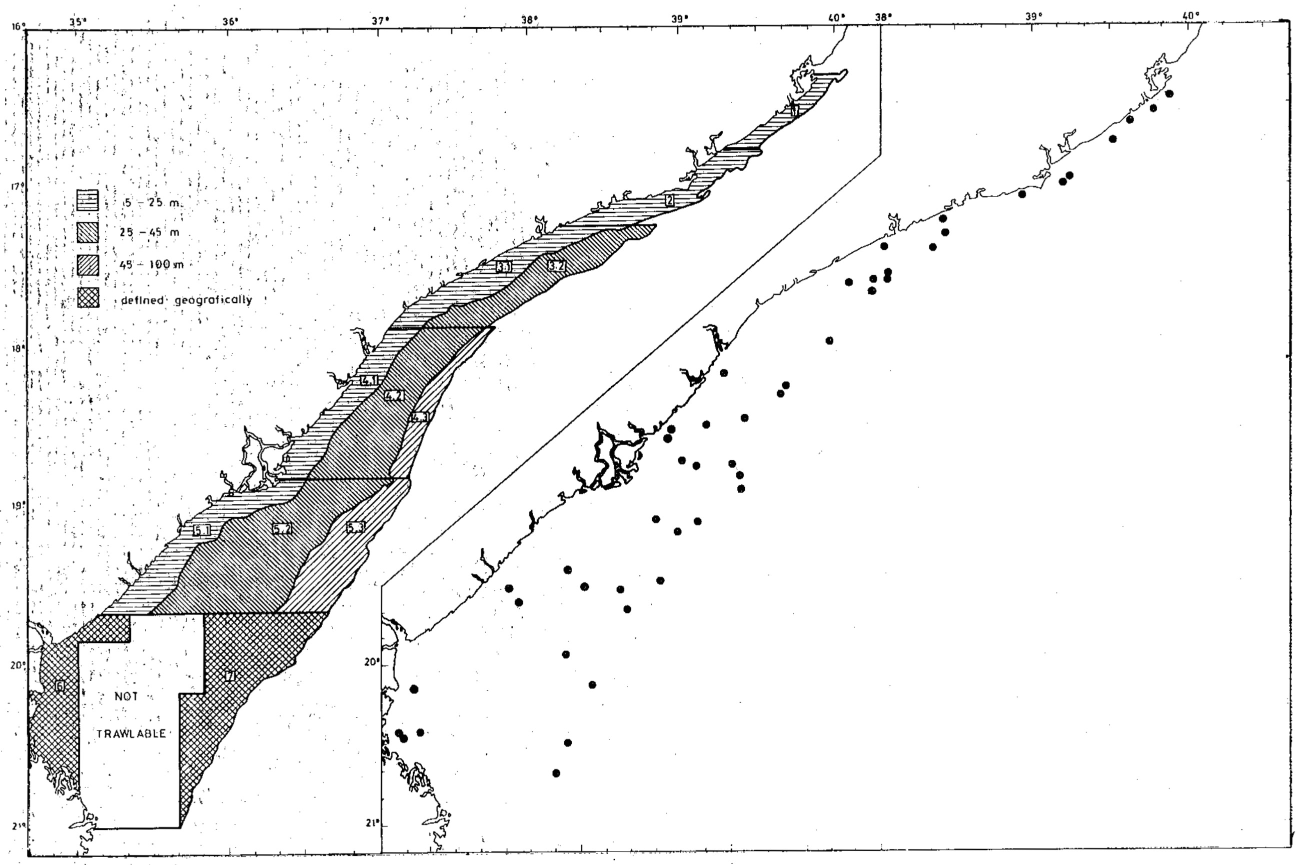

Fig. 43. The stratification scheme (left) and station pattern (right) for the shallow-water shrimp survey.

The stratified random sampling estimate of the mean catch per tow was computed applying the formulas given by COCHRAN (1966). Table 11 shows the worksheet for the computation; a mean of 6000 g per tow was obtained.

TABLE 11. Worksheet for the computation of the mean catch per tow for the total catch of shrimp.

a) Basic data

	Strata						
	1	2	3.1	3.2	4.1	4.2	6
Area (Km^2)	649	1454	2802	1521	2682	3667	1842
Nr. hauls	4	4	4	4	4	4	4
Individual Catches (g)	0	9100	9000	8500	13900	0	13200
	500	1450	24400	1580	600	8500	10200
	0	850	5000	100	8200	0	0
	0	3800	11300	400	12000	0	3010

b) Formulas

$$\bar{y}_{st} = \frac{1}{A} \times \sum_h (A_h \times \bar{y}_h)$$

$\bar{y}$ mean catch per tow within a stratum

A_h area of the stratum

$$A = \sum_h A_h$$

c) Results

	Stratum Estimates						
Statistics	1	2	3.1	3.2	4.1	4.2	6
$\bar{y}_h$: 10^3	0.13	3.80	12.43	2.65	8.68	2.13	6.60
s_h^2 : 10^6	0.0625	14.1050	70.5092	15.6441	34.5958	18.0625	37.6560
CV (%)	200.0	98.8	67.8	149.5	67.8	200.0	92.9

$\bar{y}_{st} = 6.00$

The skewness of distributions of trawl catches raises problems in constructing valid confidence limits (Fig. 44). In order to apply the normal theory, data was transformed by logarithms. As

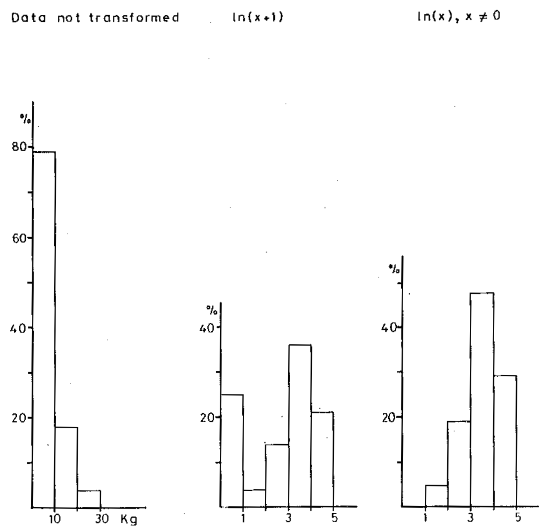

Fig. 44. The distribution of trawl catches of shrimp.

can be seen from Figures 44 and 45, the resulting distribution from ln (x + 1) transformation is still far from normal.

Transformation of data by ln (x), x = 0 seems to be the most appropriate, although the resulting distribution is skewed to the left.

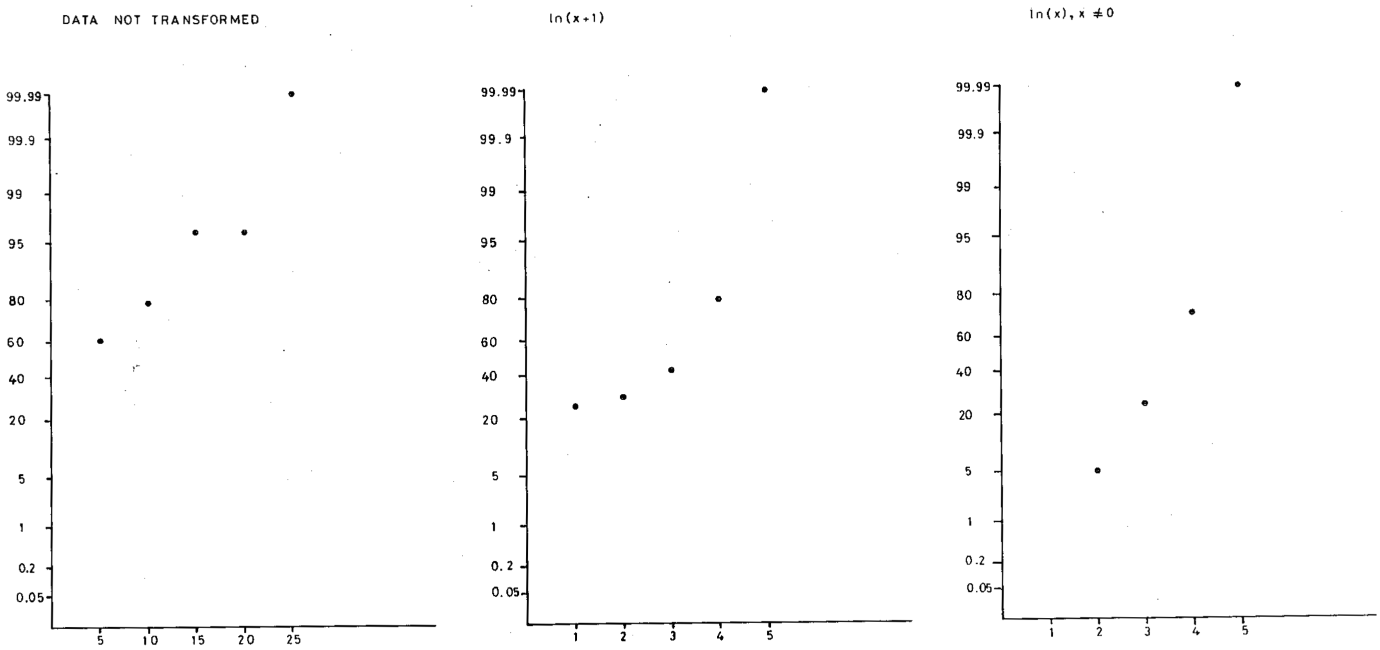

Fig. 45. Distribution of trawl catches of shrimp.

Table 12 presents the worksheet for the computation of mean catch per tow and its confidence interval based on the method described by PENNINGTON and GROSSLEIN (1978). The result obtained was 750.2<2606.8<8045.4 g. The confidence interval generated contains the arithmetic mean.

TABLE 12. Worksheet for the computation of the mean catch per tow and its confidence limits based on a post-stratification scheme and transformation of the data by ln (x) $x \neq 0$

a) Formulas

Stratified mean catch per tow and its variance

$$\bar{y}_{st} = \frac{1}{A} \times \sum_h (A_h \times \bar{y}_h)$$

$$\text{var}(\bar{y}_{st}) = \frac{1}{A^2} \times \sum_h (A^2_h \times \frac{s^2_h}{n_h})$$

Stratified mean proportion of zeros and its variance

$$p_{st} = \frac{1}{A} \times \sum_h (A_h \times p_h)$$

$$\text{var}(p_{st}) = \frac{1}{A^2} \times \sum_h (A^2_h \times \frac{p_h\, q_h}{n_h - 1})$$

p_h proportion of zeros within a stratum

$q_h = 1 - p_h$

Degrees of freedom

$$n_e = \frac{(\sum_h g_h\, s^2_h)^2}{\sum_h \frac{g^2_h\, s^4_h}{n_h - 1}} \quad \text{with} \quad g_h = \frac{A_h\,(A_h - n_h)}{n_h}$$

Confidence limits of mean catch per tow

$$\bar{y}'_{st} = \text{antilog}\left[\bar{y}_{st} - t\sqrt{\text{var}(\bar{y}_{st})}\right]$$

$$\bar{y}''_{st} = \text{antilog}\left[\bar{y}_{st} + t\sqrt{\text{var}(\bar{y}_{st})}\right]$$

$$p_{st} \pm \left[t\sqrt{\text{var}(p_{st})} + \frac{1}{2n}\right]$$

$$\bar{y}'_{st}\, p'_{st} \leq (\text{antilog}\ \bar{y}_{st})\,(p_{st}) \leq \bar{y}''_{st}\, p''_{st}$$

b) Results

Since only one value was different from zero in some **strata** , the method of collapsed stra had to be used. The following post-stratification scheme was considered: strata (1 + 2), strata (3.1 + 4.1), strata (3.2 + 4.2) and strata (6).

The following results were obtained:

$$1442.4146 \leq 3336.0994 \leq 7715.9224$$
$$0.5201 \leq 0.7814 \leq 1.0427$$
$$750.20 \leq 2606.83 \leq 8045.39$$

with $n_e = 7$ and Confidence ≃ 95%

Due to the high variability of the catches (even excluding the zero catches) and the low number of hauls, the confidence interval generated is too large. The precision of the mean could be increased by increasing the number of hauls. As the retransformed mean is not very close to the arithmetic mean if the precision is increased, this mean probably will be outside the confidence interval; for our data this method seems to be not very realistic, but this assumption has to be confirmed applying the method to data collected in future surveys.

Since there are still some doubts about the accuracy of the estimate of mean catch per tow and its confidence limits obtained by applying Pennington and Grosslein method, the biomass was estimated using the arithmetic mean. It was not possible to compute an absolute biomass estimate because the catchability coefficient (q) is not known. A minimum biomass estimate was computed by strata applying $\bar{y}_h \times A_h/a$. The swept area by tow (a) was computed considering a mean trawling speed of 3.2 knots and a horizontal opening of the net of 18 meters.

The results are shown in Table 13. A value of 1644 tons was computed for total shrimp biomass. Between 18°50' and 21°00' the biomass was 14% of the total; this proportion is not in accordance with previous computations (Muleve, 1979, Fr. Nansen, 1980). This could be due to the following reasons:

1 - In previous surveys south of Zambezi River the biomass was estimated assuming that the observed catch per hour could be applied to the whole area. This assumption most probably overestimates the biomass because a large part of that area (see Fig. 43) cannot be covered by bottom trawl.

2 - In the present survey south of Zambezi River the biomass seems to be underestimated because no shrimp was caught in the three strata defined between 18°50' and 19°40'. Although in past surveys this area has not been well covered, there is enough information that shrimp is present. The most probable source of error was the definition of strata. This problem must be considered in future surveys.

TABLE 13. Worksheet for the computation of total shrimp biomass (in weight). Swept area by tow = 1.6 x 1.852 x 0.018 km^2

	1	2	3.1	3.2	4.1	4.2	6	Total
$\bar{y}_h$ (kg)	0.13	3.80	12.43	2.65	8.68	2.13	6.60	6.00
A_h (km^2)	649	1454	2802	1521	2682	3667	1842	14617
$\bar{B}_h$ (tons)	1.6	103.6	653.0	75.6	436.5	146.4	227.9	1644

TABLE 14. Worksheet for the computation of P. indicus biomass (in weight)
a) Basic data

	Strata					
	2	3.1	3.2	4.1	4.2	6
Individual Catches (g)	1800	900	1700	4500	0	9600
	1200	2000	50	300	2100	3000
	700	500	0	2600	0	0
	3000	2400	0	2100	0	1700

b) Results

	Stratum Estimates							Total
	1	2	3.1	3.2	4.1	4.2	6	
$\bar{y}_h$ (kg)	-	1.68	1.45	0.44	2.38	0.53	3.58	1.58
A_h (km^2)	649	1454	2802	1521	2682	3667	1842	13968
$\bar{B}_h$ (tons)	-	45.8	76.2	12.6	119.7	36.4	123.6	414

TABLE 15. Worksheet for the computation of M. monoceros biomass (in weight)
a) Basic data

	Strata						
	1	2	3.1	3.2	4.1	4.2	6
Individual Catches (g)	0	200	2900	5100	3600	0	3600
	500	200	800	1300	200	6400	7000
	0	50	4200	100	3100	0	0
	0	400	7200	200	6800	0	600

b) Results

	Stratum Estimates							Total
	1	2	3.1	3.2	4.1	4.2	6	
$\bar{y}_h$ (kg)	0.13	0.21	3.78	1.68	3.42	1.60	2.80	2.31
A_h (km^2)	649	1454	2802	1521	2682	3667	1842	14617
$\bar{B}_h$ (tons)	1.6	5.7	198.6	47.9	172.0	110.0	96.7	633

TABLE 16. Worksheet for the computation of P. indicus biomass (in number)
a) Basic data

	Strata					
	2	3.1	3.2	4.1	4.2	6
Individual Catches	61	27	35	173	0	276
	31	62	3	14	40	100
	14	8	0	130	0	0
	106	59	0	43	0	38

b) Results

	Biomass estimate						
	2	3.1	3.2	4.1	4.2	6	Total
$\bar{B}$	1444797	2048799	270906	4525513	687507	3574345	12551867

TABLE 17. Worksheet for the computation of M. monoceros biomass (in number)
a) Basic data

	Strata						
	1	2	3.1	3.2	4.1	4.2	6
Individual Catches	0	19	176	283	138	0	192
	30	10	33	61	12	291	440
	0	4	*	7	172	0	0
	0	14	300	12	242	0	25

* not considered value

b) Results

	Biomass estimate							
	1	2	3.1	3.2	4.1	4.2	6	Total
$\bar{B}$	91323	320535	8919437	2589695	7094972	5005145	5676332	29697439

Tables 14–17 show the biomass estimates (in weight and number) of the main species – Penaeus indicus and Metapenaeus monoceros.

In the present survey neither proportional allocation (based on stratum areas) nor general optimum allocation (based on stratum variances and areas) was done. This error should be avoided in future surveys. As changes of shrimp distribution are not well known, data of the present survey should not be used for the optimum allocation of the sampling effort. Proportional allocation seems to be the most appropriate method until more information is available on the spatial and temporal distribution of shrimp.

A redefinition of strata should be made between 18°50' and 19°40'. The available information on environment characteristics and pattern of shrimp distribution, is not enough to set out very objectively the strata boundaries. One approach could be to consider smaller geographic strata with the same depth boundaries which could be tested in the initial cruises and changed if necessary.

The relation between tow duration and sampling efficiency is not known. However, the low values of catch per tow suggest that it is desirable to increase the length of the tow. It is important to carry out this investigation in future surveys. As this experiment is time-consuming it should be postponed until the selection of an appropriate survey trawl and fishing method is made.

5.2 Biological characteristics of the main species

Within a stratum the average length composition was computed by combining length frequency of the samples from the catches. Measurements of carapace length were grouped in 4 mm classes, due to the low number of individuals.

To obtain the overall length frequency, combined length compositions, were weighted by the estimated number of shrimp in the stratum to obtain the average length composition over all strata.

Penaeus indicus

a) Females

Carapace length varied between 22 and 55 mm ($\overline{LC}$ = 38.51 mm) with most of the individuals (72%) being between 32 and 45 mm (Fig. 46).

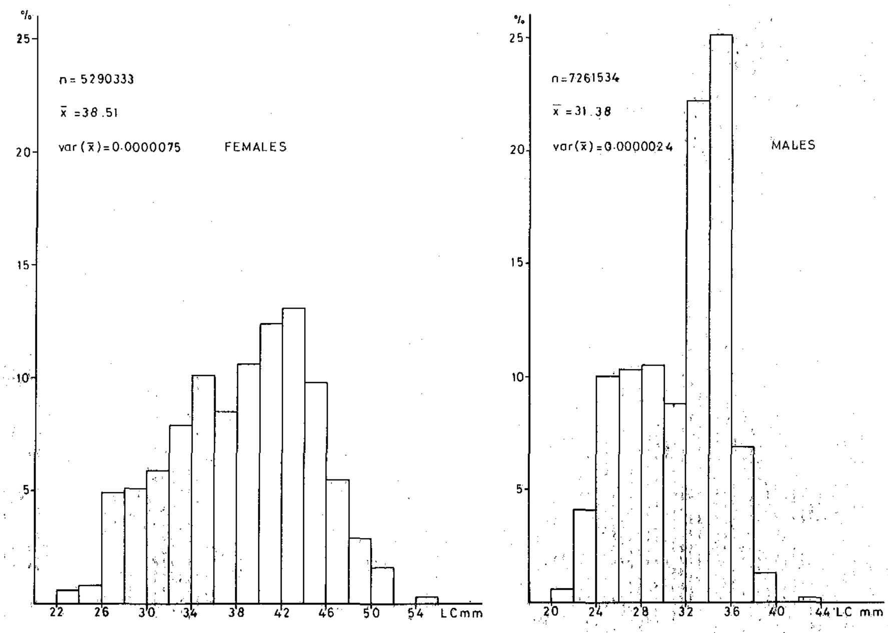

Fig. 46. Carapace length distribution of *Penaeus indicus*.

The smallest individuals were dominant in strata 4.1 (Tables 18 and 19).

Table 20 shows the percentage of the different gonad maturity stages per stratum. About 64% of the population was formed by late maturing and mature females. The highest percentages were found in strata 4.2 and 3.2.

TABLE 18. *P. indicus* ♀ - Carapace length frequency distribution
a) Basic data (number of individuals)

	Class mark																	
Strata	21	23	25	27	29	31	33	35	37	39	41	43	45	47	49	51	53	55
2			1	2	3	5	8	9	9	6	14	7	5	1				
3.1						3	3	4	8	11	10	8	3	2	2			
3.2						1	1	2	2	3	6	7	4	2	1			
4.1		2	2	12	11	8	8	8	8	8	2	9	10	4	1	2		1
4.2						1	2	3	2	6	6	8	4	5	2			
6				2	3	4	8	12	5	6	14	11	10	5	4	3		

b) Percentage in number, mean and its standard deviation (data grouped in 4 mm classes)

	Class mark									Total number	$\bar{x}$	$s_{\bar{x}}$
Strata	22	26	30	34	38	42	46	50	54			
2		4.3	11.4	24.3	21.4	30.0	8.6			70	37.49	0.63
3.1			5.6	13.0	35.2	33.3	9.3	3.7		54	39.56	0.61
3.2			3.5	10.3	17.2	44.8	20.7	3.5		29	41.17	0.83
4.1	2.1	14.6	19.8	16.7	16.7	11.4	14.6	3.1	1.0	96	35.83	0.76
4.2			2.6	12.8	20.5	35.9	23.1	5.1		39	41.18	0.75
6		2.3	8.1	23.0	12.6	28.7	17.2	8.1		87	39.66	0.65

TABLE 19. *P. indicus* ♂ - Carapace length frequency distribution

a) Basic data (number of individuals)

	Class mark											
Strata	21	23	25	27	29	31	33	35	37	39	41	43
2	1		1	11	18	20	45	32	6	1		
3.1		1	1	4	7	5	25	46	9			1
3.2							3	4	1			
4.1	2	15	35	27	14	11	21	22	9	2		
4.2				1								
6		1	5	7	17	14	33	33	10	3		

b) Percentage in number, mean and its standard deviation (data grouped in 4 mm classes)

	Class mark						Total number	$\bar{x}$	$s_{\bar{x}}$
Strata	22	26	30	34	38	42			
2	0.7	8.9	28.2	57.0	5.2		135	32.28	0.26
3.1	1.0	5.1	12.1	71.7	9.1	1.0	99	33.43	0.29
3.2							8	-	-
4.1	10.8	39.2	15.8	27.2	7.0		151	29.22	0.37
4.2							1	-	-
6	0.8	9.8	25.2	53.7	10.6		123	32.54	0.30

TABLE 20. *P. indicus* ♀ - Gonad maturity stages and biomass estimates

a) Percentage of maturity stages by stratum

M.S. \ Strata	2	3.1	3.2	4.1	4.2	6
1	8.3	-	-	2.9	-	1.6
2	26.7	44.4	17.2	44.1	10.3	31.1
3	25.0	22.2	24.1	29.4	2.6	23.0
4	40.0	33.3	58.6	23.5	87.2	44.3
Total number sampled	60	54	29	68	39	61

b) Biomass estimates

Strata	2	3.1	3.2	4.1	4.2	6	Total
♀	493345	723107	212333	1710431	670318	1480799	5290333
♀ 3+4	320674	401324	175599	904818	601946	996578	3400939
♀ 4	197338	240795	124427	401951	584517	655994	2205022

64.3% of ♀ 3+4 in the population

41.7% of ♀ 4 in the population

Sex-ratio was calculated and males were dominant (60%). However, in the areas with high percentages of mature females (strata 4.2 and 3.2) females were dominant (Table 21).

TABLE 21. P. indicus. Percentage of females by stratum

Strata	2	3.1	3.2	4.1	4.2	6
♀	34.1	35.3	78.4	37.8	97.5	41.4
Total number sampled	205	153	37	254	40	210

42.1% of ♀ in the population

b) Males

Carapace length varied between 20 and 43 mm ($\overline{LC}$ = 31.38 mm) with most of the individuals (87%) being between 24 and 35 mm (Fig. 46).

Table 19 shows that the smaller individuals were more abundant in strata 4.1.

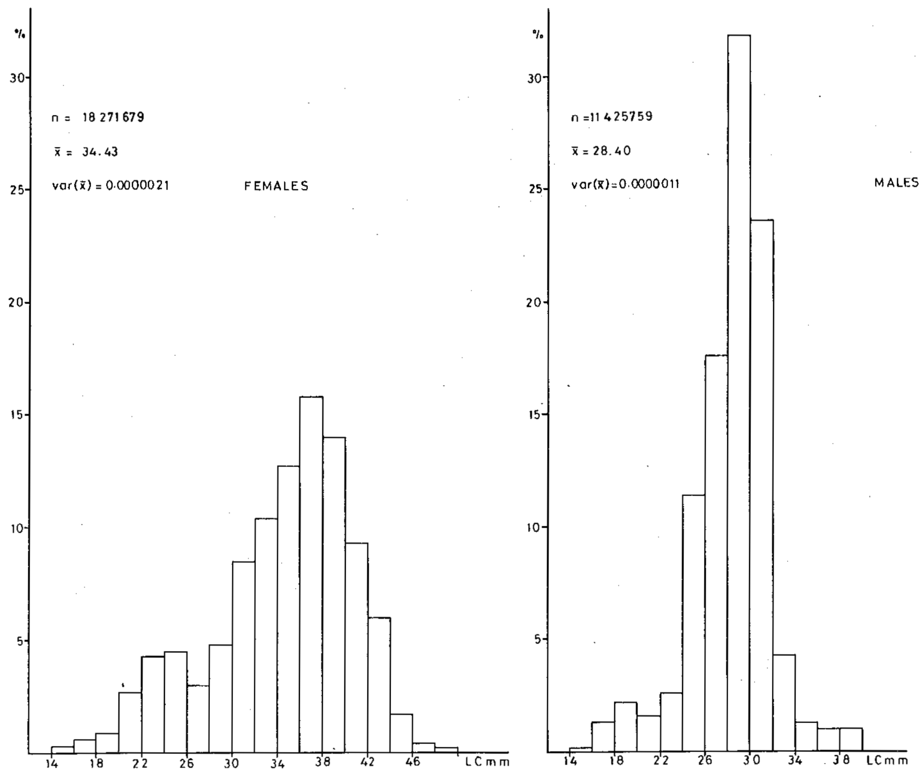

Fig. 47. Carapace length distribution of Metapenaeus monoceros.

Sex-ratio was calculated and females were dominant (61%) (Table 25).

b) Males

Carapace length varied between 14 and 39 mm ($\overline{LC}$ = 28.40 mm) with most of the individuals (84%) being between 24 and 30 mm (Fig. 47).

Table 23 shows that the smallest individuals were more abundant in strata 4.1.

5.3 Shrimp by-catch

The main objective of the analysis on magnitude and composition of the shrimp by-catch is to have data to be applied to the commercial shrimp catches, in order to know the level of exploitation of the demersal and pelagic resources of Sofala Bank.

A compilation of the available information on shrimp by-catch from the surveys made since 1979 (CRISTO 1982) confirmed that "... the use of different shrimp trawls most likely gives different information on magnitude and composition of the by-catch ..." (BRINCA et al., 1981). The use of research vessels with gears different from the gears used in the commercial trawls makes almost useless the analysis of data collected by research vessels if comparison studies are not made.

Information of the present survey is included in Annex 6 but it is not analysed due to the reasons mentioned earlier.

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ANNEX I

Settings and performance of acoustical instruments

Frequency	38 kHz	120 kHz
Basic range (m)	0–100/0–250	0–100
Bandwidth	3.0 kHz	3.0 kHz
Pulse length	0.6 msec.	0.6 msec.
TVG and gain	20 logR - 20 dB	20 logR 0 dB
Recorder gain	7	2
Transmitter power	1880 W	298 W
Transducer dimension (ceramic)	8° x 8° 30 x 30 cm	10° circular
Discriminator	5 - 7	-
Source level + voltage response	139.2 dB	112.2 dB
Measured	31 August 1982	31 August 1982
Integrator threshold	A 0.5	0
	B 0.5	0
Integrator gain	A 20 dB x 10	10 dB x 10
	B 20 dB x 10	10 dB x 10
Depth intervals (m)	A 4–50	4–50
	B 50–250	50–100
	(Varying with depth)	
Bottom stop	ON	ON

ANNEX II

DATE	TIME START	STN No.	GEAR TYPE	DEPTH (M) BOTTOM	DEPTH (M) GEAR	POSITION SOUTH	POSITION EAST	CATCH (KG) TOTAL	CATCH (KG) PR HR	DOMINANT SPECIES	WEIGTH (KG) PR HR	%
02.09	1215	160	PT	87	20	16°23'	040°05'	,0	,0	N O C A T C H	,00	,0
02.09	1449	161	BT	11	11	16°27'	039°53'	122,8	245,6	Secutor insidiator	14,80	6,0
										Upeneus vittatus	163,20	66,4
										Dussumieria acuta	9,20	3,7
										Sardinella albella	20,00	8,1
02.09	2045	162	BT	19	19	16°56'	039°19'	155,3	310,6	Pomadasys maculatus	45,00	14,4
										Otolithes ruber	43,00	13,8
										LEIOGNATHIDAE	38,00	12,2
										Upeneus vittatus	35,00	11,2
										Rhonciscus stridens	32,00	10,3
02.09	2220	163	PT	200	20	17°00'	039°18'	11,6	23,2	MYCTOPHIDAE	6,20	26,7
										Dussumieria acuta	3,20	13,7
										Sphyraena obtusata	2,20	9,4
										Decapterus sp	1,00	4,3
										Selar crumenophthalmus	4,20	18,1
										Psenes indicus	3,40	14,6
03.09	0325	164	BT	12	12	17°11'	038°39'	161,0	322,0	Thryssa vitrirostris	50,00	15,5
										Polynemus sextarius	33,00	10,2
										Johnius belangerii	32,00	9,9
										Upeneus vittatus	31,00	9,6
03.09	1600	165	PT	24	1	17°44'	037°43'	7,1	14,2	Scomberomorus commersoni	10,00	70,4
										Carangoides malabaricus	4,20	29,5
03.09	2235	166	BT	20	20	17°56'	037°15'	65,1	130,2	Otolithes ruber	19,40	14,9
										Thryssa vitrirostris	18,90	14,5
										Metapenaeus monoceros	16,20	12,4
										Mene maculata	12,16	9,3
										Pomadasys hasta	13,50	10,3
04.09	1336	167	PT	20	1	18°41'	036°41'	7,5	15,0	Carangoides malabaricus	4,40	29,3
										Saurida undosquamis	2,60	17,3
										Upeneus vittatus	2,00	13,3
										Gerres filamentosus	1,40	9,3
										MISCELLANEOUS	1,90	12,6
04.09	1700	168	PT	40	1	18°51'	036°54'	,0	,0	N O C A T C H	,00	,0
04.09	2355	169	PT	73	30	19°09'	036°46'	,0	,0	N O C A T C H	,00	,0
05.09	0332	170	PT	28	15	19°00'	036°31'	19,1	38,2	Pellona ditchela	35,20	92,1
										Sphyraena obtusata	1,20	3,1
										Dussumieria acuta	,70	1,8
										MISCELLANEOUS	1,10	2,8
06.09	1925	171	PT	30	10	19°35'	035°49'	2,4	4,8	Rastrelliger kanagurta	1,00	20,8
										Loligo sp	1,40	29,1
										Carangidae. juvenile	1,20	25,0
										Saurida undosquamis	,60	12,5
										Stolephorus sp	,54	11,2
06.09	2355	172	PT	41	25	19°58'	035°44'	38,2	76,4	Decapterus macrosoma	30,80	40,3
										Dussumieria acuta	20,40	26,7
										Stolephorus buccanerii	12,40	16,2
										Saurida undosquamis	5,20	6,8
07.09	0150	173	PT	46	10	20°05'	035°46'	197,0	394,0	Decapterus macrosoma	380,00	96,4
										Scomberomorus commersoni	14,00	3,5
07.09	0935	174	PT	40	1	20°24'	035°42'	,0	,0	N O C A T C H	,00	,0
07.09	1330	175	PT	27	1	20°13'	035°26'	,2	,4	MISCELLANEOUS	,40	100,0
07.09	1635	176	PT	18	1	20°07'	035°11'	,0	,0	N O C A T C H	,00	,0
07.09	2100	177	BT	13	13	20°22'	034°53'	172,5	345,0	Pomadasys maculatus	98,00	28,4
										Leiognathus sp	57,40	16,6
										Otolithes ruber	42,00	12,1
										Sillago sihama	42,00	12,1
08.09	0426	178	PT	22	10	20°35'	035°12'	64,0	256,0	Stolephorus buccanerii	160,00	62,5
										MOBULIDAE	96,00	37,5
08.09	0650	179	PT	25	1	20°39'	035°21'	,0	,0	N O C A T C H	,00	,0

ANNEX II

DATE	TIME START	STN No.	GEAR TYPE	DEPTH (M) BOTTOM	DEPTH (M) GEAR	POSITION SOUTH	POSITION EAST	CATCH (KG) TOTAL	CATCH (KG) PR HR	DOMINANT SPECIES	WEIGTH (KG) PR HR	%
08.09	1248	180	PT	44	20	20°47'	035°43'	,2	,4	Carangidae. juvenile	,20	50,0
										Balistidae. juvenile	,20	50,0
08.09	2110	181	PT	30	15	21°15'	035°28'	41,0	164,0	Dussumieria acuta	105,60	64,3
										Sphyraena sp	44,00	26,8
										Decapterus maruadsi	5,60	3,4
										Decapterus macrosoma	4,00	2,4
17.09	1210	182	BT	7	7	17°04'	012°40'	40,2	80,4	Trichiurus lepturus	19,00	23,6
										CARIDEA	11,80	14,6
										Galeichthys feliceps	7,20	8,9
										Otolithes ruber	7,20	8,9
17.09	1430	183	BT	15	15	17°00'	039°10'	19,9	39,8	Trichiurus lepturus	6,60	16,5
										Pomadasys hasta	6,20	15,5
										Drepane punctata	3,60	9,0
										Pomadasys maculatus	3,00	7,5
17.09	1520	184	BT	15	15	16°57'	039°12'	11,6	23,2	Trichiurus lepturus	4,60	19,8
										Pellona ditchela	2,70	11,6
										Pomadasys maculatus	2,20	9,4
										Sardinella fimbriata	1,40	6,0
17.09	1903	185	PT	19	1	16°44'	039°35'	139,0	278,0	Sardinella longiceps	58,40	21,0
										Sardinella fimbriata	56,80	20,4
										Pellona ditchela	39,20	14,1
										Secutor insidiator	36,00	12,9
17.09	2220	186	PT	16	1	16°32'	039°50'	293,0	586,0	Sardinella fimbriata	228,60	39,0
										Sardinella longiceps	97,20	16,5
										Trichiurus lepturus	55,80	9,5
										Gazza minuta	54,00	9,2
18.09	0525	187	BT	9	9	16°27'	039°52'	69,7	139,4	Secutor insidiator	59,00	42,3
										Sardinella longiceps	27,50	19,7
										Alepes djeddaba	16,00	11,4
										Sardinella gibosa	8,50	6,0
18.09	0648	188	BT	18	18	16°33'	039°47'	236,0	472,0	Upeneus vittatus	184,00	38,9
										Pelates quadrilineatus	54,40	11,5
										Secutor insidiator	28,80	6,1
										Leiognathus equulus	24,00	5,0
18.09	0822	189	BT	9	9	16°36'	039°36'	18,4	36,8	Upeneus vittatus	13,60	36,9
										Sardinella gibosa	8,00	21,7
										Secutor insidiator	7,20	19,5
										Carangoides malabaricus	1,60	4,3
18.09	0955	190	BT	9	9	16°43'	039°31'	60,2	120,4	Sardinella longiceps	18,00	14,9
										Sardinella fimbriata	18,00	14,9
										Upeneus vittatus	20,00	16,6
										Secutor insidiator	12,00	9,9
18.09	1145	191	BT	16	16	16°51'	039°21'	344,4	688,8	Sardinella fimbriata	148,80	21,6
										Hilsa kelee	112,80	16,3
										Pellona ditchela	67,20	9,7
										Polynemus sextarius	67,20	9,7
18.09	1505	192	BT	11	11	17°04'	039°01'	211,8	423,6	Thryssa vitrirostris	266,00	62,7
										Sardinella fimbriata	28,00	6,6
										Pellona ditchela	18,20	4,2
										Polynemus sextarius	19,60	4,6
18.09	2215	193	PT	13	1	17°15'	038°29'	158,0	316,0	CARIDEA	52,00	16,4
										Trichiurus lepturus	38,00	12,0
										Sardinella fimbriata	26,00	8,2
										Pellona ditchela	22,00	6,9
										Thryssa vitrirostris	46,00	14,5
19.09	0515	194	BT	12	12	17°13'	038°24'	17,9	35,8	Trichiurus lepturus	8,80	24,5
										Thryssa vitrirostris	6,40	17,8
										Penaeus indicus	6,00	16,7
										Hilsa kelee	1,80	5,0
19.09	0635	195	BT	20	20	17°18'	038°25'	38,6	76,2	Trichiurus lepturus	13,20	17,3
										Pellona ditchela	14,40	18,8
										CARIDEA	10,20	13,3
										Cynoglossus lingua	6,00	7,8

ANNEX II

DATE	TIME START	STN No.	GEAR TYPE	DEPTH (M) BOTTOM	DEPTH (M) GEAR	POSITION SOUTH	POSITION EAST	CATCH (KG) TOTAL	CATCH (KG) PR HR	DOMINANT SPECIES	WEIGTH (KG) PR HR	WEIGTH (KG) %
19.09	0752	196	BT	25	25	17°25'	038°17'	116,9	233,8	Trichiurus lepturus	36,00	15,3
										Pellona ditchela	59,20	25,3
										Upeneus vittatι	[illegible]	8,5
										Thryssa vitrir		5,1
19.09	1020	197	BT	7	7	17°24'	038°00'	110,8	221,6	Shrimps. small. non comm.	42,00	18,9
										Otolithes ruber	31,20	14,0
										Trichiurus lepturus	30,00	13,5
										Johnius belangerii	25,20	11,3
										Pellona ditchela	34,80	15,7
										Thryssa vitrirostris	24,00	10,8
19.09	1205	198	BT	23	23	17°33'	038°02'	218,3	373,2	Sphyraena obtusata	99,86	26,7
										Leiognathus equulus	113,54	30,4
										Pellona ditchela	39,67	10,6
										Upeneus sulphureus	25,99	6,9
19.09	1310	199	BT	29	29	17°35'	038°01'	359,6	719,2	Leiognathus equulus	145,00	20,1
										Pomadasys maculatus	81,20	11,2
										Upeneus vittatus	75,40	10,4
										Rastrelliger kanagurta	72,50	10,0
19.09	1425	200	BT	21	21	17°36'	037°56'	44,8	89,6	Metapenaeus monoceros	16,80	18,7
										Trichiurus lepturus	16,00	17,8
										C R A B S	9,20	10,2
										Cynoglossus lingua	10,00	11,1
19.09	1555	201	BT	34	34	17°40'	037°56'	55,0	110,0	Scomberomorus commersoni	34,80	31,6
										Upeneus vittatus	25,60	23,2
										S H A R K S	20,00	18,1
										Saurida undosquamis	9,60	8,7
										MISCELLANEOUS	11,20	10,1
20.09	0517	202	BT	17	17	17°36'	037°46'	69,2	138,4	Otolithes ruber	32,40	23,4
										Johnius belangerii	20,40	14,7
										Thryssa vitrirostris	16,20	11,7
										Cynoglossus lingua	9,60	6,9
										Metapenaeus monoceros	14,40	10,4
20.09	0750	203	BT	49	49	17°56'	037°38'	25,2	151,2	Argyrops spinifer	60,00	39,6
										Scomberomorus commersoni	24,00	15,8
										Lethrinus sp.	24,00	15,8
										Carangoides armatus	12,60	8,3
20.09	0855	204	BT	64	64	17°57'	037°40'	240,3	480,6	Upeneus moluccensis	168,00	34,9
										Upeneus vittatus	57,60	11,9
										Decapterus russelli	46,40	9,6
										Priacanthus hamrur	25,60	5,3
20.09	1200	205	BT	43	43	18°15'	037°20'	21,7	43,4	SCYLLARIDAE	7,00	16,1
										Nemipterus delagoae	8,40	19,3
										BALISTIDAE	7,60	17,5
										Decapterus russelli	5,60	12,9
20.09	1339	206	BT	52	52	18°19'	037°18'	38,3	76,6	Decapterus russelli	35,40	46,2
										Scomberomorus commersoni	11,40	14,8
										Nemipterus delagoae	7,20	9,3
										Saurida undosquamis	5,60	7,3
20.09	1608	207	BT	28	28	18°27'	037°03'	38,2	76,4	Scomberomorus commersoni	40,60	53,1
										Upeneus tragula	13,40	17,5
										Nemipterus delagoae	11,40	14,9
										MONSTO4 ??? 3,00 3,9		
20.09	1910	208	PT	15	1	18°05'	037°04'	106,0	212,0	Thryssa vitrirostris	74,40	35,0
										Pellona ditchela	57,60	27,1
										Sphyrna zygaena	23,00	10,8
										Elops saurus	15,00	7,0
21.09	0126	209	PT	19	1	18°08'	037°07'	64,9	129,8	Pellona ditchela	50,00	38,5
										Thryssa vitrirostris	45,00	34,6
										Trichiurus lepturus	13,20	10,1
										Formio niger	6,20	4,7
21.09	0513	210	BT	9	10	18°10'	036°56'	93,9	187,8	Johnius belangerii	52,00	27,6
										Otolithes ruber	32,00	17,0
										Thryssa vitrirostris	41,60	22,1
										Pellona ditchela	10,40	5,5

ANNEX II

DATE	TIME START	STN No.	GEAR TYPE	DEPTH (M) BOTTOM	DEPTH (M) GEAR	POSITION SOUTH	POSITION EAST	CATCH (KG) TOTAL	CATCH (KG) PR HR	DOMINANT SPECIES	WEIGTH (KG) PR HR	%
21.09	0830	211	BT	23	23	18°30'	036°49'	106,4	212,8	Thryssa vitrirostris	76,80	36,0
										Pellona ditchela	19,20	9,0
										Metapenaeus monoceros	12,80	6,0
										Upeneus vittatus	18,00	8,4
21.09	1020	212	PT	28	8	18°38'	036°53'	6,0	12,0	Stolephorus buccanerii	12,00	100,0
21.09	1216	213	BT	34	34	18°45'	037°00'	238,9	477,8	Lethrinus nebulosus	91,00	19,0
										Nemipterus delagoae	58,80	12,3
										Abalistes stellaris	51,00	10,6
										Argyrops spinifer	28,00	5,8
21.09	1735	214	PT	64	1	18°41'	037°11'	,0	,0	N O C A T C H	,00	,0
21.09	2135	215	PT	19	1	18°34'	036°43'	37,2	74,4	S H A R K S	40,00	53,7
										Pellona ditchela	14,80	19,8
										Thryssa vitrirostris	7,60	10,2
										Formio niger	6,80	9,1
22.09	0535	216	BT	7	7	18°31'	036°34'	13,5	27,0	LOBOTIDAE	8,80	32,5
										Arius sp	3,80	14,0
										Scomberomorus commersoni	3,20	11,8
										Johnius belangerii	2,80	10,3
22.09	0637	217	BT	8	8	18°36'	036°33'	128,2	256,4	Johnius belangerii	140,80	54,9
										Otolithes ruber	25,60	9,9
										Thryssa vitrirostris	19,20	7,4
										Pellona ditchela	19,20	7,4
22.09	0815	218	BT	22	22	18°43'	036°38'	112,4	224,8	Pellona ditchela	64,00	28,4
										Thryssa vitrirostris	33,60	14,9
										Trichiurus lepturus	22,40	9,9
										Megalaspis cordyla	20,80	9,2
22.09	1000	219	BT	30	30	18°45'	036°46'	14,6	29,2	Scomberomorus guttatus	7,40	25,3
										Saurida undosquamis	3,60	12,3
										Scomberomorus commersoni	2,80	9,5
										Leiognathus elongatus	2,80	9,5
22.09	1135	220	PT	32	8	18°48'	036°48'	1,0	2,0	Stolephorus buccanerii	1,96	98,0
										Carangidae. juvenile	,02	1,0
										FISH LARVAE	,02	1,0
22.09	1405	221	BT	41	41	18°47'	037°04'	1084,9	2169,8	Leiognathus elongatus	1073,00	49,4
										Decapterus macrosoma	944,60	43,5
										Upeneus bensasi	70,00	3,2
										Decapterus russelli	23,40	1,0
22.09	1555	222	BT	56	56	18°54'	037°04'	15,6	31,2	LOLIGINIDAE	9,40	30,1
										Platycephalus sp.	4,20	13,4
										Trachinocephalus myops	4,00	12,8
										Trigla capensis	2,60	8,3
22.09	1955	223	PT	74	20	19°05'	036°53'	,1	,2	Rastrelliger kanagurta	,20	100,0
22.09	2312	224	PT	22	1	18°53'	036°37'	31,5	63,0	S H A R K S	32,60	51,7
										Pellona ditchela	15,40	24,4
										Upeneus vittatus	5,60	8,8
										Thryssa vitrirostris	3,60	5,7
23.09	0315	225	PT	18	1	19°06'	036°20'	86,8	173,6	S H A R K S	120,00	69,1
										Pellona ditchela	25,60	14,7
										Thryssa vitrirostris	15,20	8,7
										Trichiurus lepturus	7,20	4,1
23.09	0530	226	BT	22	22	19°13'	036°05'	20,7	41,4	Scomberomorus commersoni	16,60	40,0
										CEPHALOPODA	14,00	33,8
										C R A B S	2,80	6,7
										Saurida undosquamis	2,80	6,7
23.09	0700	227	PT	26	1	19°10'	036°09'	,5	1,0	Stolephorus buccanerii	1,00	100,0
23.09	0850	228	PT	28	1	19°11'	036°13'	20,1	26,7	Thryssa vitrirostris	26,60	99,6
23.09	1140	229	BT	27	27	19°07'	036°29'	17,2	34,4	LOLIGINIDAE	14,80	43,0
										Scomberomorus commersoni	12,60	36,6
										C R A B S	1,40	4,0
										Saurida undosquamis	1,00	2,9

ANNEX II

DATE	TIME START	STN No.	GEAR TYPE	DEPTH (M) BOTTOM	DEPTH (M) GEAR	POSITION SOUTH	POSITION EAST	CATCH (KG) TOTAL	CATCH (KG) PR HR	DOMINANT SPECIES	WEIGTH (KG) PR HR	%
23.09	1320	230	BT	35	35	19°07'	036°38'	146,0	292,0	Decapterus russelli	100,00	34,2
										Upeneus bensasi	89,00	30,4
										Carangoides malabaricus	32,00	10,9
										Rastrelliger k	31,00	10,6
23.09	1450	231	BT	58	58	19°05'	036°40'	,0	,0	N O C A T C H		,0
24.09	0000	232	PT	25	5	19°19'	036°07'	43,5	87,0	Stolephorus buccanerii	51,30	58,9
										Lutjanus lineolatus	13,80	15,8
										Decapterus russelli	8,40	9,6
										Leiognathus elongatus	5,70	6,5
24.09	0645	233	BT	22	22	19°24'	035°53'	18,7	37,4	Scomberomorus commersoni	22,60	60,4
										Scomberomorus guttatus	9,40	25,1
										LOLIGINIDAE	2,60	6,9
										BALISTIDAE	1,40	3,7
24.09	0845	234	BT	29	29	19°30'	036°01'	174,5	349,0	Secutor insidiator	124,80	35,7
										Decapterus russelli	68,80	19,7
										Carangoides malabaricus	41,60	11,9
										Scomberomorus guttatus	36,00	10,3
24.09	1105	235	BT	35	35	19°32'	036°16'	268,4	536,8	Decapterus russelli	417,60	77,7
										Rastrelliger kanagurta	84,60	15,7
										CARANGIDAE	18,00	3,3
										Upeneus bensasi	7,20	1,3
24.09	1255	236	BT	50	50	19°39'	036°18'	91,0	182,0	Decapterus russelli	40,40	22,1
										Spilotichthys pictus	38,00	20,8
										Epinephelus tauvina	35,60	19,5
										Upeneus bensasi	10,00	5,4
24.09	1528	237	BT	50	50	19°26'	036°30'	29,3	58,6	Decapterus russelli	35,00	59,7
										Rastrelliger kanagurta	18,40	31,3
										TETRAODONTIDAE	2,00	3,4
										Trachinocephalus myops	,80	1,3
24.09	2329	238	PT	34	1	19°43'	036°58'	,8	1,6	Stolephorus buccanerii	1,10	68,7
										Rastrelliger kanagurta	,10	6,2
										Rastrelliger kanagurta	,40	25,0
25.09	0700	239	BT	14	14	19°19'	035°38'	136,4	136,4	Johnius belangerii	33,30	24,4
										Thryssa vitrirostris	24,80	18,1
										Pellona ditchela	15,30	11,2
										Leiognathus equulus	15,30	11,2
25.09	0855	240	BT	15	15	19°24'	035°32'	282,2	282,2	Thryssa vitrirostris	106,50	37,7
										Pellona ditchela	46,50	16,4
										Alepes djeddaba	15,00	5,3
										Trichiurus lepturus	12,00	4,2
25.09	1044	241	BT	13	13	19°24'	035°34'	176,3	176,3	Thryssa vitrirostris	49,30	27,9
										Leiognathus equulus	27,00	15,3
										Alepes djeddaba	13,80	7,8
										Pellona ditchela	29,40	16,6
25.09	1250	242	BT	12	12	19°18'	035°37'	164,0	164,0	Pellona ditchela	67,80	41,3
										Thryssa vitrirostris	24,00	14,6
										Johnius belangerii	19,20	11,7
										Leiognathus equulus	9,60	5,8
25.09	1455	243	BT	12	12	19°16'	035°44'	344,0	344,0	Pellona ditchela	218,75	63,5
										Thryssa vitrirostris	46,25	13,4
										Rastrelliger kanagurta	12,50	3,6
										Trichiurus lepturus	11,25	3,2
26.09	0805	244	BT	13	13	19°33'	035°30'	74,0	148,0	Sphyrna zygaena	100,00	67,5
										Scomberomorus commersoni	32,00	21,6
										Scomberomorus guttatus	9,80	6,6
										Seriola sp.	2,20	1,4
26.09	0942	245	BT	20	1	19°37'	035°35'	30,3	60,7	Atule mate	19,00	31,3
										Scomberomorus commersoni	22,60	37,2
										Secutor insidiator	6,80	11,2
										LOLIGINIDAE	4,20	6,9
26.09	1115	246	PT	21	7	19°40'	035°31'	,0	,0	N O C A T C H	,00	,0

ANNEX II

DATE	TIME START	STN No.	GEAR TYPE	DEPTH (M) BOTTOM	DEPTH (M) GEAR	POSITION SOUTH	POSITION EAST	CATCH (KG) TOTAL	CATCH (KG) PR HR	DOMINANT SPECIES	WEIGTH (KG) PR HR	%
26.09	1235	247	PT	21	1	19°40'	035°31'	,3	,6	Psenes indicus	,14	23,3
										Leiognathus elongatus	,20	33,3
										Carangoides malabaricus	,02	3,3
										Stolephorus buccanerii	,12	20,0
										MONACANTHIDAE	,10	16,6
26.09	2120	248	PT	15	1	20°11'	035°03'	30,6	61,2	Decapterus russelli	14,00	22,8
										Stolephorus buccanerii	12,40	20,2
										CARHARHINIDAE	5,80	9,4
										Sardinella sirm	5,60	9,1
										Pellona ditchela	7,20	11,7
27.09	0300	249	PT	42	25	19°56'	035°47'	8,5	17,0	Sardinella sirm	9,80	57,6
										Decapterus russelli	4,80	28,2
										Rastrelliger kanagurta	1,20	7,0
										Decapterus macrosoma	,80	4,7
27.09	0525	250	BT	49	49	19°50'	033°53'	25,4	50,8	Decapterus russelli	11,40	22,4
										Rastrelliger kanagurta	11,40	22,4
										LOLIGINIDAE	7,40	14,5
										Nemipterus delagoae	6,60	12,9
27.09	0805	251	BT	58	58	20°05'	036°05'	9,9	19,8	Scomberomorus commersoni	15,40	77,7
										LABRIDAE	1,20	6,0
										Trachinocephalus myops	,80	4,0
										Smaris cristatus	,80	4,0
27.09	1155	252	BT	65	65	20°28'	035°55'	2,3	4,6	MISCELLANEOUS	4,60	100,0
27.09	1440	253	BT	57	57	20°39'	035°48'	2,1	4,2	C R A B S	1,40	33,3
										Trachinocephalus myops	1,20	28,5
										LOLIGINIDAE	,80	19,0
										SCYLLARIDAE	,20	4,7
										MISCELLANEOUS	,60	14,2
28.09	0307	254	PT	13	1	20°58'	035°11'	219,7	439,4	Stolephorus buccanerii	290,00	65,9
										Atule mate	35,00	7,9
										Leiognathus elongatus	32,00	7,2
										Decapterus russelli	21,00	4,7
28.09	1305	255	BT	9	9	20°27'	034°49'	333,8	667,6	Pellona ditchela	182,40	27,3
										Thryssa vitrirostris	122,40	18,3
										Sardinella gibosa	112,80	16,8
										Sardinella albella	81,60	12,2
28.09	1408	256	BT	8	8	20°25'	034°47'	132,5	265,0	Thryssa vitrirostris	65,00	24,5
										Pellona ditchela	59,00	22,2
										Trichiurus lepturus	18,00	6,7
										Johnius belangerii	12,00	4,5
28.09	1550	257	BT	13	13	20°24'	034°55'	247,0	494,0	Sphyraena obtusata	198,00	40,0
										Scomberoides commersonianus	72,00	14,5
										Leiognathus equulus	44,00	8,9
										Psenes indicus	62,00	12,5
28.09	2025	258	PT	27	10	20°30'	035°29'	82,6	165,2	Decapterus russelli	79,60	48,1
										Decapterus macrosoma	28,40	17,1
										Stolephorus buccanerii	22,40	13,5
										Scomberomorus commersoni	14,00	8,4
29.09	0545	259	BT	5	5	20°28'	034°52'	165,2	330,4	Pellona ditchela	105,00	31,7
										Johnius belangerii	49,00	14,8
										Thryssa vitrirostris	46,20	13,9
										Pomadasys maculatus	35,00	10,5

ANNEX III

	St.		7		8		9		10		11		12		13		14		15		16		17		18		19		20		21		22		23		24		25		26		27		N	L	s^2
	No.	5		5		5		5		5		5		5		5		5		5		5		5		5		5		5		5		5		5		5		5		5		5			
PELAGIC FISH																																															
CARANGIDAE																																															
Alepes djedaba	187																			5	5	6	15	9	4	7	1	3	1	1	–	3	1											61	18.4	2.43
Selar crumenophthalmus	163																																	2	1	1	5	2	3	–	–	–	1		15	24.4	1.27
CLUPEIDAE																																															
Sardinella sirm	248																	5	9	12	8	5	–	–	–	–	1																		40	15.8	0.67
	249	2	5	12	10	16	8	2																																					55	8.3	0.53
	250																										1	3	6	2	1	–	1												14	20.4	0.55
S.albella	161																1	6	7	9	2	2	8	6	7																				48	16.5	1.59
	255																		3	3	14	8	2	11	8	3																			52	17.1	0.98
S.gibbosa	187																	5	13	19	10	2	1																						50	15.7	0.30
	190																1	2	–	12	2	3																							20	15.8	0.41
	255																		4	8	25	7	2	3	1																				50	16.3	0.41
S.fimbriata	191																						7	8	14	12	7	2																	50	18.4	0.47
	192																					1	4	7	6	10	3	1	1																33	18.3	0.61
Dussumieria acuta	161																				4	10	16	11	6	2																			49	17.4	0.40
	163																	1	3	3	10	8	4	5	6	1																			41	16.8	0.99
	172																4	7	3	13	10	7	1	1	3																				49	15.9	1.04
	181																			3	9	7	7	10	8	4	1	1																	50	17.4	0.95
SPHYRAENIDAE																																															
Sphyraena obtusata	198																														5	3	7	5	13	11	5	4	3	–	–	1			57	23.3	1.36
ARIOMMIDAE																																															
Ariomma indica	257										1	4	5	16	11	9	3	1	1	1	1																								53	12.7	0.93

ANNEX IV

	St.		7		8		9		10		11		12		13		14		15		16		17		18		19		20		21		22		23		24		25		26		27		28		29		30		31		32		N	$\bar{L}$	s^2
	No.	5		5		5		5		5		5		5		5		5		5		5		5		5		5		5		5		5		5		5		5		5		5		5		5		5		5		5			
DEMERSAL FISHES																																																								
MULLIDAE																																																								
Upeneus moluccensis	204														1	-	3	6	9	8	11	4	9	4	2	2	1	1																									61	16.8	1.77
U.tragula	207									1	3	6	8	10	9	8	8	1	-	1																																	55	13.5	1.05
U.bensasi	213										1	1	8	16	13	8	10	6	2	2																																	67	13.9	0.94
POLYNEMIDAE																																																								
Polynemus sextarius	164					1	-	1	1	3	5	8	5	3	2	3	2	5	3	3	2	1	2																														50	13.7	4.30
TERAPONIDAE																																																								
Pelates quadrilineatus	188						2	-	3	7	11	12	13	3	1																																						52	12.0	0.69
CYNOGLOSSIDAE																																																								
Cynoglossus lingua	200													1		1		4		9		11		4		10		10		6		7		1		-		-		-		1											65	19.1	6.58
	202							1		-		-		2		3		2		2		2		5		14		8		7		2		1																			44	18.9	7.21
LUTIANIDAE																																																								
Lutianus lineolatus	232							3	8	9	10	14	15	7	2																																						68	12.0	0.80
TRIGLIDAE																																																								
Trigla capensis	222												3	1	2	10	14	5	2																																		37	14.5	0.54
SYNODONTIDAE																																																								
Trachinocephalus myops	222													1	-	-	-	1	1	10	7	5	5	5	5	-	-	2	-	-	-	-	1																				43	17.4	2.36
Saurida undosquamis	172											1		-	-	2		10		7		9		10		5		7																									51	17.6	3.66
	206																							1		2		4		1		3		2		2		2		3		2		3		-		1		-		1		27	24.4	13.56
POMADASYIDAE																																																								
Pomadasys hasta	162																	1		-		3		-		1		1																									6	18.0	3.10
	166		2		-		1		28		19																																											50	10.7	0.72

ANNEX V.- Design of the survey

1. Strata definition

Information from the surveys (Muleve, Haeckel, Pantikapey, F. Nansen, Meleia) and from the activity of the commercial vessels (Ulltang et al; 1980; Ulltang, 1980), gave the first indication for establishing sub-areas whose geographic and depth boundaries were chosen on the basis of the density distribution of the shrimp.

According to that information the area between 16° 20' S and 21° 00' S was divided in seven sub-areas, which were subdivided according to depth in twelve strata .

Sub-area	Geographic limits	Stratum	Depth boundaries
1	16° 20' - 16° 47'.5	1	5 - 20m
2	16° 47'.5- 17° 15'	2	5 - 20m
3	17° 15' - 17° 52'.5	3.1 3.2	5 - 25m 25 - 45m
4	17° 52'.5- 18° 50'	4.1 4.2 4.3	5 - 25m 25 - 45m 45 - 100m
5	18° 50' - 19° 40'	5.1 5.2 5.3	5 - 25m 25 - 45m 45 - 100m
6	19° 40' - 21° 00 (west of 35° 40')	6	-
7	19° 40' - 21° 00' (East of 35° 40')	7	-

2. Definition of the sampling units

Each stratum was sub-divided into 7.5' latitude x 5' longitude rectangles. As stratum boundaries were irregular relative to lines of latitude and longitude it was not possible to subdivide the entire stratum into uniform rectangles. Sampling units irregularly shaped were formed with areas approximately equivalent to 7.5' x 5' rectangles; care was taken to make each unit as homogeneous as possible. Taking in account that each trawl operation has a duration of 30 minutes with a velocity of 3 knots, each sampling unit was sub-divided into 6 smaller rectangles of 2.5' latitude x 2.5' longitude.

3. Method of station selection

Two stage selection of trawl stations was used. Station selection was performed stratum by stratum at random. For this purpose within each stratum the sampling units were numbered consecutively; the smaller rectangles were also numbered consecutively. By stratum, four sampling units were selected at random without replacement. In each selected sampling unit, the position of the station was than choosen, at random, from the smaller units.

If the position of the trawl station has bottom unsuitable for trawling, an alternative position shall be choosen from the adjacent rectangle within the same sampling unit. (The position found untrawlable should be recorded on the stratification charts). The direction of the fishing operation must be paralel to the bathimetric boundaries of the stratum.

ANNEX VI. Shrimp by-catch

All computations were based on data from stations with shrimp catches. Data on magnitude and composition of the by-catch was grouped by strata and by shrimp catch rate intervals.

Magnitude of the by-catch

TABLE 1 - Total catch rates and percentages of shrimp in catches by strata

Strata	% Shrimp	Nr. of hauls
1	0.2	1
2	17.5	4
3.1	20.5	4
3.2	1.5	4
4.1	10.4	4
4.2	8.8	1
6	4.3	3

TABLE 2 - Shrimp percentage in catches by shrimp catch rate intervals. (A comparison with "F. Nansen Oct.-Nov./80")

Shrimp catch rate		<10 kg/h	10-25 kg/h	>25 kg/h
F. Nansen 1980	%	2.7	10.9	27.6
	Nr. of hauls	9	11	15
F. Nansen 1982	%	2.0	10.8	9.9
	Nr. of hauls	9	8	3

Composition of the by-catch

TABLE 1. Percentage in weight of the most important families and species for the different strata

	% in weight						
	1	2	3.1	3.2	4.1	4.2	6
SCIAENIDAE	-	13.5	32.2	1.1	47.0	6.8	8.1
Otolithes ruber	-	7.4	18.2	0.6	10.1	4.8	2.1
Johnius belengerii	-	5.3	12.2	0.2	33.5	-	5.2
POMADASYIDAE	1.2	9.4	2.5	7.2	2.2	4.2	3.7
Pomadasys hasta	1.2	5.1	1.3	0.8	2.2	4.2	0.2
Pomadasys maculatus	-	4.3	1.2	6.4	-	-	3.5
MULLIDAE	43.5	2.1	4.1	15.1	1.8	13.7	0.5
Upeneus vittatus	39.3	2.1	4.0	10.4	1.4	10.3	-
TRICHIURIDAE	0.3	27.2	15.6	2.6	5.0	6.8	2.0
THERAPONIDAE	11.6	2.1	0.7	3.8	0.3	-	1.5
POLYNEMIDAE	-	2.0	2.4	2.2	-	1.4	0.3
CYNOGLOSSIDAE	0.7	-	8.8	0.8	2.0	1.4	-
SYNODONTIDAE	0.3	-	0.3	1.0	-	-	0.7
Others	2.6	11.8	3.4	1.9	2.4	2.1	3.1
TOTAL DEMERSAL	60.2	68.1	70.0	35.7	60.7	36.4	19.9
CARANGIDAE	4.6	4.4	0.2	6.0	3.6	2.0	5.7
Megalaspis cordyla	-	0.8	-	-	3.4	-	0.5
Scomberoides tol	-	-	0.2	-	0.1	-	4.6
Caranx sexfasciatus	3.2	0.4	-	2.0	-	-	-
Selar crumenoph.	-	-	-	4.0	-	-	-
CLUPEIDAE	6.2	11.9	13.1	9.4	16.6	11.0	49.0
Pellona ditchela	-	6.1	12.9	7.6	15.8	11.0	29.1
S. gibbosa	0.3	0.6	-	-	-	-	10.3
S. albella	-	-	-	-	-	-	6.8
S. longiceps	3.1	0.8	-	-	-	-	-
Dussumieria acuta	2.4	0.1	0.2	0.6	-	-	-
LEIOGNATHIDAE	16.4	3.3	1.9	24.5	0.7	-	3.2
Leiognathus equulus	5.1	-	1.5	20.2	0.6	-	1.4
Secutor insidiator	6.2	2.7	0.1	4.3	0.1	-	1.8
Gazza minuta	5.1	0.6	0.3	-	-	-	-
ENGRAULIDAE	0.3	11.4	13.9	1.6	16.2	43.8	19.6
T. vitrirostris	-	11.1	12.9	1.5	15.9	43.8	19.6
SPHYRAENIDAE	-	-	-	11.3	-	-	-
Sphyraena obtusata	-	-	-	11.3	-	-	-
Others	5.0	0.9	-	8.0	1.6	6.8	2.7
TOTAL PELAGIC	32.5	31.9	29.1	60.8	38.7	63.6	80.2
SHARKS & RAYS	7.3	-	0.9	3.4	0.6	-	-
Fish catch-rate(kg/h)	467.8	35.9	96.8	348.6	150.1	175.4	396.4
Shrimp C.R. (kg/h)	1.0	7.6	24.9	5.3	17.3	17.0	17.6
% shrimp	0.2	17.5	20.5	1.5	10.3	8.8	4.3
Nr. of hauls	1	4	4	4	4	1	3

TABLE 7. Percentage in weight of the most important families and species for hauls with shrimp catch rate > 10 kg/h

	% in weight					
	3.1		4.1		6	
SCIAENIDAE	34.0		48.4		2.2	
Otolithes ruber		19.6		10.4		0.8
Johnius belengerii		14.0		34.5		1.4
POMADASYIDAE	2.6		2.3		1.1	
Pomadasys hasta		1.5		2.3		0.3
Pomadasys maculatus		1.1		-		0.8
MULLIDAE	3.4		1.9		-	
Upeneus vittatus		3.3		1.5		-
TRICHIURIDAE	13.4		5.0		2.7	
THERAPONIDAE	0.4		0.3		1.7	
POLYNEMIDAE	2.0		-		0.3	
CYNOGLOSSIDAE	7.3		2.1		-	
Others	4.0		0.3		3.4	
TOTAL DEMERSAL	67.1		60.3		11.4	
CARANGIDAE	0.2		3.6		6.5	
Megalaspis cordyla		-		3.6		-
Scomberoides tol		0.2		-		6.1
CLUPEIDAE	15.1		17.0		55.2	
Pellona ditchela		15.1		16.3		27.9
Sardinella gibbosa		-		-		14.2
Sardinella albella		-		-		9.4
LEIOGNATHIDAE	1.6		0.7		2.0	
Leiognathus equulus		1.1		0.6		0.5
Secutor insidiator		0.2	—	0.1		1.5
ENGRAULIDAE	14.9		16.8		21.6	
Thryssa vitrirostris		14.0		16.4		21.6
TOTAL PELAGIC	31.8		39.1		88.6	
SHARKS & RAYS	1.1		0.6		-	
% Shrimp	21.3		10.6		5.1	
Nr. of hauls	3		3		2	

RECORD OF SHRIMP SURVEY

Station Nr.	Strata Nr.	Shrimp catch per tow (kg)	% in weight					Remarks
			P.indicus	M.monoceros	P.monodon	P.japonicus	Others	
182	2	9.10	19.8	2.2	1.1	-	76.9	
183	2	1.45	82.8	13.8	-	-	3.4	
184	2	0.85	82.3	5.9	-	-	11.8	
187	1	-						
188	1	0.50	-	100.0	-	-	-	
189	1	-						
190	1	-						
194	2	3.80	79.0	10.5	10.5	-	-	
195	3.1	9.00	10.0	32.2	1.1	-	56.7	
196	3.2	8.50	20.0	60.0	3.5	16.5	-	
197	3.1	24.40	8.2	3.3	2.4	-	86.1	
198	3.2	1.58	3.2	82.3	-	12.6	1.9	
199	3.2	0.10	-	100.0	-	-	-	
200	3.1	5.00	10.0	84.0	6.0	-	-	
201	3.2	0.40	-	50.0	-	-	50.0	
202	3.1	11.30	21.2	63.7	0.9	0.9	13.3	
204	4.3	-						
205	4.3	-						
206	4.3	-						
207	4.2	-						
210	4.1	13.90	32.4	25.9	7.2	-	34.5	
211	4.2	8.50	24.7	75.3	-	-	-	
213	4.2	-						
216	4.1	0.60	50.0	33.3	-	-	16.7	
217	4.1	8.20	31.7	37.8	1.2	-	29.3	
218	4.1	12.00	17.5	56.7	-	9.2	16.7	
219	4.2	-						
221	4.3	-						
222	5.3	-						
226	5.1	-						
229	5.2	-						
230	5.2	-						
231	5.3							Net damaged
233	5.1	-						
234	5.2	-						
235	5.2	-						
236	5.3	-						
237	5.3	-						
244	5.1	-						
245	5.1	-						
250	7	-						
251	7	-						
252	7	-						
253	7	-						
255	6	13.2	72.7	27.3	-	-	-	
256	6	10.2	29.4	68.6	-	-	2.0	
257	6	-						
259	6	3.01	56.5	19.9	3.3	19.9	0.3	

From GEOLOGICAL-GEOPHYSICAL ATLAS OF THE INDIAN OCEAN, Moscow 1975.

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