The Marine Fish Resources of Mozambique

Reports on survey with the R/V Dr Fridtjof Nansen.

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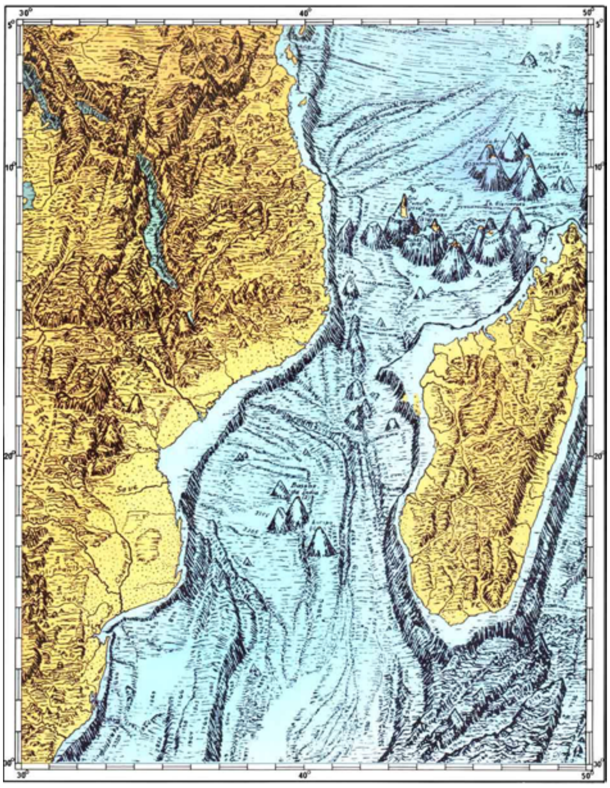

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PREFACE

In addition to the present authors the following people have contributed to this report:

Ch. 9 - MESOPELAGIC FISH, Jakob Gjøsæter
Ch. 13 - WHALES AND DOLPHINS, Carl Jakob Rørvik

Åsmund Bjordal has worked up the data from the pot catches. We also want to thank our colleagues both in Maputo and in Bergen for fruitfull discussions during the preparation of this report.

RESUMO DAS CONCLUSÕES

No processamento dos resultados da expedição conjunta levada a cabo pelo navio de investigação "Dr. Fridtjof Nansen" foi utilizada toda a informação existente, incluindo a de expedições anteriores. Neste relatório está por conseguinte resumido tudo o que até à data se apurou sobre os recursos marinhos da República Popular de Moçambique.

Recomendações para futuras investigações

As conclusões a que se chegou levam os autores a recomendar que, no sentido de aumentar este conhecimento sobre os recursos marinhos, se realizem investigações sobre os seguintes aspectos:

a) Recursos costeiros, incluindo os recifes de coral e os mangais;

b) Amostragem e controlo da exploração da fauna acompanhante do camarão;

c) Cruzeiros de reconhecimento do estado dos principais "stocks" localizados sobre a plataforma;

d) Pesca exploratória com gaiolas;

e) Investigações oceanográficas (principalmente sobre a plataforma).

No Quadro 15.1 apresentam-se os resultados do presente relatório. Todas as estimativas de abundância ("Maximum stock size") assim como as do rendimento potencial ("maximum potential yield") máximo devem ser tomadas mais como una primeira aproximação ou indicativo da ordem de grandeza, do que como cálculos muito precisos. Isto porque tanto os dados utilizados como os métodos de calculo empregues introduzem erros. É importante notar também que as estimativas de abundância se baseiam nos valores máximos observados. Por isso recomendase que qualquer aumento na exploração deve ter como alvo um valor menor que o rendimento máximo que aqui se apresenta, pelo menos ate que outras estimativas mais perfeitas possam ser calculadas.

Peixe demersal

O "stock" do Banco de S. Lázaro é constituido por espécies de grandes dimensões, com baixas taxas de crescimento. O rendimento anual é possivelmente da ordem das 1000 toneladas. A pesca deste recurso pode ser realizada com barcos pequenos de madeira, utilizando principalmente gaiolas e linha individual.

Nas áreas em que é possivel efectuar o arrasto, o rendimento potencial das espécies de fundo é da ordem das 50 mil toneladas por ano. As espécies dominantes são os peixes encarnados, corvinas, roncadores e peixe pedra e o peixe lagarto. As capturas actuais são provenientes não só da fauna acompanhante de camarão, como também dos arrastões soviéticos. Calculase que haja um aumento nas quantidades capturadas devido a maior esforço e melhor conhecimento das zonas de pesca. Um aumento notável da frota de camarão poderá levar as capturas a valores próximos do potencial máximo, pelo que os rendimentos em espécies demersais devem ser cuidadosamente seguidos.

Peixe pelágico

A espécie pelágica mais importante é a anchoveta de Buccaneer concentrada no banco de Sofala. Este peixe de 7-8 cm tem um ciclo de vida muito curto, pelo qual se estima que o rendimento máximo seja aproximadamente do mesmo valor do "stock". E no entanto um recurso que sofre grandes flutuaçcões, e portanto o rendimento máximo apresentado - 300 mil tonelados por ano - só será atingido pressupondo condições óptimas de pesca. De momento a sua exploração é nula devido ao seu comportamento que difere das restantes espécies pelágicas no facto de não se concentrar perto do fundo durante o dia, nunca podendo capturares com redes de arrasto de fundo. E no entanto capturável com grande facilidade com rede de arrasto de superfície e provavelmente sê-lo-á também com rede de cerco.

Para os outros peixes pelágicos estimamos o rendimento máximo anual de cerca de 150 000 toneladas. A maior parte de captura é representada por carapaus (Decapterus spp.), sardinhas (Pellona spp.), anchova grande (Thryssa spp.) e patanas (Leiognathus spp.). No que respeita às espécies demersais a captura actual é proveniente da pescaria do camarão e dos barcos soviéticos. O manancial está muito pouco explorado e há possibilidades de se aumentar as capturas.

O grupo “grandes pelágicos” é constituido principalmente de atuns, serras e tubarões. Os dados disponíveis não dão sequer possibilidades de fazer uma estimativa da abundância destas espécies.

Os peixes serras estão distribuidos a profundidades inferiores a 50 metros; os tubarões são também frequentes para além destas profundidades. Por isso estas espécies podem ser um importante subproduto, numa pescaria de pequenas anchovas.

Peixes mesopelágicos

Neste grupo estão incluidos principalmente os peixes que habitam a parte mais profunda do Oceano durante o dia solar e migram para a superficie ao pôr do sol.

Estão distribuidos na maior parte dos Oceanos do Mundo e são especialmente abundantes no norte do Oceano Indico. Os cálculos da abundância foram levados a cabo para uma área desde a linha de costa até 30 milhas em direcção ao mar. Embora a estimativa de 1 milhão de toneladas pareça impressionante, este grupo parece não representar qualquer recurso significativo de imediato. A razão principal para tal é a falta de concentrações de interesse commercial. Alguma contribuição deste grupo poderá de certo modo ocorrer como subproduto das redes de arrasto de fundo a profundidades superiores a 200 metros.

Crustáceos

As estimatives para o camarão de águas pouco profundas foram tiradas de ULLTANG, BRINCA e SILVA (1979). Para posteriores comentários sobre este manancial, aconselha-se a consulta deste trabalho.

A estimativa para o camarão de águas profundas não inclue infelizmente o talude do Banco de Sofala. Este último é presentemente explorado pela frota espanhola a qual deve capturar alguns milhares de toneladas anualmente.

O manancial da lagosta está estimado em cerca de 1000 toneladas, que é provavelmente uma subestimativa. As estimativas de rendimento calculadas com base na pesca Sul Africana na área nos últimos anos da década 60e os primeiros da 70 sugerem que uma quantidade da mesma ordem de grandeza pode ser produzida. Estão em curso cruzeiros de pesca exploratória conjunta Moçambicano/Japonesa que deverá aumentar significativamente os dados básicos necessários para a sua avaliação.

O manancial de lagostim é considerado da ordem de algumas centenas de toneladas. Não existe qualquer pescaria específica para este crustáceo e as capturas são principalmente um subproduto da pesca de camarão de águas profundas. As possibilidades de sobreexploração deste manancial são pequenas devido ao hábito do lagostim de se enterrar no fundo.

A costa entre Cabo Delgado e Angoche está cercada por recifes de coral e por isto é inadequada para pescaria de arrasto. Investigações de outras áreas de recifes na região sugerem que uma produção anual potencial de 5 toneladas/km^2 deve ser esperada. Isto provávelmente dará um rendimento potencial de mais ou menos 5-10 000 toneladas. Não há informação disponóvel sôbre a pescaria prevalecente na região, e por isso também as possibilidades de aumentar a pescaria.

Por pesca costeira entendemos a pesca a profundidades inferiores a 10 metros. Se uma produção anual de cerca de 2 ton./km^2 é razoável então esperase um rendimento potencial de 5 a 10 mil toneladas. A pesca da magumba é levada a cabo nas baias de Maputo e Beira. A captura total na Baía de Maputo foi de cerca de 900 toneladas em 1977. Para a Beíra assim como para as outras pescarias não há nenhuma informação disponival. Assim não é possivel estimar a captura total destas pescarias.

1. INTRODUCTION

1.1 Program and objectives

According to the agreement between the government of the People's Republic of Mozambique and the Norwegian Agency for Development, (NORAD) an expedition was planned to survey the fishing potential of the waters adjacent to Mozambique with the Norwegian research vessel "Dr. Fridtjof Nansen". The investigation was carried out from 24 August 1977 to 20 June 1978. During this time four complete coverages of the coast were performed. The program was executed by a joint team of Norwegian and Mozambican scientists.

The main objectives of the program were as follows:

1. To locate the areas of the commercially important species concentrations with special emphasis on the pelagic and mesopelagic species.

2. To map out the distribution areas of those concentrations.

3. To carry out biological studies of the commercially important species.

4. To carry out oceanographic studies in the distribution areas of those species, particularly in the commercial concentration zones.

5. To estimate the abundance of the localized stocks.

6. To evaluate the efficiency of the different fishing gears.

7. To introduce the Mozambican participants to the methods of acoustic fish stock assessment.

After each coverage of the coast a preliminary cruise report was presented (ANON. 1977 b, 1978 a, 1978 b, 1978 c) giving the methods and a resume of the main findings. During work with the final report it was agreed by the Norwegian scientists and their Mozambican counterparts to also include data from all other sources available in order to summarize the present knowledge of the fishery resources off Mozambique.

This report will deal with the pelagic and demersal fish resources as well as the deep-water crustaceans. An attempt at abundance estimation of the shallow-water shrimp stock is given by ULLTANG, BRINCA and SILVA (1979). Only the by-catch of the shallow-water shrimp fishery will therefore be discussed here. The present report also includes a brief description of the most conspicuous hydrographic features and some comments on whales.

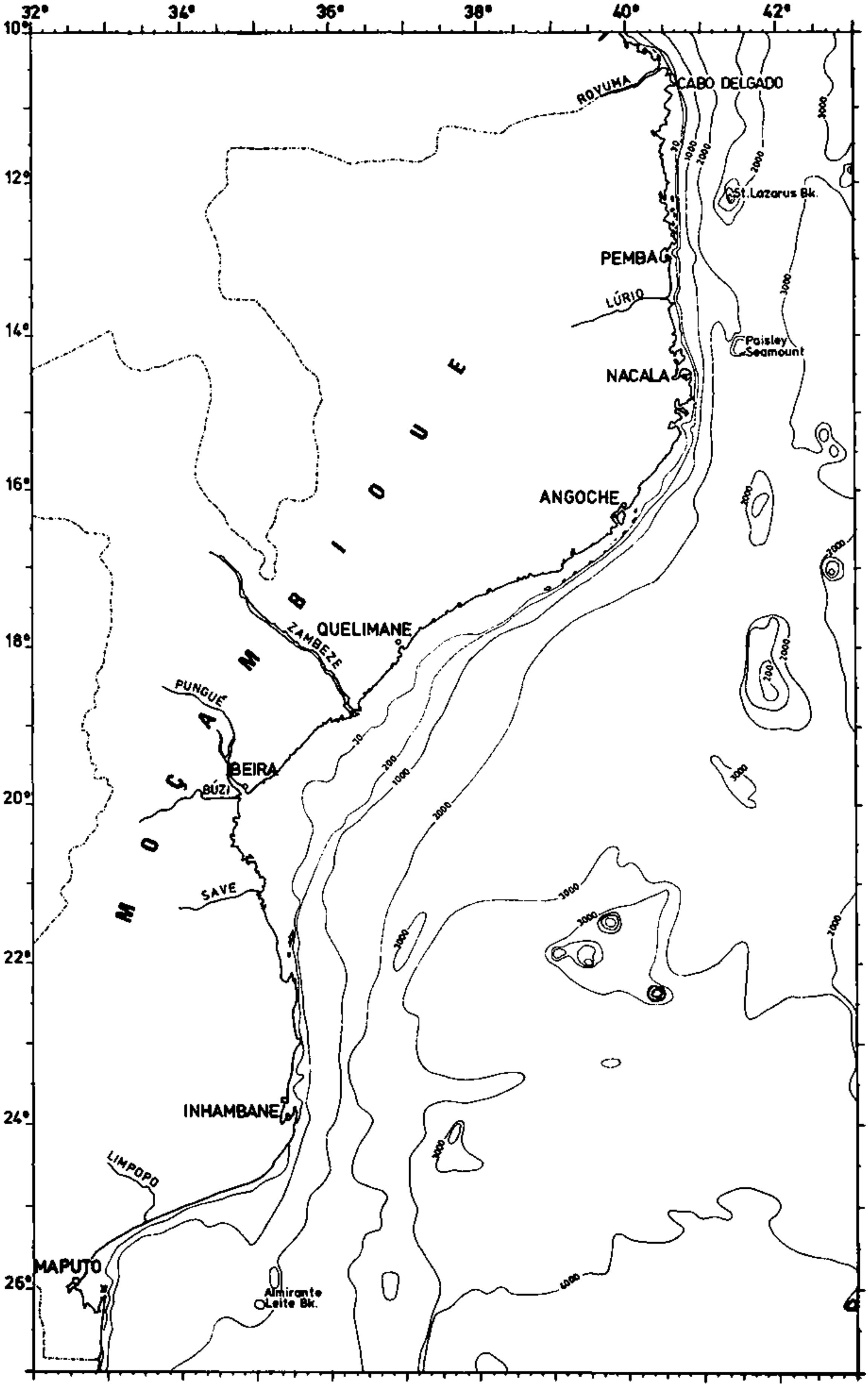
1.2 General geographical description

Mozambique lies on the east coast of Africa between latitudes 10°20' to 26°50' South (Fig. 1.1). The coastline has a length of more than 2500 km. The Mozambique Channel which separates Mozambique from Madagascar Island is about 400 km wide at its narrowest point. In the extreme north, Cape Delgado forms the dividing point of the Southern Equatorial Current. The southward flowing branch of this current, known as the Mozambique Current and further south as the Agulhas, has a far-reaching influence on the climate and life of southern Africa.

The climate of Mozambique is dominated by two regimes. South of the Zambezi River it is characterized by the passage of the depressions of the SE Trade Wind Zone, and north of the Zambezi by the southern end of the East African Monsoon System (TINLEY, 1971). The coast receives rain in all months of the year with a maximum during the southern summer.

In the northern part of Mozambique the winds follow the alternating monsoon system with NE winds during the southern summer and SW winds during the southern winter. Central and Southern Mozambique receives easterly prevailing winds and, especially during southern summer, southerly gales can seriously affect fishing activity.

Fig. 1.1. Bathymetric map of the waters off Mozambique.



The major rivers of Mozambique (Fig. 1.1) are: Rovuma, Lúrio and Zambezi in the north, Pungué, Buzi, Gorongosa and Save in the Sofala Bay and Limpopo, Incomati and Maputo in the Delagoa Bay. All these rivers carry tremendous volumes of silt. This high silt load has an important effect on the life on the continental shelf and sandbanks occur far out to sea in Sofala Bay. At the mouth of these rivers mangrove swamps occur, these are believed to be important for the reproduction cycle of the local shrimps. In these areas there is also an exploitation of the stock of mangrove crab.

The tidal range on the Mozambican coast is one of the highest in Africa. Tidal amplitudes of more than 6 m are recorded in Sofala Bay. From this area the tidal amplitude decreases both to the south and north along the coast.

The continental shelf of Mozambique out to the 200 m depth contour is approximately 70 000 km^2 (Fig. 1.1). The extreme north of Mozambique is markedly different from south of the 15th Latitude. In the north the continental shelf is very narrow, only several hundred meters wide, and deeply scarred with submarine canyons and edged by corala reef. The shelf is widest at Sofala Bank off Beira. Shallow banks or seamounts are found off the coast at St. Lazarus Bank NE of Pemba, Paisley Seamount off Nacala and Almirante Leite Bank east of Maputo. The central and southern part of the shelf is mostly sand and silt with some coral patches along the Delagoa and Inhaca shores.

1.3 A synopsis of the present fisheries of Mozambique

Most of the fishing along the coast of Mozambique is of the subsistence type and is confined to the immediate coastal waters. However, over the last two decades an industrial shrimp fishery has developed and a semi-industrial fishery started exploiting the inshore fish resources.

For the artisanal fishery no official statistics are available. This fishery is carried out from small craft, 3 to 8 m in length, and includes fishing gear such as traps, beach seines and gill-nets. There are indications that the total catch of this fishery may exceed 20 000 tonnes and that its contribution to the internal fish consumption is about 80%. In addition to fish this small-scale fishery also includes some inshore shellfish and holothurians.

The semi-industrial fishery is worked mainly by small trawlers and gillnetters, 10 to 12 m long, which operate at depths between 10 and 20 m. The national industrial fishery is for the moment exclusively a shrimp fishery, and it is expected that the Mozambican fleet will fluctuate in the near future between 40 and 50 units.

Table 1.1. Total and crustacean landings of the industrial and semi-industrial fisheries during 1965-1975 (tonnes).

YEAR	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
Total landings	4181	5347	5047	5707	7028	7634	10423	10413	13338	15655	11486	
Crustacea landings	599	1019	1037	1070	1125	1128	2554	2689	3442	6072	4339	4822
Total landings in main ports	-	-	-	-	-	-	5513	6332	9329	12628	8289	-

Table 1.1 gives the crustacean and total landings for the last 12 years according to the official statistics (ANON, 1976 b). The crustacean landings include 10 tonnes of lobster in 1971 and 1975, and 48 tonnes in 1974.

As can be seen the national shrimp production increased more than 10 times during these years and the total landings approximately four times. The lower catches following 1974 were a consequence of the disorganization after the exodus of the Portuguese personnel and the government's new approach in giving more attention to the small-scale fishery. Landing data for 1976 are not available. Table 1.2 gives the landings for 1977. In addition there is a licensed foreign fleet which has an estimated yearly catch of about 5000 tonnes of shrimps (ULLTANG et al, 1979).

Table 1.2. Landings of the industrial fishery from different size classes of vessels in 1977 (tonnes).

Vessel type and average size		No. of units	Shrimps/Lobsters		Marine fish	
			tonnes	%	tonnes	%
Stern trawler	- 16 GRT	10	125	31.7	567	82.0
Stern trawler	- 40 GRT	6	190	59.4	130	40.6
Pair trawler	- 120 GRT	24	2343	89.9	263	10.1
Pair trawler	- 360 GRT	2	485	90.3	52	9.7
Lobster trawler	- 95 GRT	1	24	77.4	7	22.6
Total		-	3159	81.4	721	18.6

The fish landings from the industrial fishery are a by-catch from the shrimp trawling. Most of this by-catch is not utilized but discarded at sea due to the small freezing capacity of the ships and lack of manpower to take care of the fish catches. Small shrimp trawlers below 40 GRT in the bays of Maputo and Beira are, however, landing all the fish caught.

Table 1.3. Total catch from the Soviet trawlers September 1977 - June 1978 (tonnes).

Species	Sofala	Bazaruto	Delagoa	Total
Demersal fish	1920	1	260	2181
Pelagic fish	3367	1	1147	4515
Mixed fish	2570	3	536	3109
Sharks - Rays	392		12	409
Total	8249	5	1955	10209

Since September 1977 some licensed Soviet trawlers have been fishing off Mozambique. Table 1.3 gives the total catch for the period when "Dr. Fridtjof Nansen" was working in the area.

A gill net fishery is carried out on kelee shad (Hilsa kelee) in the bays of Maputo and Beira. In 1977 this amounted to 916 tonnes in Maputo Bay.

1.4 Previous investigations

The first attempt at estimating the fish resources of Mozambique was made by Shomura (GULLAND 1970). They arrived at a potential annual yield from demersal resources of the shelf region of 300 000 tonnes/year. This very rough estimate depends on obtaining a reliable figure for the yield per unit area in one region and extrapolating this to another area. The method is crude with several significant sources of error, and the result should therefore be treated with caution.

In May 1975 the Polish research vessel "R/V Professor Siedlecki" carried out a cruise along the coast of East-Africa (ORLOWSKI, 1975). Unfortunately the report is only published in Polish and thus not available for the present authors.

As part of the FAO Indian Ocean Programme the "R/V Professor Measyatsev" carried out fishery investigations along the coast of Mozambique in January-February 1976. The studies were continued in August 1977. Results from the first part of the work have been published by BURCZYNSKI (1976). By using a combination of acoustic methods and catch rate he gives the size of the stock for the time of the survey as seen in Table 1.4.

Due to bad weather conditions the stock size in Delagoa Bay was probably gravely underestimated. From the same investigations BIRKETT (1978) presented some abundance estimates based on the "swept area method". These estimates are shown in Table 1.5.

Table 1.4. Stock size in thousand tonnes January-February 1976 (BURCZYNSKI, 1976).

Area	Sofala	Delagoa	Total
Demersal fish	97	8	105
Pelagic fish	65	11	76
Total	162	19	181

Table 1.5. Abundance estimates in thousand tonnes from the "Professor Mesyatsev" (BIRKETT, 1978).

Area	Sofala		Delagoa	
	Jan. 1976	Aug. 1977	Jan. 1976	Aug. 1977
Demersal fish	62.4	35.1	23.1	21.2
Pelagic fish	94.5	42.4	40.2	4.6
Total	156.9	77.5	63.3	25.8

Under an agreement between Mozambique and U.S.S.R. the Soviet trawler "Aelita" carried out fishery investigation in Mozambican waters during three periods in 1976 and 1977:

18 June to 13 August 1976,
30 October 1976 to 26 February 1977,
and 15 April to 31 June 1977.

After completion of each investigation period an interim report was presented.

The final report, BUDNICHENKO et al (1977), includes results from the exploratory fishing, the hydrographic investigations, and the biological studies on crustaceans and fish. It also includes estimates of total fish abundance based on the "swept area method" for the Boa Paz area, the shelf between Bazaruto Island and Ponta Zavora, and the Sofala Bank area. Table 1.6 gives the results.

Table 1.6. Estimates of total fish stock size in thousand tonnes according to BUDNICHENKO et al (1977).

Area	Time	Latitude	Fishing area (n. mile)^2	Depth (m)	Stock
Boa - Paz	June - August 1976	24°48' - 25°00'	188	20-100	6.0
	December 1976 - January 1977	24°48' - 25°01'	161	20-100	10.6
	April - June 1977	24°54' - 25°08'	191	20-100	13.8
Bazaruto Island - Ponta Zavora	January 1977	21°34' - 24°42'	625	150-450	9.3
	April - June 1977	21°31' - 21°52'	121	180-200	10.4
	April - June 1977	21°55' - 24°47'	637	50-450	8.6
Sofala Bank	June - August 1976	16°47' - 19°25'	2915	17-100	29.9
	October - December 1976	17°23' - 19°38'	3553	17-100	77.9

From 2 October to 12 December 1977 the trawler "Kattegat" from the German Democratic Republic carried out fishery investigations in Delagoa Bay and at the Sofala Bank (ANON, 1978 e). A total of 188 trawl stations were carried out mainly using shrimp or bottom trawls. This investigation concentrated on fishing and gear techniques.

2. MATERIALS AND METHODS

"Dr. Fridtjof Nansen" was working off Mozambique from 24 August 1977 to 20 June 1978. The whole coast was covered four times. Details on tracks and the work carried out are fully described in the cruise reports (ANON. 1977 b, 1978 a, 1978 b, 1978 c) and will not be repeated here. As an example of the survey grid, Fig. 2.1 is presented. This shows the vessel's track and stations along the southern part of the coast during cruise no. 4.

Table 2.1. Number of fishing stations on the different surveys.

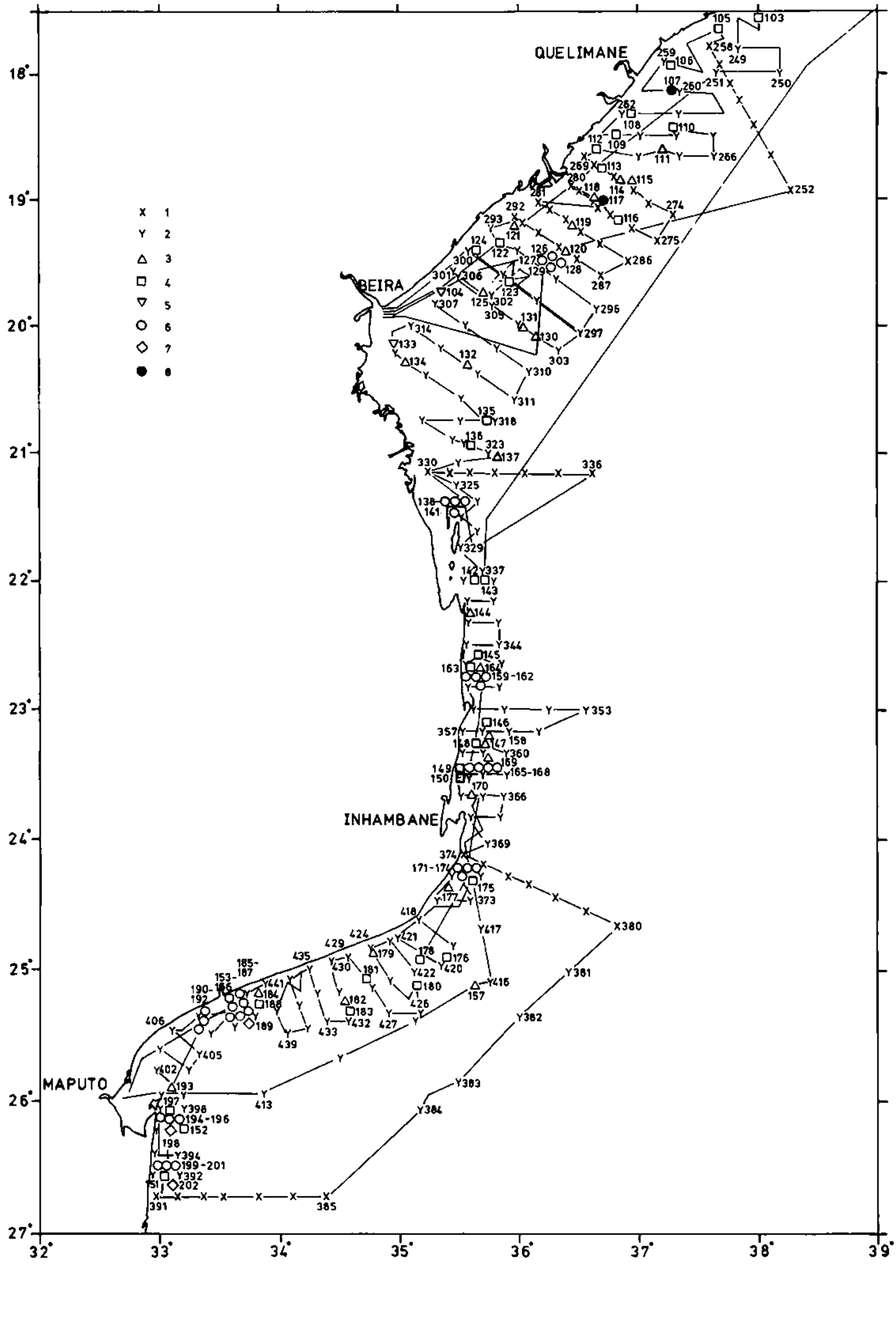
GEAR	Aelita	Professor Mesyatsev	Kattegat	Dr. Fridtjof Nansen
Bottom/Shrimp trawl	556	164	169	96
Pelagic trawl			18	76
Long line	29			24
Gill-net				7
Hand line				12
Pots				55

In addition to data from the "Dr. Fridtjof Nansen", trawl data from the following expeditions have also been included in the present report: "Aelita", "Kattegat" and "Professor Mesyatsev". Table 2.1 reviews the number of fishing stations on each survey. The surveys of "Aelita" and "Kattegat" were mainly trawl surveys while that of "Professor Mesyatsev" was a combined trawl and acoustic survey. On the survey of "Dr. Fridtjof Nansen" the main emphasis was put on acoustic surveying. Some data from the Soviet commercial trawler have also been included in the report, together with data on fisheries statistics for 1977 from SIP (Servico de Investigacoes Pesqueiras) in Maputo.

Vessel and gear

R/V "Dr. Fridtjof Nansen" is a 150-foot combined stern trawler and purse seiner. The main engine of 1500 Hp gives a maximum speed of 13 knots. There is accommodation for 28 men. All winches are hydraulic. The boat carries two pelagic trawls, one bottom trawl and one purse seine, gill-nets, long-lines, hand lines and pots. A satellite navigator allows very precise determination of position.

Fig. 2.1. Survey routes and stations - southern part during cruise no. 4.



1) Hydrographic station 2) Bathythermograph station 3) Pelagic trawl 4) Bottom trawl 5) Handline 6) Pots 7) Long-line 8) Gill net.

Acoustics

The acoustic equipment consists of three scientific sounders (120, 50 and 38 kHz), two echo integrators, each of two channels, one sonar (18 kHz) and one netsonde (50 kHz). The two echo integrators were coupled to the 38 kHz sounder.

Echo integrator values were read at each nautical mile and averaged over five nautical miles. Continuous watch was kept on the acoustic instruments and fishing carried out whenever the echo recordings changed characteristics. The acoustic data were scrutinized once a day. Integrator contributions from false bottom, wakes etc. were deleted and the readings were split into four categories: small pelagic fish, demersal fish, plankton and fish larvae, and mesopelagic fish. The values within each group were plotted on charts. The integrator readings on the charts were split into strata, depending on the value. By drawing isolines, areas of different fish density were obtained. The size of the areas was calculated by mean of a planimeter. These values multiplied with the average integrator readings gave relative abundance indices.

Following FORBES AND NAKKEN (1972) the output of an echo integrator is proportional to the fish density:

$$P_A = C_W \cdot M \qquad (1)$$

where P_A is the fish density expressed in weight per unit area, M is the integrator reading and C_W a conversion coefficient depending on the fish species and size, as well as on the characteristics of the sounder and integrator used. It can be shown that C_W is proportional to the length of the fish (NAKKEN 1975, NAKKEN and OLSEN 1977).

The numerical value of C_W applied to the “Dr. Fridtjof Nansen” data was 10.5 tonnes/mm per nautical mile · (n. mile)^2. This figure was established for a mixture of mainly pelagic species with an average length of about 17 cm (ANON 1977 a). The density coefficients, C_W used in the present study will then be:

$$C_W = 10.5 \frac{\ell}{17} \qquad (2)$$

where *l* is the mean length in cm of the observed species.

The total fish abundance, B, can then be calculated using the equation:

$$B = \oint P_A \, dA = C_W \cdot \overline{M} \cdot A \qquad (3)$$

where $\overline{M}$ is the average integrator reading and A the corresponding area.

The value of C_W, equation (2), is believed to be reliable for small pelagic species. The distribution area of pelagic fish was split into subareas where the species composition and the average length of the different species were determined by means of the trawl catches. The calculation was than carried out according to equations (2) and (3). The same equations were also applied for mesopelagic fish, assuming that the scattering properties of these fish are similar to those of pelagic fish.

For demersal species, however, the acoustic estimate will be less reliable, as there are no observations of C_W for these fish. Due to lack of other information on the sound reflecting properties of demersal fish from the region, a C_W = 10.5 tonnes/mm per nautical mile · (n.mile)^2 was chosen. For the snapper (Lutjanus sp.) at St. Lazarus Bank the value of C_W was doubled.

Due to a misunderstanding the acoustic investigations of Cruise no. 3 were not carried out the same way as on the other three cruises. The abundance estimates from this cruise have therefore been deleted from the present report.

Fishing gear

The pelagic trawl in use had dimensions of 16 × 16 fathoms around the trawl mouth, usually corresponding to a height of 17 m when fishing. It was operated with superkrub doors and 120 m bridles, and was always used together with a net sonde.

The bottom trawl covered a track of about 60 m between the doors when fishing using 40 m bridles. The footrope was equipped with 0.5 m bobbins, and the effective vertical opening of the net was 6.5-7.0 m.

Three types of pots were used:

TYPE RF. This pot was originally constructed for fishing black cod (Anoplopoma fimbria) on the west coast of USA and Canada (HIPKINS, 1974). It is a metal frame pot with webbing cover of 60 mm mesh size. The pots used in this investigation were slightly smaller than the original and had the dimensions 0.75 × 0.75 × 2.25 m.

TYPE RK. This pot was designed for fishing crayfish (Nephrops norvegicus) in Norwegian waters. It is also a metal frame pot with webbing cover of 28 mm mesh size. It has four entrances.

TYPE RQ. This pot construction is used for fishing Queencrab (Chionocetes sp.) in Canadian waters. It is a cone-shape pot with largest and smallest diameter of 1.20 m and 0.75 m respectively. The height is 0.65 m and it has only one entrance.

The floating gill-nets were both of the mono filament 120 mm mesh size and multifilament 60 mm mesh size type. The long lines consisted of 100 hooks each with hook size varying between 3 and 7.

Fish biology

The literature used for identification is listed in the references. The nomenclature in the FAO Species Identification Sheets for Fishery Purposes (Fishing Areas 57/71) was used when there were any conflicts of nomenclature in the literature. For sharks the nomenclature of the Oceanographic Research Institute in Durban was adopted.

Catches were sorted by species and measurement of total length, weight, sex and maturity stage were carried out for the most abundant species. The total length of small specimens was measured to the nearest 0.5 cm below, and large ones to the nearest 1 cm below. The following maturity scale was used:

Maturity stage	**Stage no.**
Immature	1
Mature unripe	2
Mature ripening	3
Mature nearly ripe	4
Mature ripe (non spawning)	5
Mature ripe running (spawning)	6
Mature spent	7

Plankton

Plankton samples were obtained at each hydrographic station by a vertical haul 100-0 m with a 36 cm diameter Juday net of 500 μ mesh size. Wet displacement volume of the samples was measured on board. The contribution to the echo integrator readings from plankton was plotted on separate maps.

Hydrography

Six fixed hydrographic sections were carried out along the coast. In addition, four sections at Sofala Bank were worked in order to follow the fresh water outflow from the Zambezi River from Cruise no. 2 onwards. The hydrographic sections were repeated during each of the four coverages. The locations of the sections appear in Fig. 2.2.

At the hydrographic stations temperature and salinity were observed at the following standard depths: 0-10-20-30-50-75-100-125-150-200-250-300-400-500 m. Samples for oxygen titration-were taken from 0-10-20-30-50-75-100-150-200-300-500 m. At SECTION V samples were taken at standard depths to the bottom during cruises 1 and 4.

The salinity and oxygen samples were analyzed on board. At approximately each 30 nautical miles, the vertical distribution of the temperature down to 250 m or bottom was observed by means of a bathythermograph. At these stations the surface salinity was also observed. The surface current was mapped by observing the drift of the vessel.

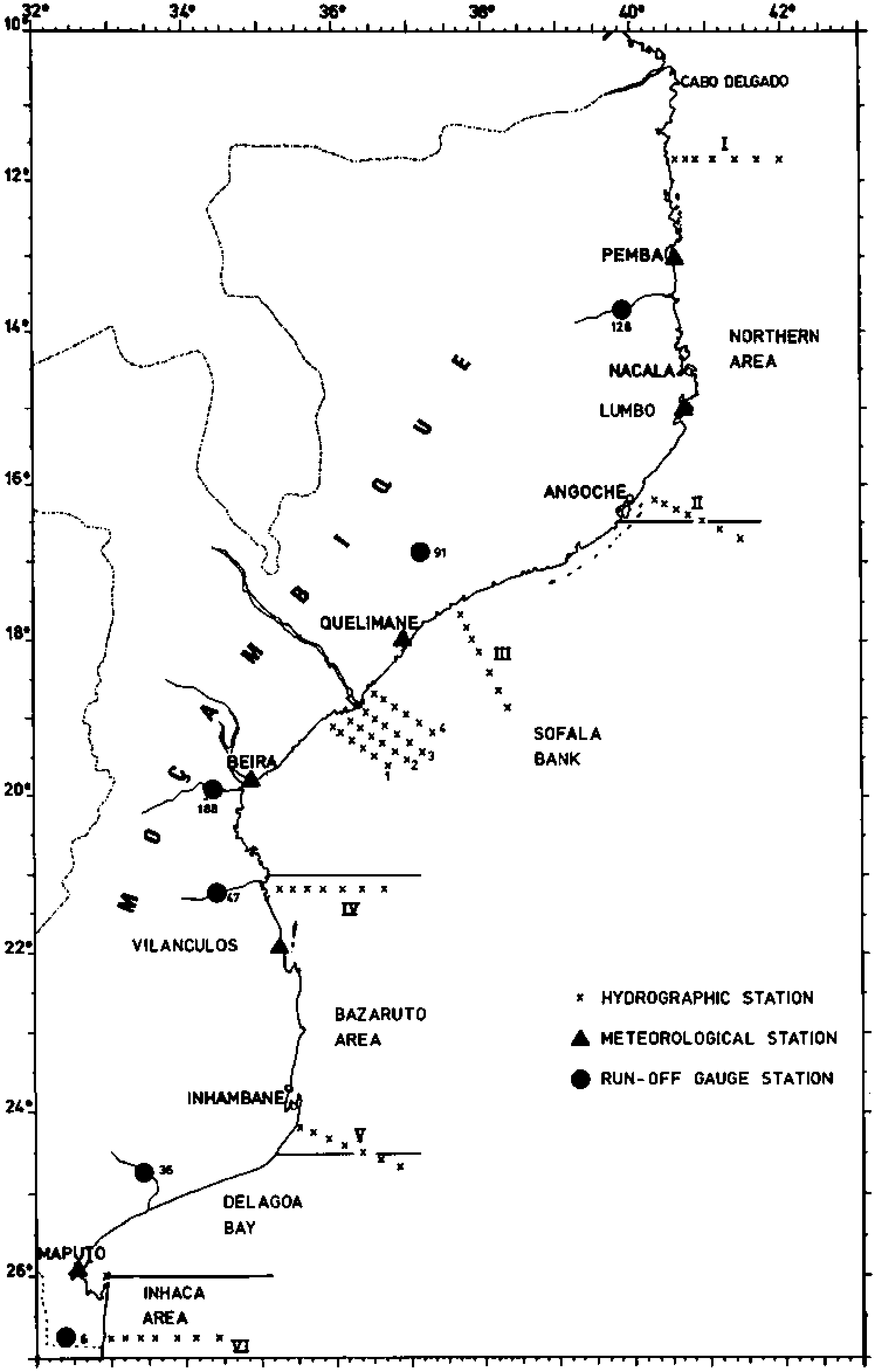
Data on wind from Aug. 1977 to June 1978 and the average fresh water run off were obtained from SIP in Maputo. The locations of the stations used appear in Fig. 2.2.

<u>Trawl bottom</u>

The quality of the trawl bottom as judged from the echo recordings was characterized at depths shallower than 250 m according to the following scale:

Impossible to use bottom trawl	1
Possible with caution	2
Good trawl bottom	3

Fig. 2.2. Hydrographic sections, meteorological stations and freshwater runoff gauges.



3. BOTTOM CONDITIONS

The trawl bottom conditions of the waters adjacent to Mozambique are shown in Fig. 3.1. The map is a compilation of the information from the "Dr. Fridtjof Nansen", "Kattegat" and "Aelita" expeditions. Off the northern part of the coast from Cabo Delgado to Angoche including the St. Lazarus Bank, it is, in general, impossible to use bottom trawl. This is due to several submarine canyons and the narrow shelf with fringing corals. The coral extends south along the coast approximately to Angoche, where it spreads out to sea. It continues southward to about 17°30' S as isolated submarine platforms forming a chain of small islands on the shelf some 70 km offshore (TINLEY, 1971).

Fig. 3.2 is an echo recording from the depth range 0-250 m showing a transsection across the St. Lazarus Bank. The distance between the vertical lines is one nautical mile, and the depths of the bank between 20 and 30 m.

The Sofala-Bank area south to Beira gives only small problems in relation to bottom trawling at depths less than 100 m. An area of corals occurs at depths between 40 and 100 m between the Zambezi delta and Quelimane. The continental slope is very precipitious and partially uneven with sharp edges, so trawling has to be carried out with caution.

The shelf area south of Beira between 19°30' S and 21°30' S is unfishable with bottom trawls at depths less than 50 m. This is caused by the undulating character of the bottom, as shown by the echo recording in Fig. 3.3. The distance between the vertical lines is one nautical mile and the depth is between 20 and 40 m. The waves are most likely sandwaves generated by the strong tidal currents in the area. The wavelength is between 200 and 400 m and the amplitude mainly 10-15 m, in some cases even 20 m.

The area between Bazaruto Island and Ponta Zavora is partly unfishable at depths less than 150 m due to bottom irregularities, rocky outcrops and canyons. In deeper water the bottom is muddy or sandy and characterized as a good trawling area.

Fig. 3.1. Trawl bottom conditions. 1) Impossible to use bottom trawl. 2) Possible with caution. 3) Good trawl bottom.

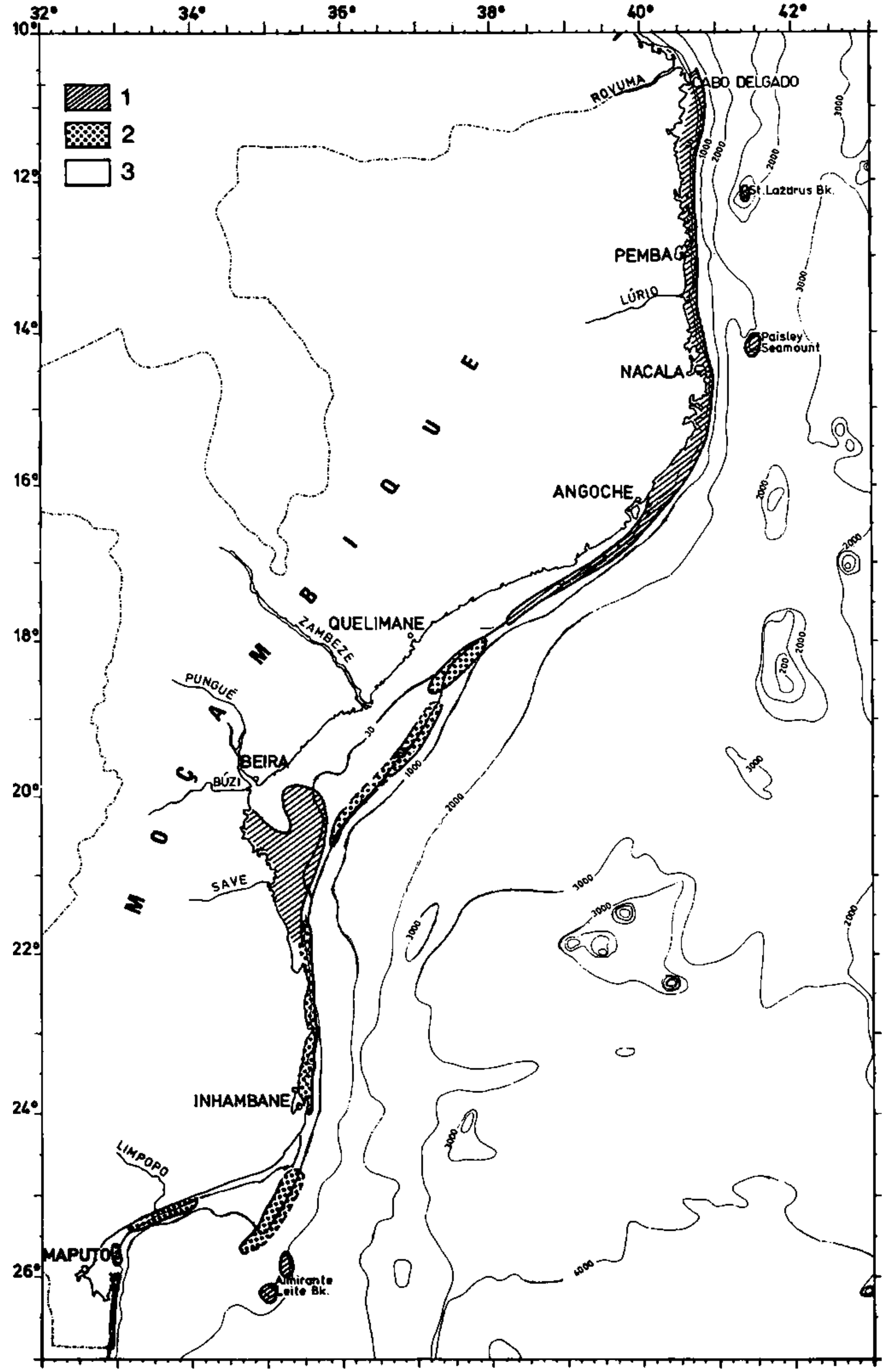
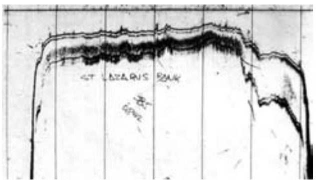


Fig. 3.2. Echo recording across the St. Lazarus Bank.



In the Delagoa Bay, some areas at depths less than 150 m are unfishable, especially south-east of the Quissico lighthouse at 40-50 m, and off the Limpopo River. At greater depths there are usually no problems in using a bottom trawl.

On the stretch Ponta do Ouro to Inhaca Island it is difficult to trawl due to coral and rocks at depths less than 100 m. Generally there are no problems in deeper waters, but some rocky outcrops and canyons have also been observed here.

The area of the shelf zone has been calculated using British Admiralty charts. The results are shown in Table 3.1. The total area of the shelf between 10 and 200 m is about 70 000 km^2. The frequently cited area of 120 000 km^2 from MOISEEV (1969) for the upper 200 m is obviously too large. The splitting of the Mozambican coast into five different areas appears in Fig. 2.2.

Fig. 3.3. Echo recording from Sofala Bank.

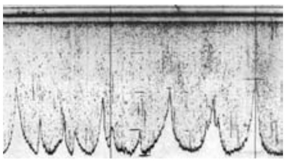


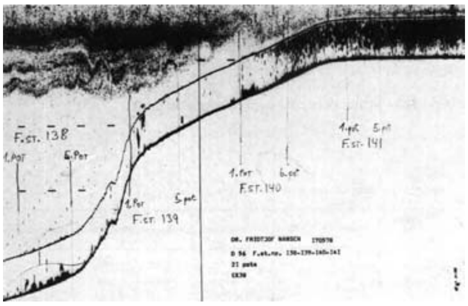
Table 3.1. Area of the shelf of Mozambique (km^2).

Area\Depth	Northern	Sofala	Bazaruto	Delagoa	Inhaca	Total
10-50 m	Including St. Lazarus Bank = 133 km^2	38020	4240	4570	320	
51-100 m		7380	1350	3020	290	
101-150 m		490	960	1280	160	
151-200 m		490	960	1280	160	
10-200 m	6190	46380	7510	10150	930	71160
200-400 m		1960	4120	7900	950	

4. PLANKTON

The echo abundance of plankton was recorded during the “Dr. Fridtjof Nansen” survey. In addition to zooplankton and phytoplankton, fish larvae were also included in the scattering layer labelled ‘plankton’. During the night lantern fish migrated to the surface layer and mixed with the plankton as well.

Fig. 4.1. Distribution of plankton over the continental slope.

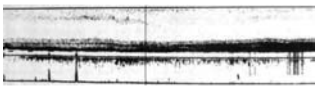


Usually, the maximum plankton abundance was observed over the continental slope, as seen in Fig. 4.1. This was probably caused by the hydrographic condition, as the shear or transition zone between the south-going Mozambique Current and shelf counter current coincided with the slope. During night the plankton seemed to be more or less evenly distributed in the whole water column in the shelf area, as shown in Fig. 4.2. A significant proportion of the plankton biomass apparently stayed very close to the bottom during day and spread out in the whole water column during the night.

Fig. 4.2. Typical night recording of plankton at the shelf.

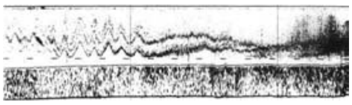
During daytime the plankton was usually concentrated in one or more separate layers. Fig. 4.3 shows a typical day recording from Sofala Bank at 50-60 m depth. There is a maximum abundance layer 5-10 m above the bottom and nearly no plankton below. On several occasions this phenomenon was observed to be connected with a decrease in temperature in the near-bottom layer. Fig. 4.4 is another example of a plankton recording with several layers of concentration. The undulating character of the layers is probably due to internal waves which were occasionally observed in the vicinity of the continental slope.

Fig. 4.3. Typical day recording of plankton at Sofala Bank.



The average integrator deflection attributed to plankton was used to establish an acoustic plankton abundance index for the different areas. The results are shown in Fig. 4.5. The minimum plankton abundance occurred during Cruises I and II, i.e. during the southern summer. The maximum values were observed during Cruise I, i.e. in September - October. The minimum abundance seemed to occur later along the northern coast than further south.

Fig. 4.4. Day recording of plankton near the continental slope.



The acoustic abundance index will be a function not only of the total plankton biomass but also of the species composition. The sound reflecting properties of a plankton layer depend on the size of the organisms as well as on the frequency of the echo sounder. The abundance indices in Fig. 4.5 therefore do not necessarily give a correct measure of the relative variation of the plankton biomass. The reliability of the abundance indices can be improved by using an echo sounder of higher frequency.

Fig. 4.6 shows the average wet displacement plankton volumes for different areas and cruises. Both in the northern area and in the Bazaruto area the time variation of this parameter shows approximately the same tendency as the acoustic indices. At Sofala Bank and in Delagoa Bay, however, the pattern of variations seems to be different. Maximum displacement volume was observed during Cruise III which was the time of minimum acoustic abundance. We have no obvious explanation for this phenomenon.

In order to see if there was any difference in the average plankton volume between day and night hauls the value

$$\frac{V_D}{V_D + V_N} \cdot 100\%$$

was calculated for each cruise and for three areas. V_D is the average volume during the day and V_N during the night. Fig. 4.7 shows the result. As seen, the night hauls usually gave a higher plankton volume except on Cruise II where the day hauls contributed most. This feature, as well as the time variation of the plankton volumes at Sofala Bank and in Delagoa Bay shown in Fig. 4.6, might be explained by seasonal variation in the species composition of the plankton.

Fig. 4.5. Acoustic plankton abundance indices.

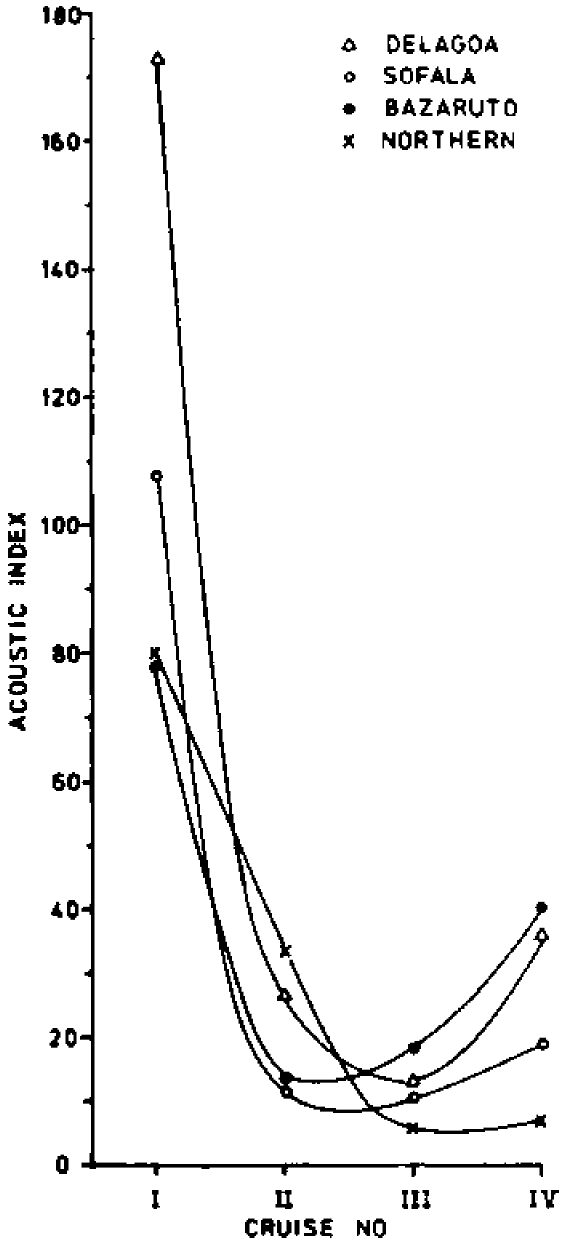


Fig. 4.6. Average wet displacement volume of plankton.

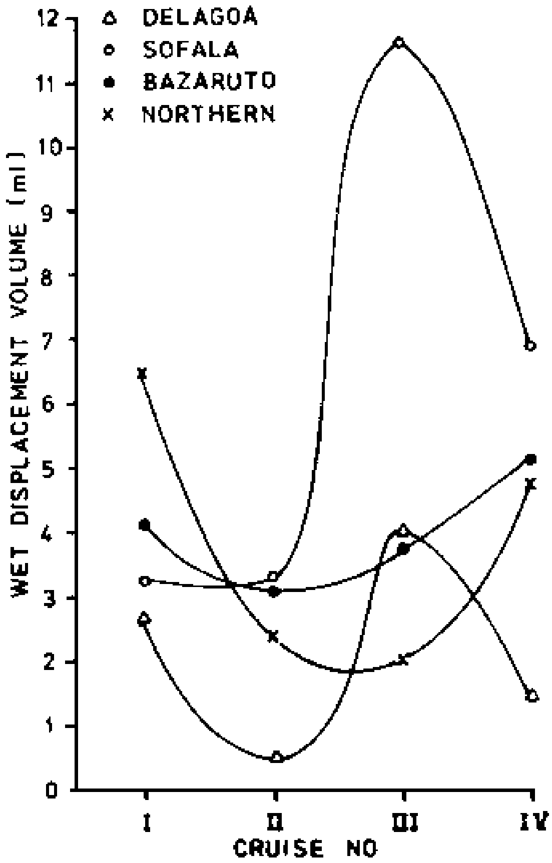
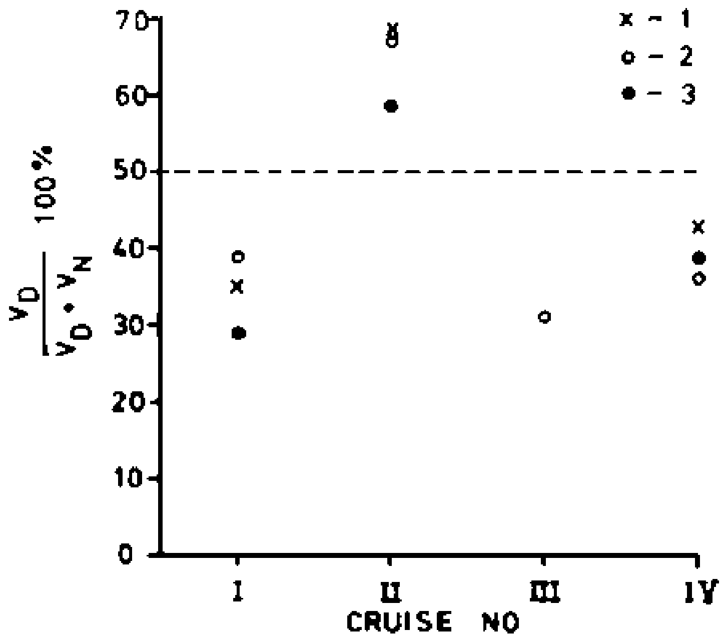


Fig. 4.7. Ratio between night and day hauls of plankton.



1) Northern, 2) Sofala, 3) Bazaruto.

5. HYDROGRAPHY

5.1 Introduction

The Mozambique Current is usually considered as a part of the anticyclonic subtropical gyre consisting of the South Equatorial Current, the Agulhas Current system and the eastward flow situated to the north of the subtropical convergence (WYRTKI, 1973). Several opinions exist concerning the status of the Mozambique Current. The classical concept of the Agulhas Current being an extension of the Mozambique Current has been questioned by MENACHÉ (1963). He claims that during at least some parts of the year the water transported by this current turns back at the southern mouth of the Mozambique Channel and flows north along the west coast of Madagascar. HARRIS (1972), however, observed that a fraction of the Mozambique Current passed through the southern part of the channel as one of the tributories to the Agulhas Current. LUTJEHARMS (1976), making use of all the available data from the north-east monsoon season, concluded that the origin of the inflow to the Agulhas Current is a function of depth and that the Mozambique Current is the major source for the upper layers during this season.

CREPON (1964) gives some indications of a looping of the West Madagascar Current to form the Mozambique Current. An interpretation of this observation together with that of MENACHÉ (1963) is that a closed anticyclonic circulation exists within the Mozambique Channel.

By isentropic analysis of data from spring 1964 HARRIS (1972) showed the presence of a front of constrasting water properties along the eastern boundary of the Mozambique Current from Durban to the northern end of the Mozambique Channel. Along this front a series of deep anticyclonic vortices were identified.

The core of the southward-moving Mozambique Current is generally found close to the continental slope. The northern part of the Mozambique Current as well as its main source, the South Equatorial Current, is directly influenced by the monsoon winds. Considerable seasonal variations in velocity and volume transported are therefore to be expected. The South Equatorial Current is strengthened during the South-West Monsoon in April-October but only one third of this water turns south as the East Madagascar and the Mozambique Current (WYRTKI, 1973). It is likely, however, that also this ratio is subject to seasonal variations.

According to the British Admiralty Sailing Directions the Mozambique Current has its minimum velocity during May-July and its maximum during August-January. DARBYSHIRE (1964) claims the Agulhas Current to be strongest in April and weakest in October. Other authors have shown that this current has its maximum speed both in spring and in autumn. The problem of the seasonal changes in the Mozambique and the Agulhas Currents has thus not yet been resolved (LUTJEHARMS 1977). PEARCE (1977) deals with the short-term variations of the Agulhas Current and has observed meanders over tens of kilometers off Durban.

Several authors have observed an inshore current along parts of the coast, flowing in a contrary direction to the main current. This counter current seems not to be a permanent feature but highly influenced by the prevailing winds (CLOVES, 1950). In general the counter currents are weak, but have occasionally been observed to flow at high speeds. STAVROPOULOS and DUNCAN (1974) present a current section off Durban showing maximum northward currents of 100 cm/s in the inner 20 km. In Beira Bay a strong and fairly permanent longshore counter - counter current have been reported (TINLEY, 1971).

5.2 Wind and freshwater outflow

Table 5.1 gives the monthly wind direction frequency at six localities (Fig. 2.2) along the coast of Mozambique from August 1977 to June 1978. The observations were only carried out during daytime at 0900, 1500 and 2100 hrs. The alternating monsoon system with winds from the north-east during the southern summer (November-April) and from the south-west during the southern winter (May-October) is pronounced along the northern coast south to Sofala Bay.

Along the southern part winds between North and East dominated from September to December both at Vilanculos and in Maputo. In August and from January to June winds between East and South were prevailing at Vilanculos while the situation was more variable in Maputo. Northerly winds were especially frequent in Maputo in May.

It is uncertain to which degree these coastal observations are representative for the more offshore areas. Some of the meteorological stations might be influenced by local topographic conditions. The coastal stations also show a diurnal variation in wind direction, with nocturnal offshore winds and onshore winds during daytime.

Fig. 6.1 shows the average monthly freshwater discharge from some of the main rivers of Mozambique. The localities of the water gauges appear in Fig. 2.2. As seen, there is a maximum freshwater outflow in February-March and a minimum in October. The whole Mozambican coast seems to belong to the same hydro-logical regime, with a possible exception for Maputo River which has a rather small seasonal variation. Unfortunately it has not been possible to obtain discharge data from one of the major freshwater sources, namely the Zambezi River. The lack of data makes it difficult to estimate the total freshwater outflow flow Mozambique. The average outflows shown in Fig. 6.1 are, however, believed to give a correct qualitative picture of the seasonal variations.

5.3 Characteristic hydrographic features and water masses

The hydrographic SECTION V from May 1978 shown in Fig. 5.2 elucidates some of the most conspicious hydrographic features found off the coast of Mozambique. A thermocline is observed usually at depths between 50 and 100 m. From this there is a gradual decrease in temperature with depth to about 2.5°C at about 2000 m. There is a subsurface salinity maximum at about 200 m depth. The vertical distribution of oxygen shows a minimum zone situated slightly above the salinity maximum. Another oxygen minimum is seen at 1000-1200 m. Between the shallow and the deep oxygen minima is situated an intermediate oxygen maximum. These features are found more or less pronounced in the whole Indian Ocean north of 40°S (WYRTKI, 1971).

Fig. 5.3 shows the temperature-salinity relationship from the same section as in the previous figure. This is representative for the whole Mozambican coast. Following mainly WYRTKI (1971, 1973) four main water masses can be identified:

Surface water. This is characterized by temperatures between 22°C and 30°C with salinity below 35.2‰. The surface water mostly has a salinity below 35.0‰ with increasing values southward. This water consists of the low-salinity tropical surface water transported westward across the Indian Ocean by the South Equatorial Current. The salinity of this water is kept low by the freshwater runoff from the coast of Mozambique.

Subtropical surface water. This water is formed in the center of the subtropical anticyclonic gyre where it sinks to more than 500 m. From here it spreads to form a sub-surface salinity maximum throughout the entire gyre system. Off the coast of Mozambique it is usually found at depths between 150 and 250 m. The highest salinity values of this maximum zone are observed along the southern part of the coast.

Antarctic intermediate water. This water mass is formed by mixing along the Antarctic polar front of the cold and low-salinity surface water of Antarctic and warmer water of higher salinity from the north. The mixing products sink and continue on north as the Antarctic intermediate water.

The linear temperature-salinity relationship between the subtropical surface water and the Antarctic intermediate water is by some authors called Central water. The apparent salinity maximum of 34.8‰ at 5°C is probably water of Red Sea origin.

In Fig. 5.4 is plotted σ_t versus temperature from the same section as the previous figures. The relationship could be rather nicely fitted to the following expressions:

$\sigma_t = 30.95 - 0.3\ t$ for $t > 16°C$
$\sigma_t = 28.10 - 0.12\ t$ for $t < 16°C$

These equations seem to be valid for the whole Mozambican coast except for surface water of salinity below 35.0‰. This means that the interior mass distribution of the hydro-graphic sections is fairly well described by the temperature field. For that reason no σ_t sections are presented.

5.4 Surface currents

The surface currents were mapped by observing the drift of the vessel. Though the vessel was equipped with a satellite navigator allowing very precise determination of position, the time between each reliable satellite fix could be up to five hours. It is thus obvious that smaller details in the current picture, such as current shear and vortices, will not be observed. Additionally, the wind component effecting the drift of the vessel is difficult to estimate. In spite of these reservations, some conspicious features of the surface current are very pronounced in the drift observations:

In September 1977 there was a northward current off Cabo Delgado, and the dividing area of the South Equatorial Current seemed to be at about 11°20'S. During the rest of the observation period the southward-flowing Mozambique Current was observed along the whole coast. North of Nacala the strongest currents were usually found in the eastern part of the investigated area, about 80-100 km from the coast. From Nacala to Inhambane the highest current velocities were observed close to the continental slope with decreasing values eastwards. At the southern end of the Boa-Paz Bank the current core moves toward South-South-West without the previous tendency to follow the bathymetrical curves and without intruding into Delagoa Bay.

The maximum velocity observed was about 200 cm/s and the highest values were in general found north of 18°S. The area off Angoche seemed to be the area of maximum current velocity.

Northward counter currents were observed between 26° and 27°S, in Delagoa Bay and at Sofala Bank. These appeared to be most pronounced and reached the highest velocities, up to 100 cm/s, during February-March.

5.5 Hydrographic structure

<u>September 1977</u>. The horizontal distribution of temperature is shown in Fig. 5.5. The temperature decreased from 25.5°C off the northern part of the coast to about 23°C in Delagoa Bay. A tongue of slightly cooler water extended southward from the mouth of Zambezi River which was probably associated with the freshwater outflow from this river.

The highest salinities were found close to the coast along the northern part of the coast south to Quelimane (Fig. 5.6). Water of salinity below 35‰ was recorded 70-130 km off the coast. The outflow from Zambezi River could be seen as a tongue of low salinity water propagating southward. North-west of Inhambane more saline water was brought into the area from the east.

Figs. 5.7-5.12 give the vertical distributions of temperature, salinity and oxygen in the six hydrographic sections. In all the sections the characteristic features described in Ch. 5.3 of a salinity maximum at about 200 m and a oxygen minimum zone slightly above this maximum, are pronounced.

As an aid in the interpretation of the hydrographic data, the vertical geostrophic velocity distribution relative to the surface was calculated for each hydrographic section.

At SECTION I (Fig. 5.7) there seemed to be two cores of maximum southward velocity; one about 50 km from the coast and another at the outermost stations 140-150 km seawards. In the inner 30-40 km a northward current seemed to occur, which was associated with the lowsalinity water of the upper 100 m. The northward current seemed to have its maximum value close to the coast.

The maximum southward current in SECTION II (Fig. 5.8) was probably found about 50 km from the coast. In the part of the section nearest the coast indications of a weak northward current were seen. Centered about 100 km from the coast there seemed to be a cyclonic eddy. This eddy was most pronounced in the deep layer below the thermocline.

In SECTION III (Fig. 5.9) two maximum zones in the southward current were indicated, one 50-60 km from the coast and another 100-120 km seawards. There were also indications of a coastal counter current over the shelf.

In SECTION IV (Fig. 5.10) the tongue-like lowsalinity water from the Zambezi River which was pronounced in the surface salinity distribution (Fig. 5.6) was seen in a narrow zone over the shelf. The baroclinic structure of the section was weak and southward transport through the section seemed to be negligible. A maximum northward current seemed to occur 110-120 km offshore. It also seemed from the surface salinity distribution as the southward flow was deflected to the east and northeast, and that only a small fraction of this water passed further south.

It was also indicated by the surface salinity distribution that more saline water from the east was being fed into the Mozambique Current along two possible routes, one east of Bazaruto Island and another north-east of Inhambane.

The latter could be followed in SECTION V (Fig. 5.11) as a zone of decreased temperature and increased salinity. In this section the subtropical surface water usually found in about 200 m was lifted to the surface. This appeared to be due to a cyclonic eddy which was situated outside the southward long-shore flowing water.

The northbound current indicated at the inner 20-30 km of SECTION VI (Fig. 5.12) was also observed by the drift of the vessel. The southward current core seemed to be about 50 km offshore. Further seawards a cyclonic circulation was indicated, resulting in a pronounced shear zone clearly seen in all three parameters.

The depth to the thermocline, D, can be defined as $t_O - t_D < 1°C$, where t_O is the temperature at the surface and t_D the temperature at the upper boundary of the thermocline. The thickness of this mixed and homogeneous layer was about 100 m along the northern coast with decreasing values southwards and when approaching the coast.

<u>November 1977</u>. During this cruise the surface temperatures (Fig. 5.13) were 2-3°C higher than during the previous cruise. They decreased southward from 28.5°C along the northern coast to about 25°C in Delagoa Bay. Along the northern coast south to Quelimane the lowest temperatures were recorded close to the coast while usually the contrary was observed further south. The salinities (Fig. 5.14) along the northern coast south to about 18°S were slightly higher than in September. Both the salinity as well as the temperature distribution gave some indications of an eddy over St. Lazarus Bank. On Sofala Bank the salinity was approximately the same as in September, but the tongue of lowsalinity water was missing. As in September, more saline water was observed coming in from east off Inhambane. In Delagoa Bay the surface salinity was slightly higher compared to the September distribution.

SECTION I (Fig. 5.15) the salinity distribution showed an apparent ascending of the Subtropical surface water. Indications of this, however, were found neither in the temperature nor in the oxygen distribution. The maximum southward flow was probably about 130 km seaward. There was some indication of a north-going current in the inner part of the section, with a possible reversal at about 200 m.

As observed during the previous cruise, the strongest southward current occurred about 50 km off the coast in SECTION II (Fig. 5.16). More seawards, a cyclonic eddy was indicated. The northward current at the outermost stations might have been the inner part of another cyclonic eddy.

Due to bad weather conditions the outermost stations of SECTION III (Fig. 5.17) were only carried out by use of bathythermographs. The strong current shear indicated by the temperature distribution might therefore have been caused by this change in observation method.

SECTION IV (Fig. 5.18) showed a weak baroclinic structure, with indications of northerly currents of low velocities along the whole section. As also observed during the previous cruise the southward transport through this section seemed to be negligible.

Also in SECTION V (Fig. 5.19) the baroclinic structure was weak, and the southward transport seemed to be small. The distribution of surface salinity and temperature (Figs. 5.13-5.14), however, indicated transport of water from east and north-east into the section.

SECTION VI was not carried out during this cruise due to lack of time.

Figs. 5.20-5.23 show the four hydrographic sections off the Zambezi River. The effect of the freshwater outflow is clearly seen. A strong vertical haline stratification is seen at the innermost station of SECTION 3. Further out, mixing took place, resulting in only weak or non-haline stratification. The sections show the typical wedgeshape of a freshwater generated coastal current with northward transport. The influence of the freshwater outflow goes down to the bottom as far out as about 50 km from the coast.

The thickness of the mixed and homogeneous upper layer was about 25 m along most of the coast, except in the northernmost part where it reached down about 100 m. The depth of the thermocline increased gradually offshore, but in the whole area it was shallower than on the previous cruise.

January-March 1978.

During cruise no. 3 in February-March 1978 (Fig. 5.24) the surface temperatures were in general 1-3°C higher than during cruise no. 2. The highest temperatures were found at Sofala Bank where values more than 30°C occurred. In Delagoa Bay the temperature was about 27°C. Except for the southern part of Sofala Bank the lowest temperatures were found close to the coast.

A pronounced decrease in salinity compared to November was observed along the whole coast during February-March (Fig. 5.25). Except for the area between Pemba and Cabo Delgado the salinity in the zone nearest the coast was below 35 ‰. The lowest salinity, about 30‰, was observed in Beira Bay.

SECTION I (Fig. 5.26) showed the typical feature of a coastal upwelling with an intensification of the southward current close to the coast. The geostrophic velocity in 500 m relative to the surface was about 230 cm/s northward at the inner stations. It would seem to be unlikely to have had such southward velocities at the surface, which means that there was probably a reversal of the current with north-going transport in the deeper layers along the coast.

Indications of ascension of water from the deeper layers when approaching the coast were also present in SECTION II (Fig. 5.27). The core of the south-going current seemed to occur about 80-90 km off the coast. The innermost part of the section had apparently a northgoing current.

SECTION III (Fig. 5.28) probably had a northward current at the inner stations and mainly southward currents in the rest of the section. The maximum southward current seemed to be about 70 km from the coast.

SECTION IV (Fig. 5.29) shows the typical wedge-shape salinity distribution of a north-going coastal current over the shelf. An apparent lifting of the sub-surface water close to the slope was visible. The southward current seemed to have its maximum values 80-90 km from the coast.

SECTION V (Fig. 5.30) indicated a cyclonic vortice at depths below the thermocline. The maximum southward current seemed to be associated with the surface salinity minimum.

Also in SECTION VI (Fig. 5.31) the feature of a cyclonic eddy seemed to be present with north-going currents near the coast and the strongest southward currents about 100 km offshore.

The hydrographic sections off the Zambezi River are shown in Figs. 5.32-5.35. As observed on the previous cruise, the strongest haline stratification was found in SECTIONS 1 and 2. The vertical temperature gradient close to the bottom over the shelf was more pronounced than in November.

The depth of the homogeneous layer was about 25 m along the entire coast, increasing to 50 m further offshore. The thickness of this layer was less than during cruise no. 1 and rather similar to that observed during cruise no. 2 in November.

April-June 1978

In April-June 1978 the maximum surface temperature (Fig. 5.36) of about 30°C was found off the northern coast decreasing to about 22°C in Delagoa Bay. The lowest temperatures was recorded close to the coast.

Surface salinities (Fig. 5.37), above 35‰ were not observed north of Angoche. At Sofala Bank there seemed to be slightly lower salinities compared to February-March, while in Delagoa Bay they were slightly higher. As observed on previous cruises there was water of high salinity penetrating towards the coast from east off Imhambane.

As also seen during the previous cruise, the lifting of the isotherms near the coast was pronounced in SECTION I (Fig. 5.38). The vertical distribution of the geostrophic velocity at the two inner stations gave a northward velocity of about 230 cm/s in 300 m relative to the surface. It is therefore reasonable to suggest a reversal of the southward current near the coast at a depth of 150-200 m with a north-going current below this. The northbound current seemed to reach the surface just outside the wedge of lowsalinity water. Further east, southward currents seem to dominate.

Also in SECTION II (Fig. 5.39) the geostrophic velocity distribution at the two inner stations revealed a turning depth of the current with north-going currents down to about 150 m and southward currents below.

SECTION III (Fig. 5.40) appeared to have north-going currents over the shelf and slope, and southward currents further offshore.

In SECTION IV (Fig. 5.41) a core of lowsalinity water was seen 60-70 km from the coast. The same observation was made in September 1977, but that time the core was closer to the shore. If this was not an isolated patch of water, the surface salinity distribution indicate that it must have been brought into the area from the north-east. If it was a part of a tongue of low-salinity water from the area between Beira and Zambezi River it should also have been detected in the surface salinity samples. There is possibly a northward current over the shelf. The rest of the section shows southerly currents with a possible maximum in velocity about 140-150 km offshore.

Both in SECTION V (Fig. 5.42) and in SECTION VI (Fig. 5.43) there is a northerly current close to the coast.

The Zambezi sections (Figs. 5.44-5.47) show more or less the same feature as on the previous cruises, with northerly a current over the shelf.

5.6 Discussion

The seasonal variation in temperature seemed to be between 4 and 6°C along the coast of Mozambique. The highest seasonal variations were found in Delagoa Bay and the lowest off the northern part of the coast. There seemed to be a decrease in temperature from north to south throughout the year. Usually the temperature increased while moving away from the coast, except at the southern part of Sofala Bank and in the area between Pebane and Angoche in February-March. These results agree nicely with those of WYRTKI (1971).

The maximum salinities in the coastal waters of Mozambique were observed in November and the minimum in March-April. This is in correlation with the seasonal variation of the freshwater outflow (Fig. 5.1). The lowest salinities were found at Sofala Bank where a large proportion of the area had surface salinities below 30‰.

The surface salinities in the water transported by the South Equatorial Current seemed to have minimum values during March-June and maximum values from November to February (WYRTKI, 1971). In general, the surface salinities off Mozambique de creased seawards. The seasonal salinity variations seemed to be dominated by the local freshwater outflow which reached its maximum usually in February and its minimum in September-October (Fig. 5.1).

Along the northern coast south to Angoche the typical feature of a coastal upwelling appeared to occur during the north-east monsoon from November to April. As seen in Table 5.1 the conditions were favourable for a wind-induced coastal upwelling during that time. The upwelling seemed to start in SECTION I in November (Fig. 5.15) and in January (Fig. 5.26) it was fully developed. It seemed to last until April (Fig. 5.38). The upwelling was confined to the inner 30-40 km.

Several authors have shown that the characteristic length scale of a coastal upwelling might be expressed by the baroclinic radius of deformation. Off the northern coast of Mozambique this appeared to be in the order of 30-50 km and is thus in good agreement with the observed width of the upwelling zone.

From theoretical and numerical models of coastal upwelling (e.g. ALLEN, 1973, O'BRIEN and HURLBURT, 1972) as well as from observations (SMITH, 1974) it is expected that the longshore currents are mainly geostrophic. Fig. 5.48 shows the vertical geostrophic velocity profiles relative to the surface from the inner station pair of SECTION I in January and April 1978. These baroclinic components of the longshore velocity make it reasonable to believe in a reversal of the current in the deeper layers, otherwise unrealistic southward velocities would occur at the surface. The hydrographic data give some support to a "guesstimate" of about 200 m as the turning depth of the current. This would give a southward surface current of 120-140 cm/s and a counter current below 200 m of approximately the same order.

A common feature of coastal upwelling regions seems to be a baroclinic surface coastal jet and a subsurface counter current. The coastal surface jet is predicted by multi-layer numerical models (O'BRIEN and HURLBURT, 1972, McNIDER and O'BRIEN, 1973) and in the continuously stratified model of ALLEN (1973). The model of HURLBURT and THOMPSON (1972) manages to produce a realistic subsurface counter current. Observational evidence for a near-surface coastal jet and a subsurface counter current has been presented by MOOERS et al (1974) from the Oregon coast, and by JOHNSON et al (1975), from the Canary Current upwelling region.

The velocities of both the coastal jet and the subsurface counter current off the northern part of Mozambique appeared to be larger than observed in other upwelling regions. This is specially so for the undercurrent which in other areas is reported by several authors to have a current speed of 5-20 cm/s.

In April (Fig. 5.38) the vertical geostrophical velocity distribution revealed a northward current at the surface on the seaward side of the coastal jet. MOOERS et al (1976) combined direct current observations and hydrographic data to find the absolute geostrophic velocity field in the upwelling region off Oregon. The zero isotach of his section off Depoe Bay makes a pronounced upward bend on the seaward side of the coastal jet. This might indicate that the counter current can reach the surface at the seaward side of the jet, as probably is the case in SECTION I in April (Fig. 5.38). This feature is not seen in the numerical models. A reason for this might be that the different models all deal with an ocean initially at rest and thus ommitting the effects of the more permanent ocean currents.

During cruises nos. 1 and 2 in September and November respectively, there seemed to be a retroflexion of the southward Mozambique Current off the southern part of Sofala Bank. The southward transport through SECTION IV (Figs. 5.10 and 5.18) appeared to be negligible during this time. The surface salinity distributions (Figs. 5.6 and 5.14) support the concept of a recirculation at about 21 °S. Water from the east feeds the Mozambique Current between 22°S and 25°S. In February and May there seem to be a significant southward transport through SECTION IV, but negligible through SECTION V in May.

The classical concept of the Agulhas Current as an extension of the Mozambique Current has been questioned by MENACHÉ (1963) who claims that the Mozambique Current did not penetrate into the area south of 25°S at all during October-November 1957. HARRIS (1972) from his analysis of the data from spring 1964 concludes that only about half of the transport passing SECTION V consisted of water carried by the Mozambique Current from the north. The other half was water which had flowed north up the west coast of Madagascar. LUTJEHARMS (1976) treated all available hydrographic data during the north-east monsoon season. His conclusion was that during this season only part of the surface flow of the Mozambique Current runs through the Mozambique Channel, with a large volume recurving at the southern mouth to flow northward in the middle of the Channel. He also found that at σ_t surface 26.8 situated of about 400-500 m, there was no continuous flow through the Mozambique Channel. The Mozambique Current below this depth would therefore derive all its water from the East Madagascar Current feeding the Mozambique Current at about 18°S.

From this it might be concluded that during most of the year a large proportion of the southward transport by the Mozambique Current does not pass the southern mouth of the Mozambique Channel, but recirculates northward further east in the Channel. This retroflexion seems to occur between 22° and 25°S and is probably weakest during the north-east monsoon season. This retrogression is followed by a feeding of the Mozambique Current by water from the east, which also appears in the investigations of HARRIS (1972) and LUTJEHARMS (1976). Further evidence of this transport is also given by GRÜNDLINGH (1977) from drift observations of a satellite-tracked buoy in August-October 1975, and he suggests an explanation in terms of a westward deflection of the East Madagascar Current.

Eddies were observed on several occasions. In the area off Angoche (SECTION II) in September (Fig. 5.8) there seemed to be a cyclonic eddy on the seaward side of the south-flowing Mozambique Current. An apparent eddy could also be seen in November (Fig. 5.16). In February (Fig. 5.27) and in April (Fig. 5.40), however, the dome shape of the isotherms might have been caused by an intensification of the northward current in the region nearest the coast, combined with local upwelling. HARRIS (1972) found a small cyclonic eddy in the same area in the spring. This eddy might be caused by a seamount slightly north of SECTION II at about N16°, E41°31' reaching up to 230 m. It also seems reasonable to believe in local small-scale eddies over Paisley Seamount and St. Lazarus Bank further north. The grid of stations was not dense enough to locate such eddies but some indications were observed in the surface distribution of temperature and salinity over St. Lazarus Bank in November.

Eddies also seem to be a characteristic feature of SECTION V, as seen in Fig. 5.11 from September and in Fig. 5.30 from March. The cyclonic eddy seen also appeared in the data of LUTJEHARMS (1976) and GRÜNDLINGH (1977) and seems to be topographically induced. The surface salinity distribution in March (Fig. 5.25) and in May (Fig. 5.37) both indicate a cyclonic eddy in Delagoa Bay off Maputo. This eddy was also found in June 1961 by ORREN (1963).

The main features of the coastal hydrography off Mozambique can be summarized as follows:

- Along the northern coast south to about 16°S coastal up-welling occurs, resulting in a southward coastal jet and a northward counter current during the north-east monsoon season.

- A retroflexion of the southward Mozambique Current occurs between 22° and 25°S. This retrogression seems to be weakest during the north-east monsoon season and is followed by a feeding of the Mozambique Current with water from the East Madagascar Current.

Semi-permanent cyclonic topographically-induced eddies seem to occur off Angoche and in Delagoa Bay. A probably topographic eddy is also situated over the Boa-Paz Bank.

5.7 Tables and figures

Table 5.1. Frequency distribution of wind direction Aug. 1977 - June 1978 (Number of observations within each sector. C = calm).

Pemba									
	C	N	NE	E	SE	S	SW	W	NW
Aug									
Sep									
Oct									
Nov	1	0	10	53	13	4	3	3	1
Dec	1	6	46	18	12	0	0	8	0
Jan	6	23	18	28	1	2	0	5	4
Feb	10	16	13	29	1	0	3	6	3
Mar	14	2	8	17	14	14	9	12	1
Apr	14	0	3	12	17	18	18	6	2
May	2	0	0	0	12	57	14	7	0
Jun	0	0	0	0	10	52	20	7	0

Lumbo									
	C	N	NE	E	SE	S	SW	W	NW
Aug	16	1	2	13	6	35	20	0	0
Sep	7	2	12	35	13	12	9	0	0
Oct	5	2	16	18	8	14	4	0	0
Nov	3	9	13	35	14	12	1	1	0
Dec	21	4	20	36	7	2	1	0	1
Jan	19	10	25	20	7	2	0	2	6
Feb	29	6	16	19	4	2	0	3	1
Mar	33	10	9	15	10	4	2	6	0
Apr	34	3	1	9	10	13	12	8	0
May	30	0	0	1	6	34	17	5	0
Jun	19	0	0	0	5	26	35	4	0

Quelimane									
	C	N	NE	E	SE	S	SW	W	NW
Aug	18	6	14	22	15	6	5	1	0
Sep	7	8	25	35	10	2	1	0	1
Oct	5	7	16	46	17	0	0	0	1
Nov	8	11	17	41	7	2	2	0	1
Des	8	17	26	19	9	1	3	2	5
Jan	10	10	11	17	15	17	6	2	4
Feb	14	11	13	15	12	5	9	2	2
Mar	17	10	8	18	14	9	3	9	2
Apr	21	11	4	16	11	13	10	4	0
May	31	6	2	19	15	4	9	3	3
Jun	12	3	2	4	22	20	22	5	0

Beira									
	C	N	NE	E	SE	S	SW	W	NW
Aug	1	4	9	12	24	21	12	7	1
Sep	1	2	7	23	29	17	2	6	1
Oct	1	1	6	28	38	11	4	2	1
Nov	0	7	9	25	26	13	4	2	2
Des	0	3	14	24	27	13	5	6	1
Jan	3	2	10	9	23	24	3	17	1
Feb	1	2	7	9	18	23	8	10	4
Mar	0	5	6	9	21	29	16	6	1
Apr	1	4	6	9	13	24	14	14	5
May	2	8	6	13	20	17	5	9	13
Jun	2	3	4	4	8	20	21	26	2

Vilanculos									
	C	N	NE	E	SE	S	SW	W	NW
Aug	20	10	2	8	10	24	13	3	3
Sep	8	9	21	29	8	13	2	0	0
Oct	7	20	31	4	18	12	0	1	0
Nov	2	25	8	22	13	18	0	0	1
Dec	5	25	9	17	13	23	1	0	0
Jan	18	11	7	16	9	32	0	0	0
Feb	9	12	8	18	6	26	3	1	1
Mar	10	10	6	15	14	33	0	5	0
Apr	24	6	3	10	6	31	3	7	0
May	39	10	7	11	3	9	3	8	2
Jun	16	2	0	10	3	42	5	12	0

Maputo									
	C	N	NE	E	SE	S	SW	W	NW
Aug	10	12	13	10	6	15	14	3	9
Sep	7	11	17	25	4	13	9	1	3
Oct	5	13	23	24	6	15	3	0	4
Nov	1	15	11	29	11	20	3	0	0
Dec	6	8	31	15	9	18	4	0	2
Jan	9	4	13	12	8	31	13	0	3
Feb	9	7	14	11	6	18	15	0	4
Mar	19	7	11	24	7	10	10	1	4
Apr	9	8	14	5	3	15	15	0	10
May	12	26	7	7	6	10	13	4	7
Jun	15	8	5	10	8	6	22	11	5

Fig. 5.1. Average freshwater runoff from six localities (Fig. 2.2.).

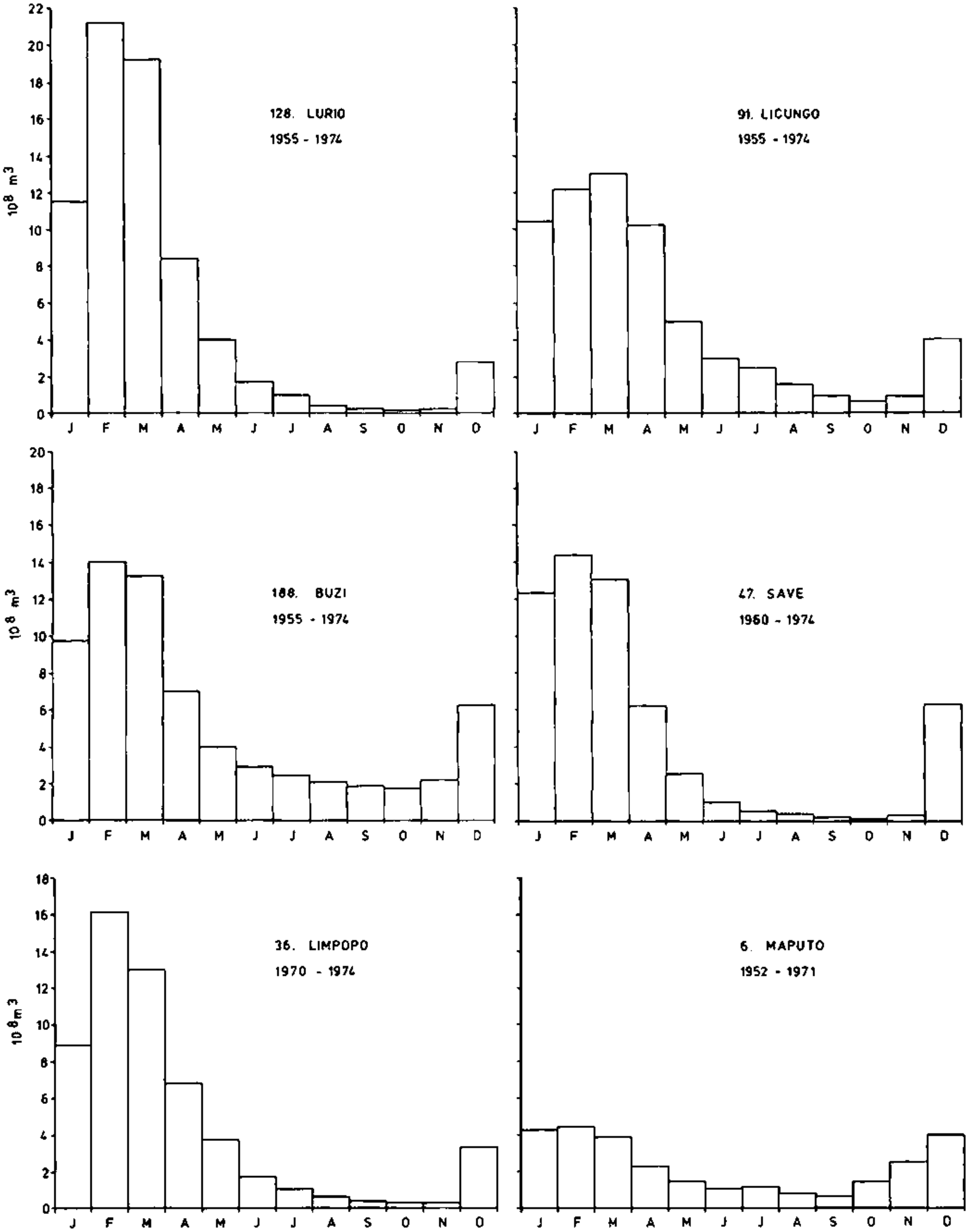


Fig. 5.2. SECTION V - 23 May 1978.

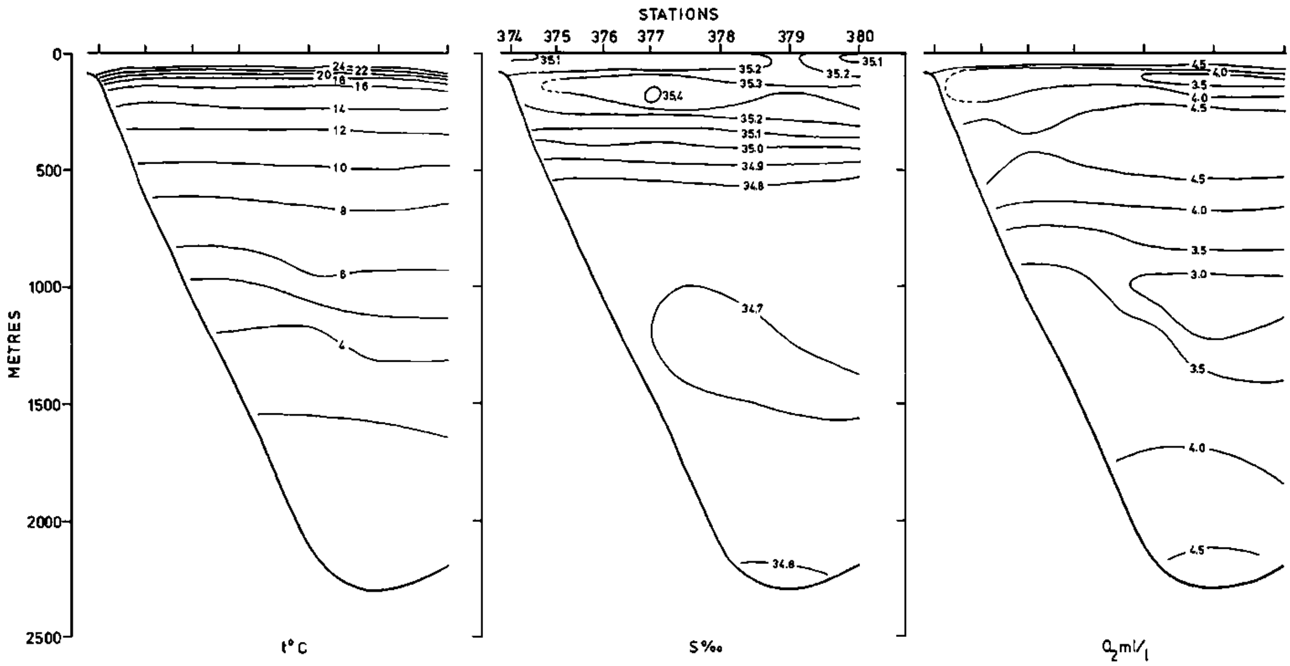


Fig. 5.4. σ_t - t relation at SECTION V - 23 May 1978

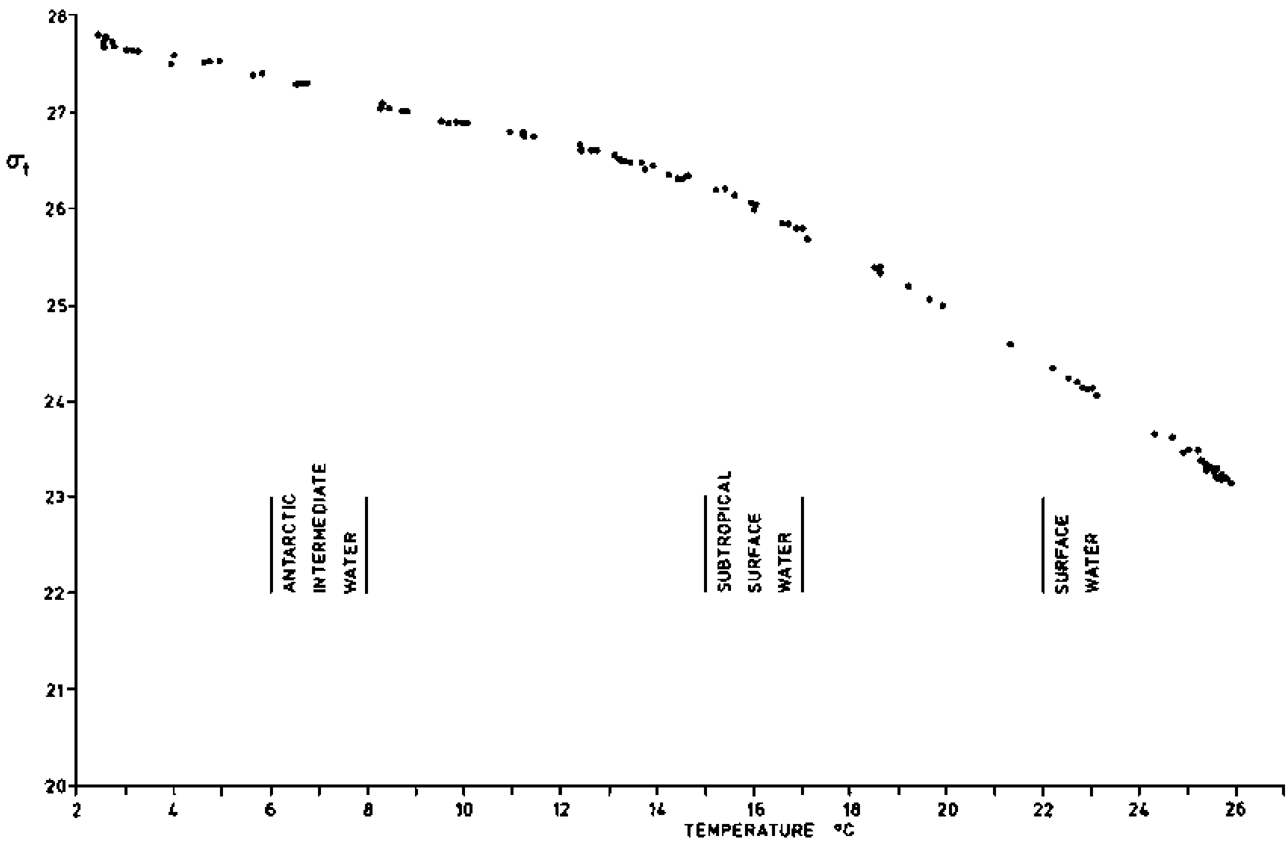


Fig. 5.3. Temperature - salinity relation at SECTION V - 23 May 1978.

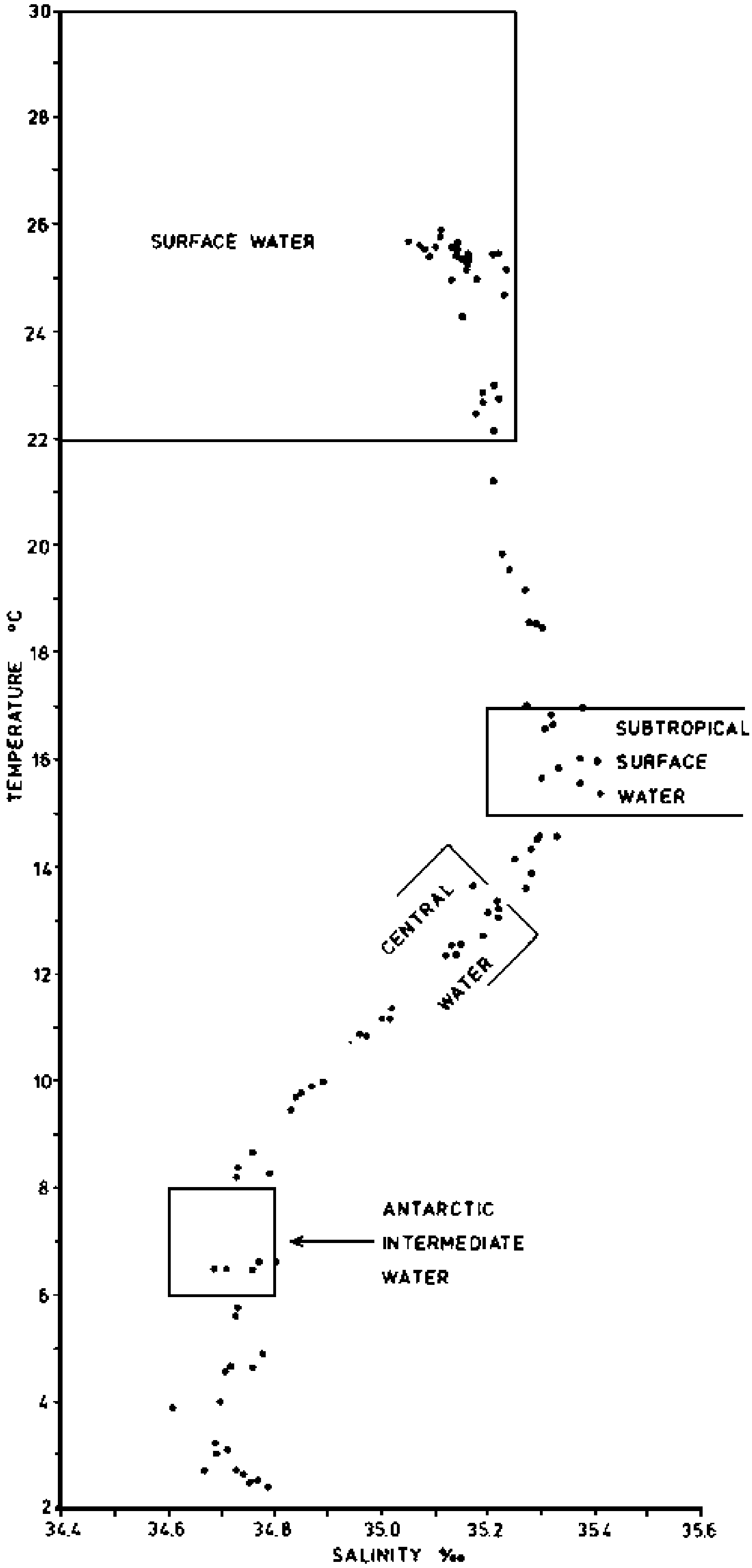


Fig. 5.5. Surface temperature - September 1977.

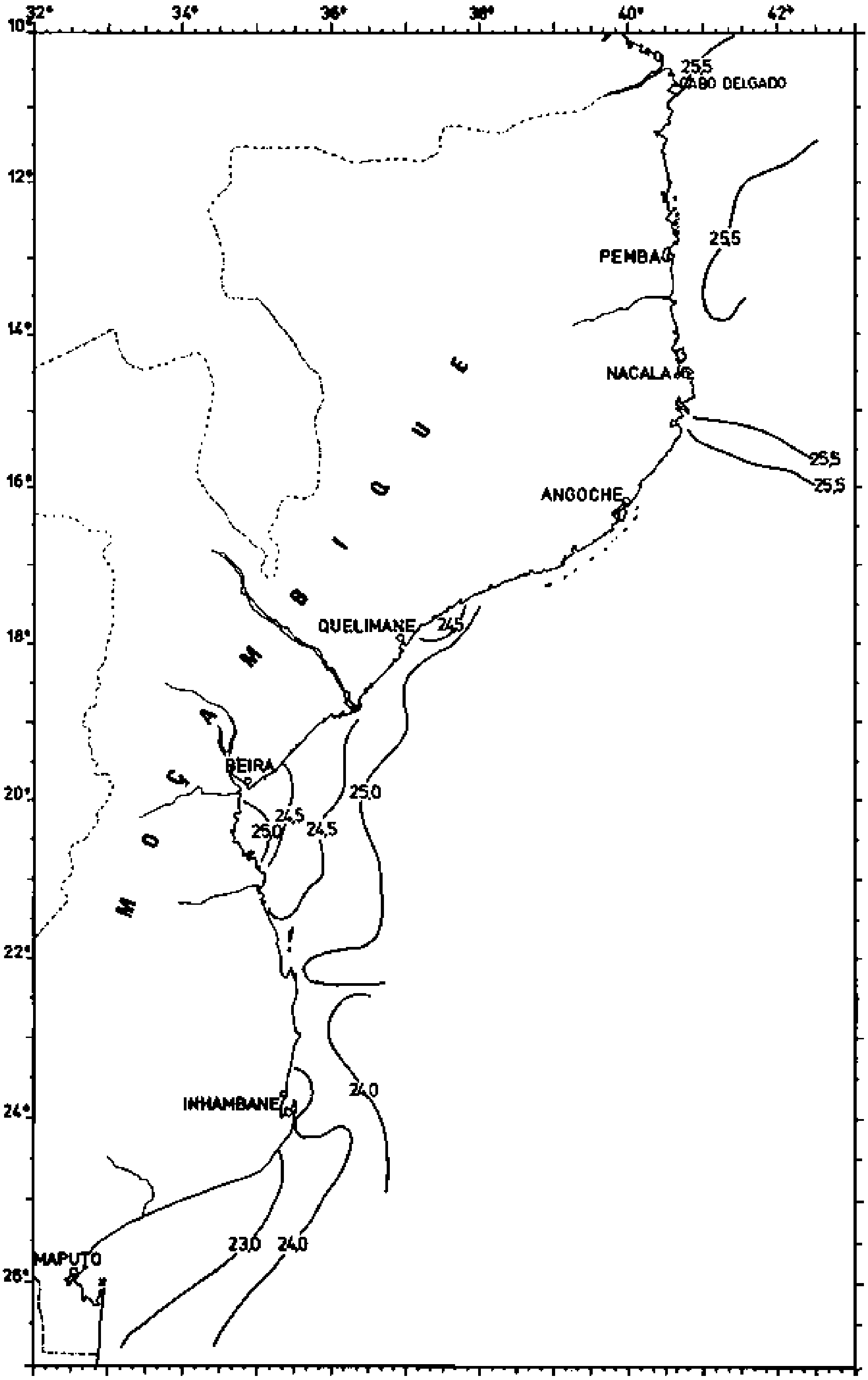


Fig. 5.6. Surface salinity - September 1977.

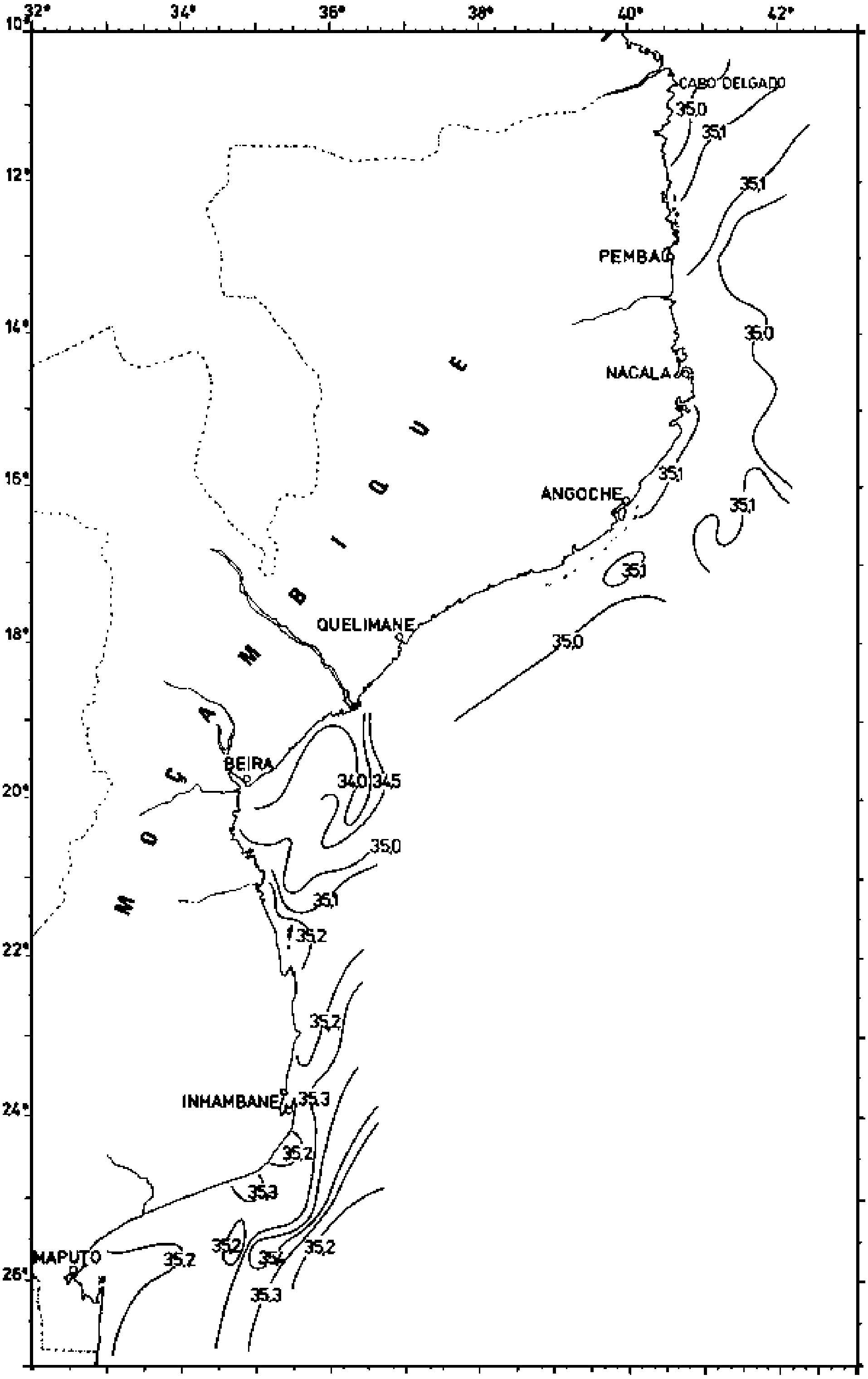


Fig. 5.7. SECTION I - 1 September 1977.

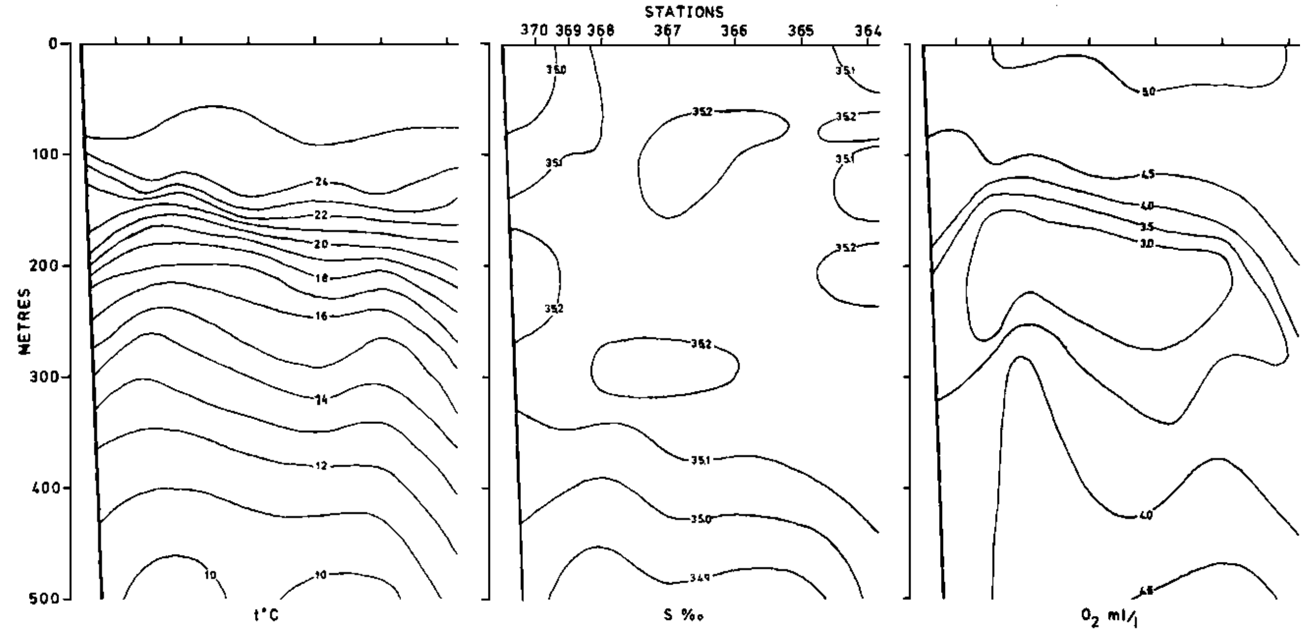


Fig. 5.8. SECTION II - 8 September 1977.

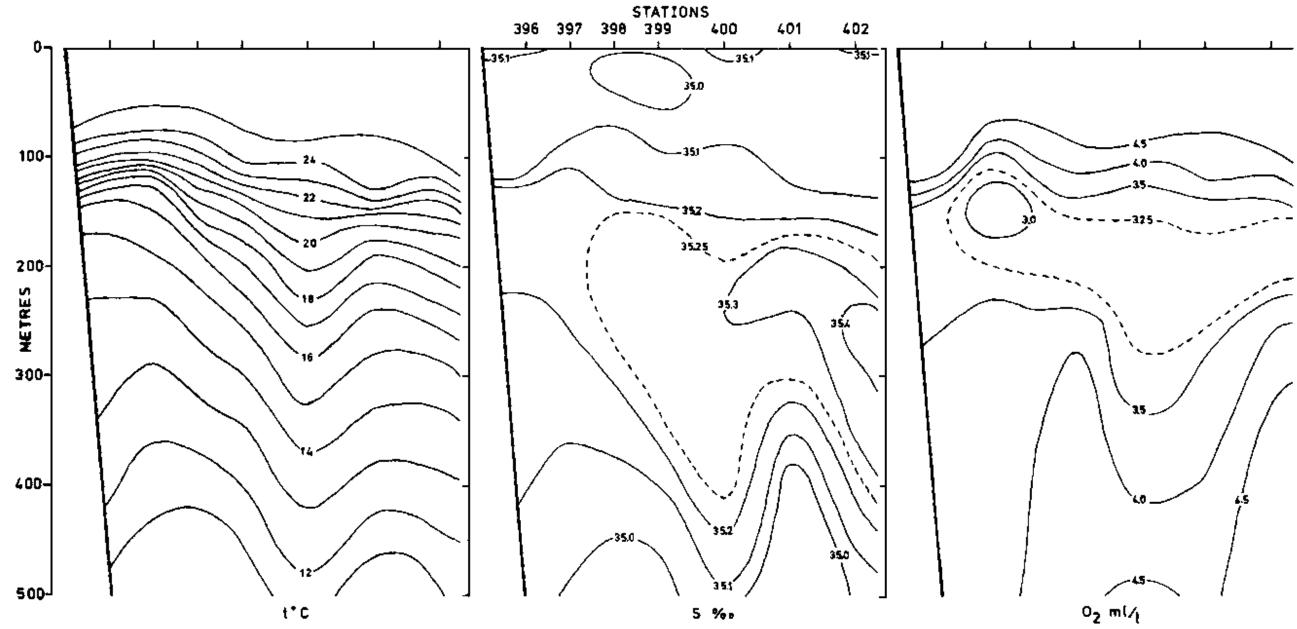


Fig. 5.9. SECTION III - 18 September 1977.

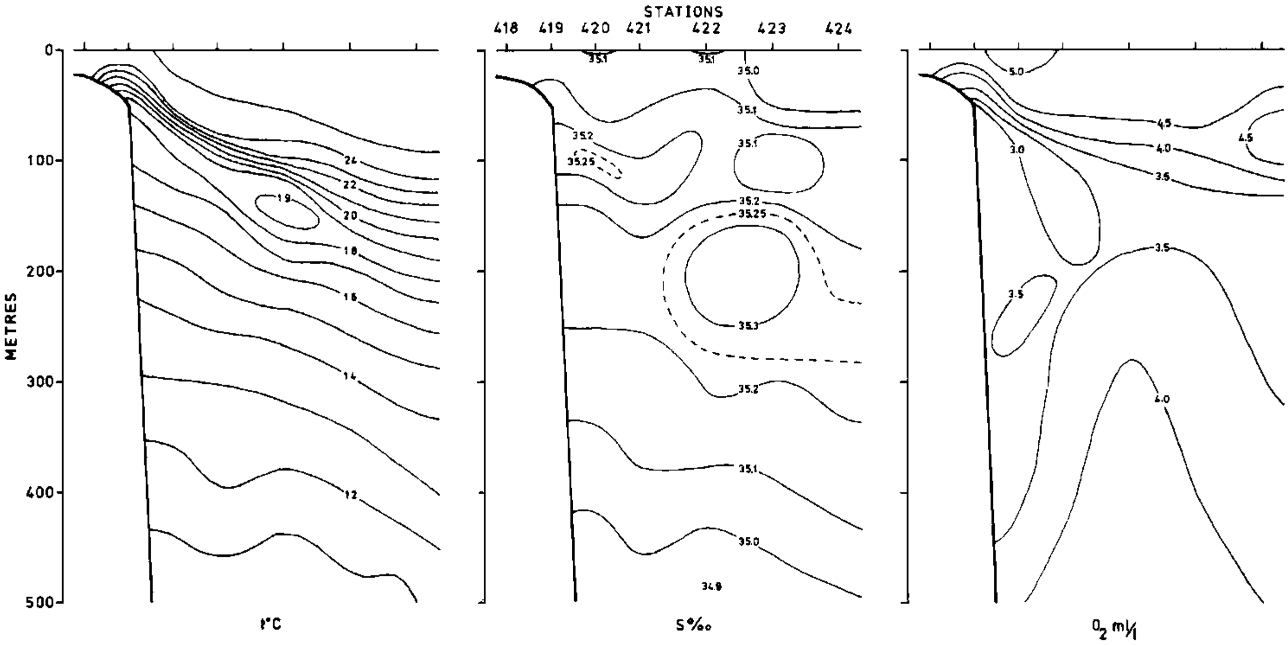


Fig. 5.10. SECTION IV - 22 September 1977.

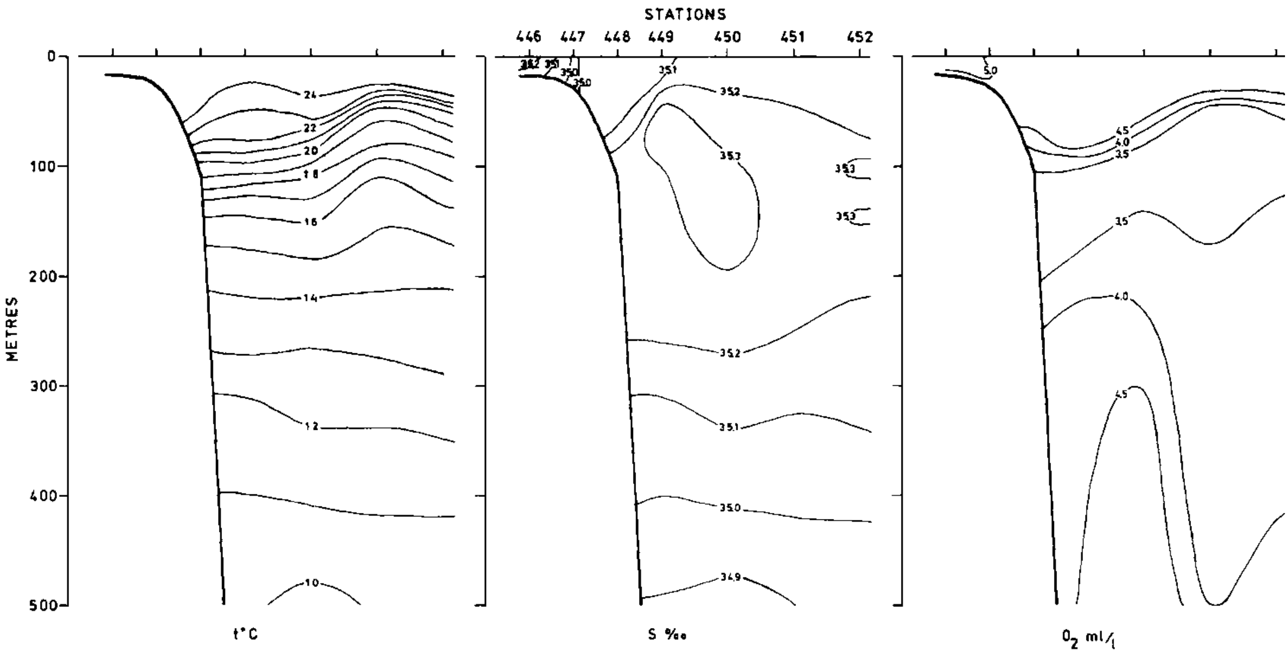


Fig. 5.11. SECTION V - 25. September 1977.

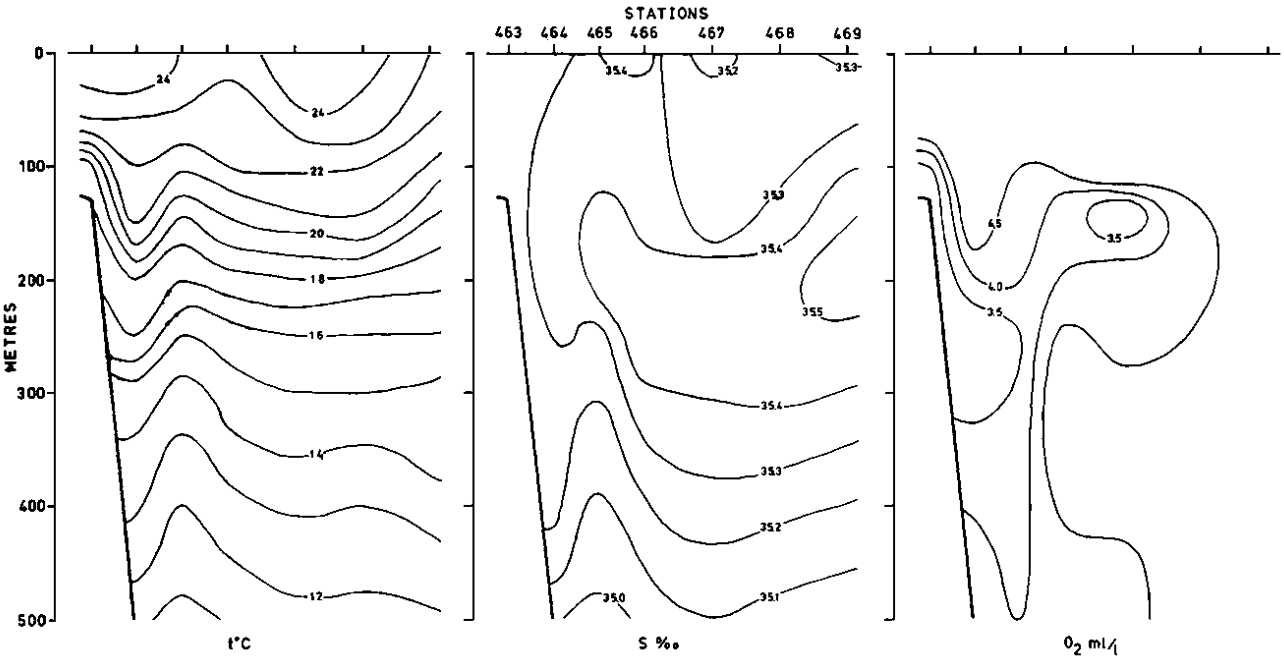


Fig. 5.12. SECTION VI - 27. September 1977.

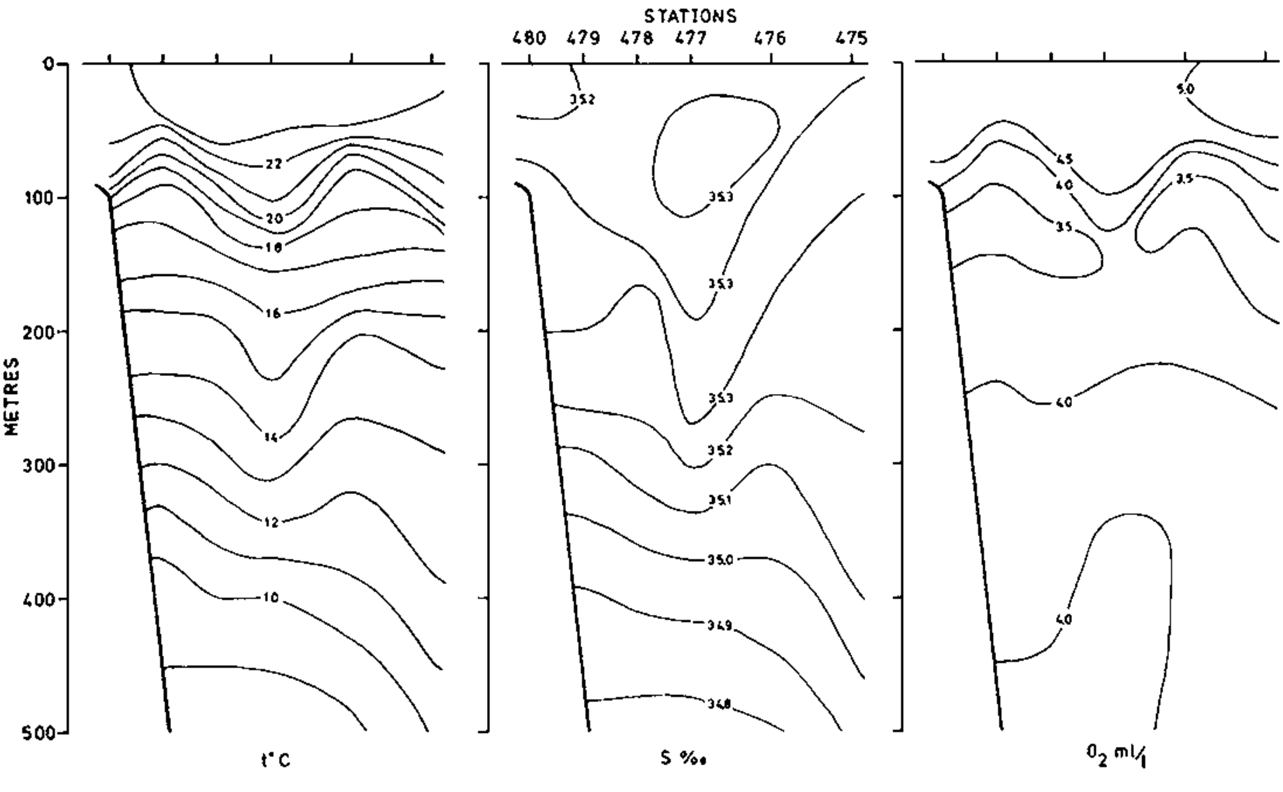


Fig. 5.13. Surface temperature - November 1977.

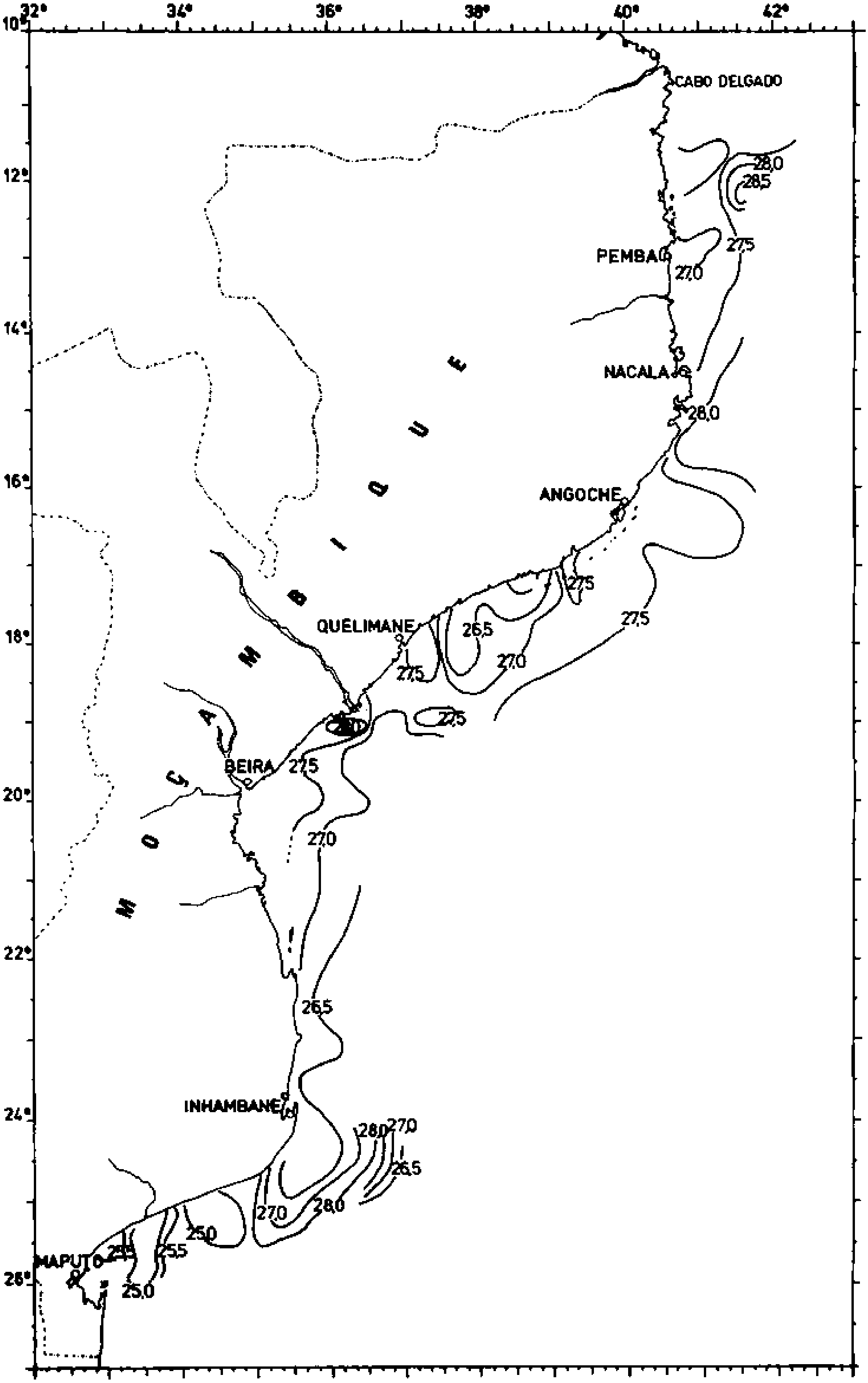


Fig. 5.14. Surface salinity - November 1977.

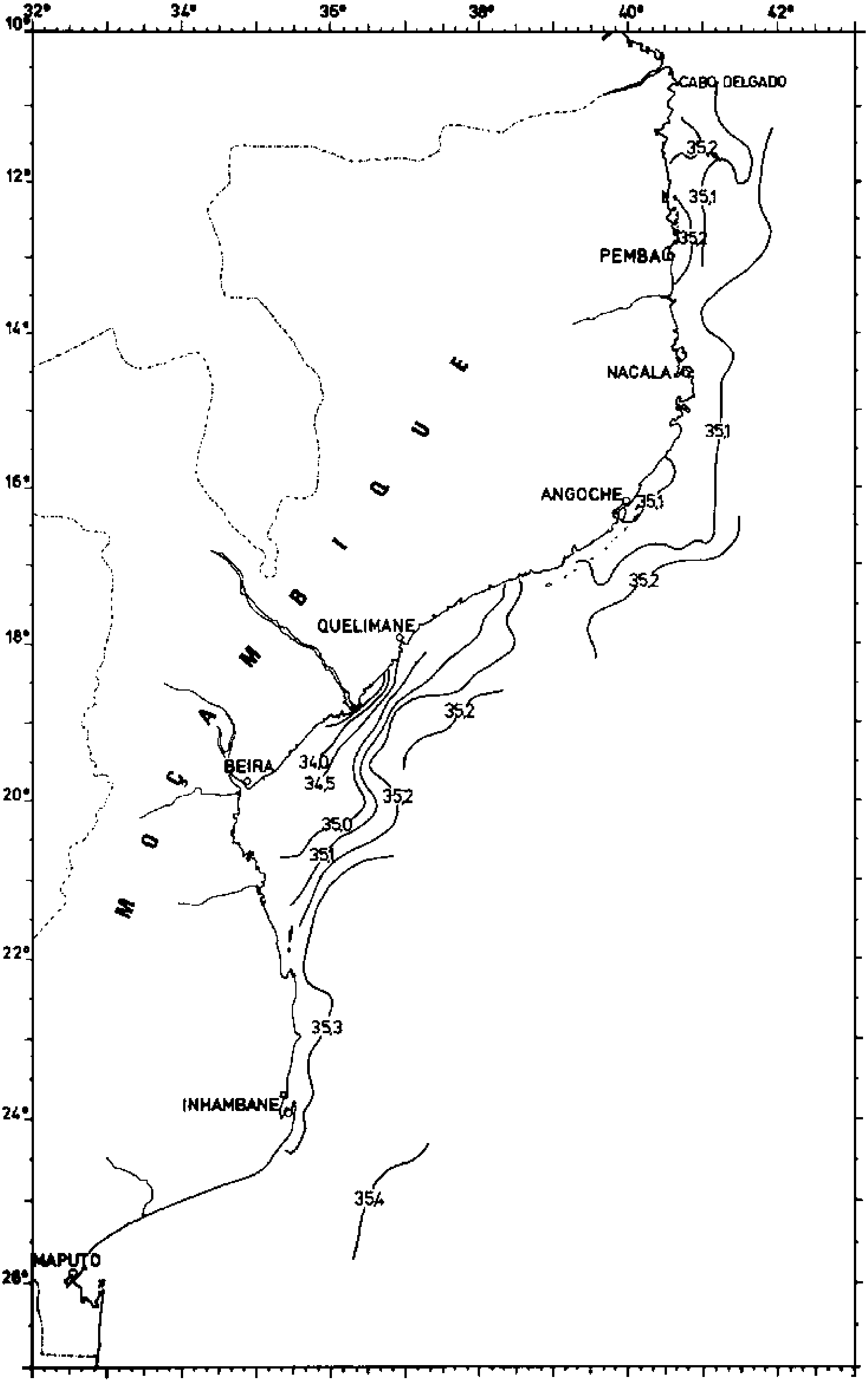


Fig. 5.15. SECTION I - 1 November 1977.

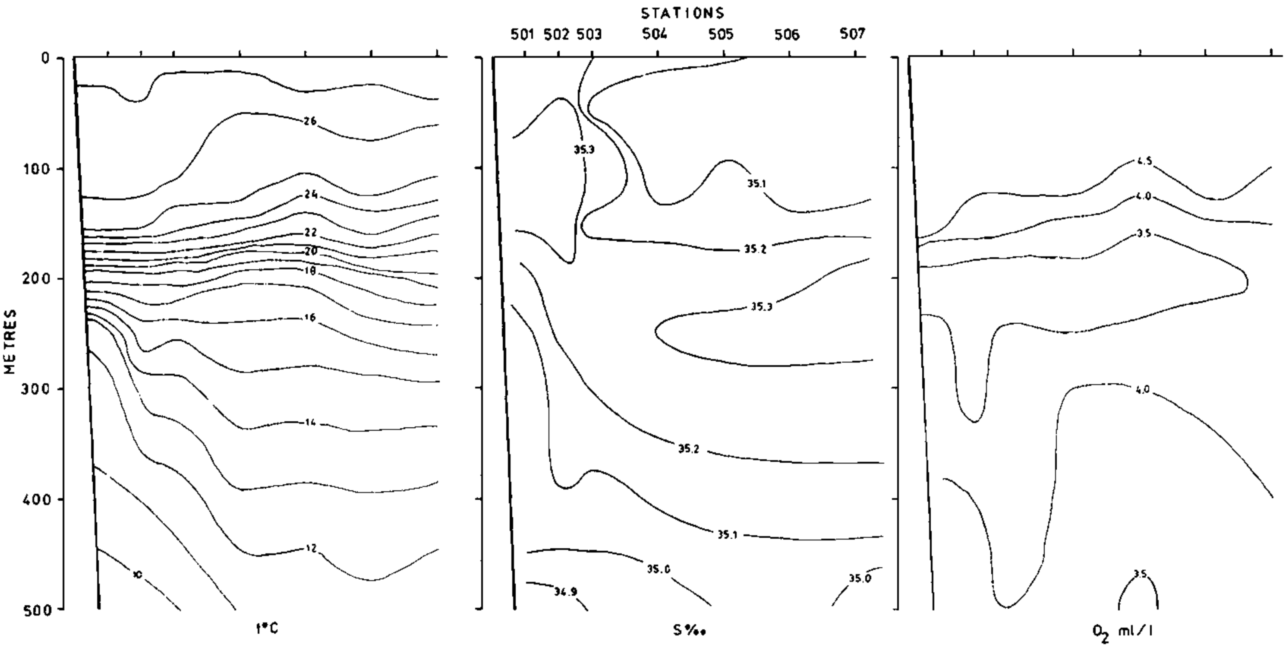


Fig. 5.16. SECTION II - 12 November 1977.

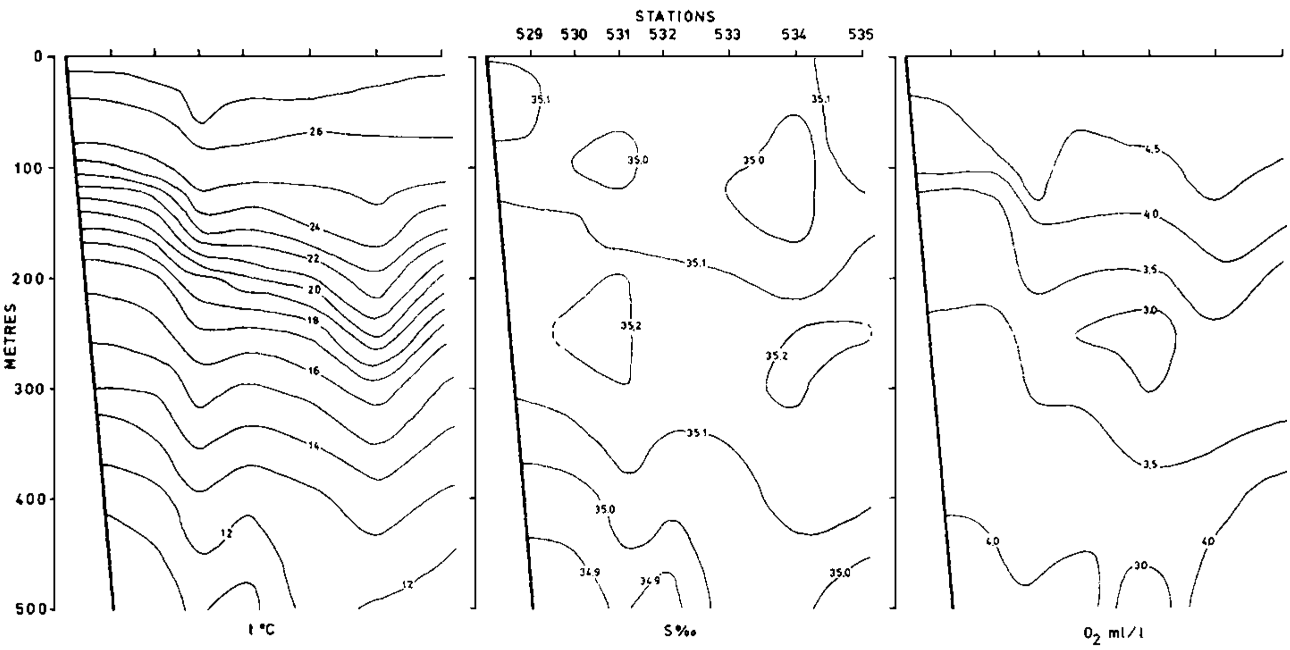


Fig. 5.17. SECTION III - 15 November 1977.

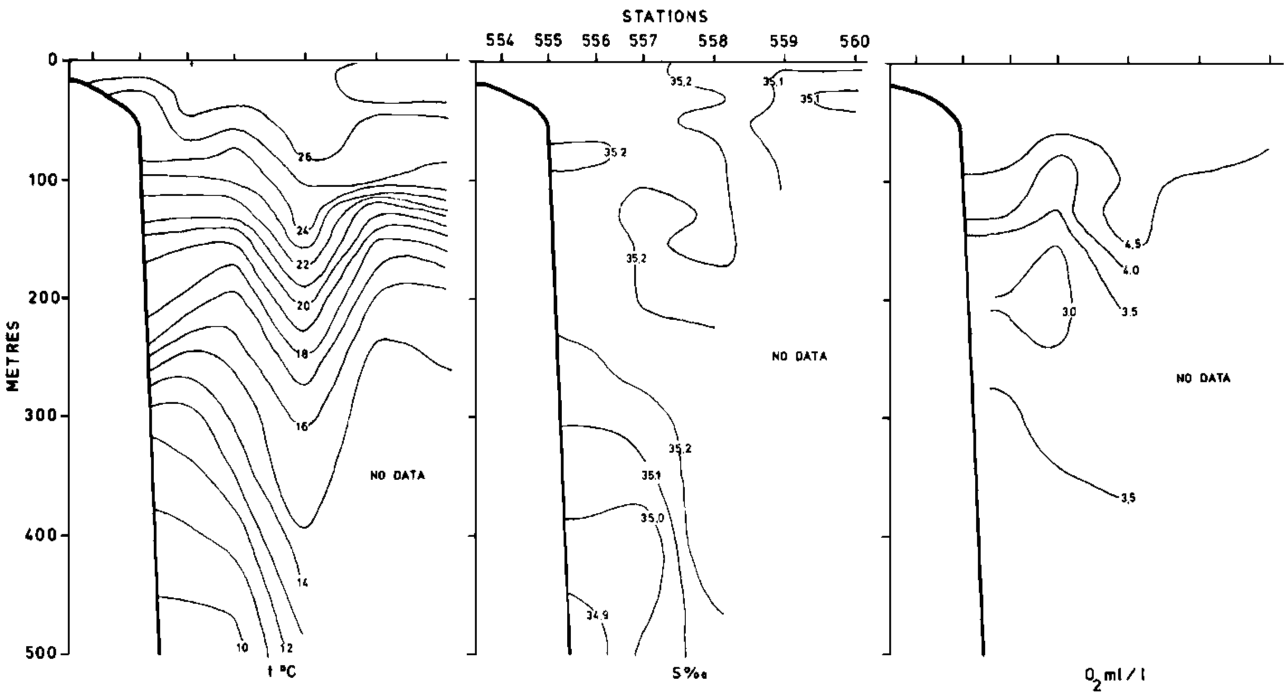


Fig. 5.18. SECTION IV - 26 November 1977.

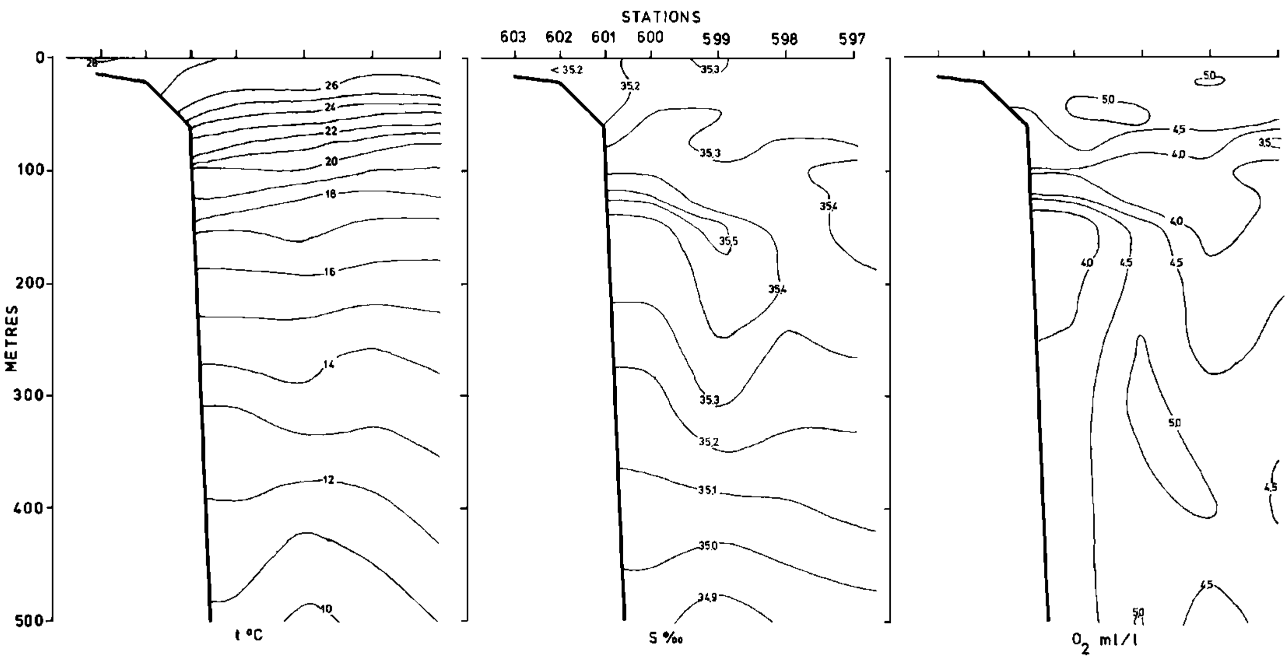


Fig. 5.19. SECTION V - 29. November 1977.

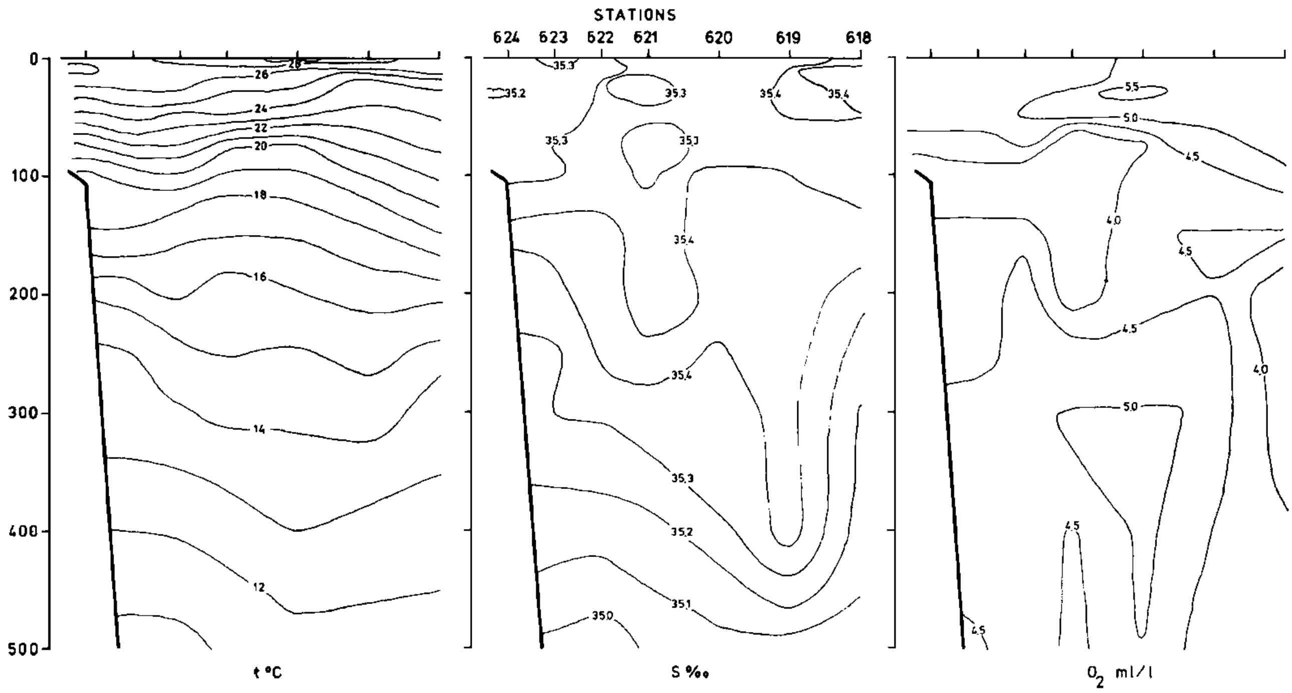


Fig. 5.20. Zambezi section 1-22 November 1977.

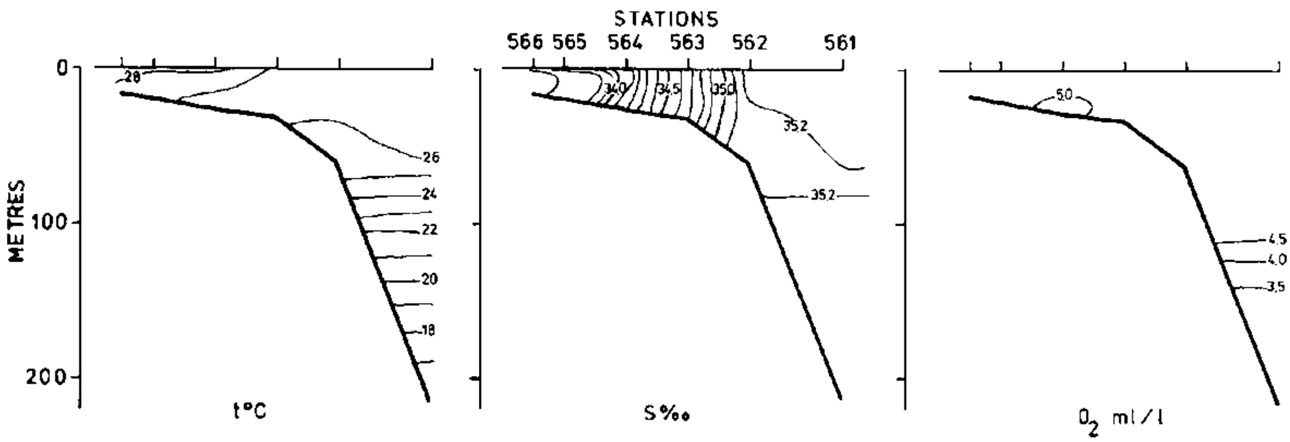


Fig. 5.21. Zambezi section 2-22 November 1977.

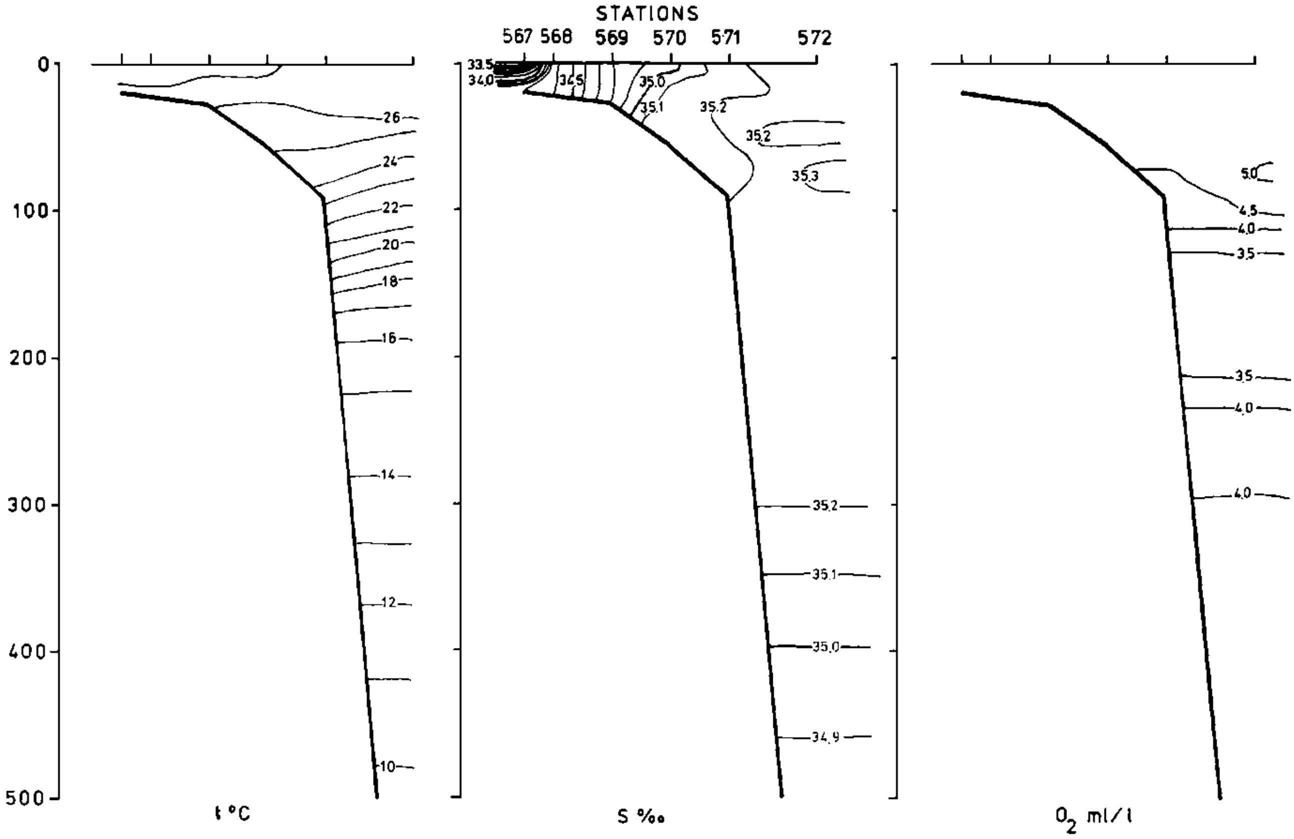


Fig. 5.22. Zambezi section 3-23 November 1977.

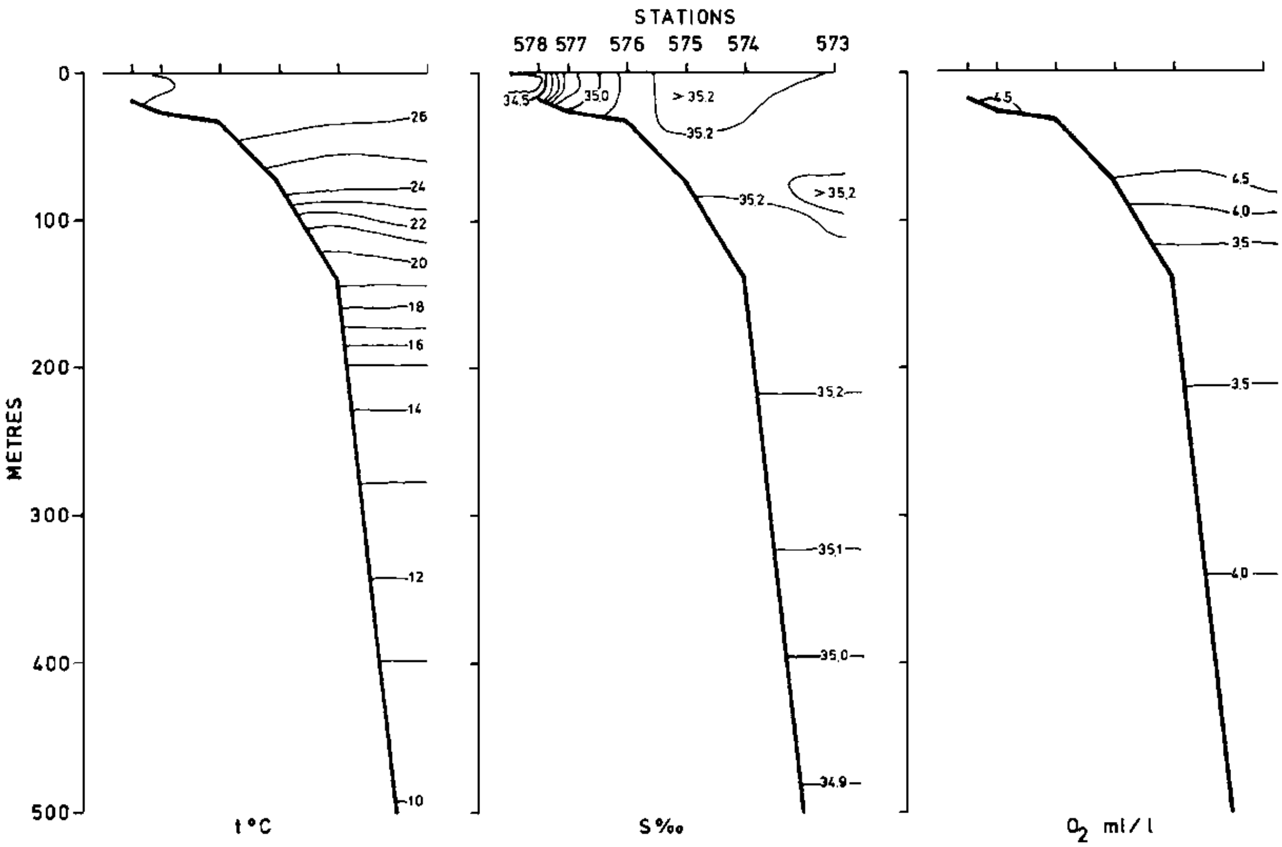


Fig. 5.23. Zambezi section 4-23 November 1977.

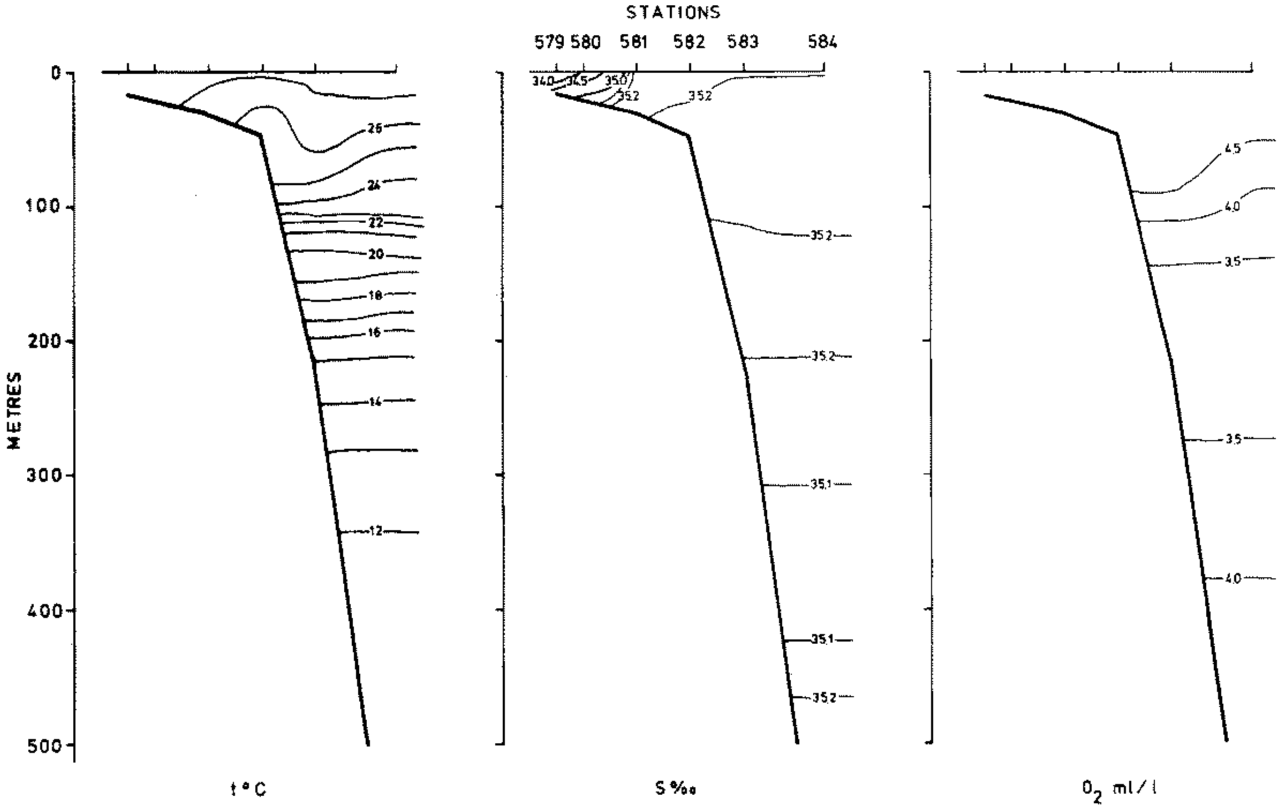


Fig. 5.24. Surface temperature - February - March 1978.

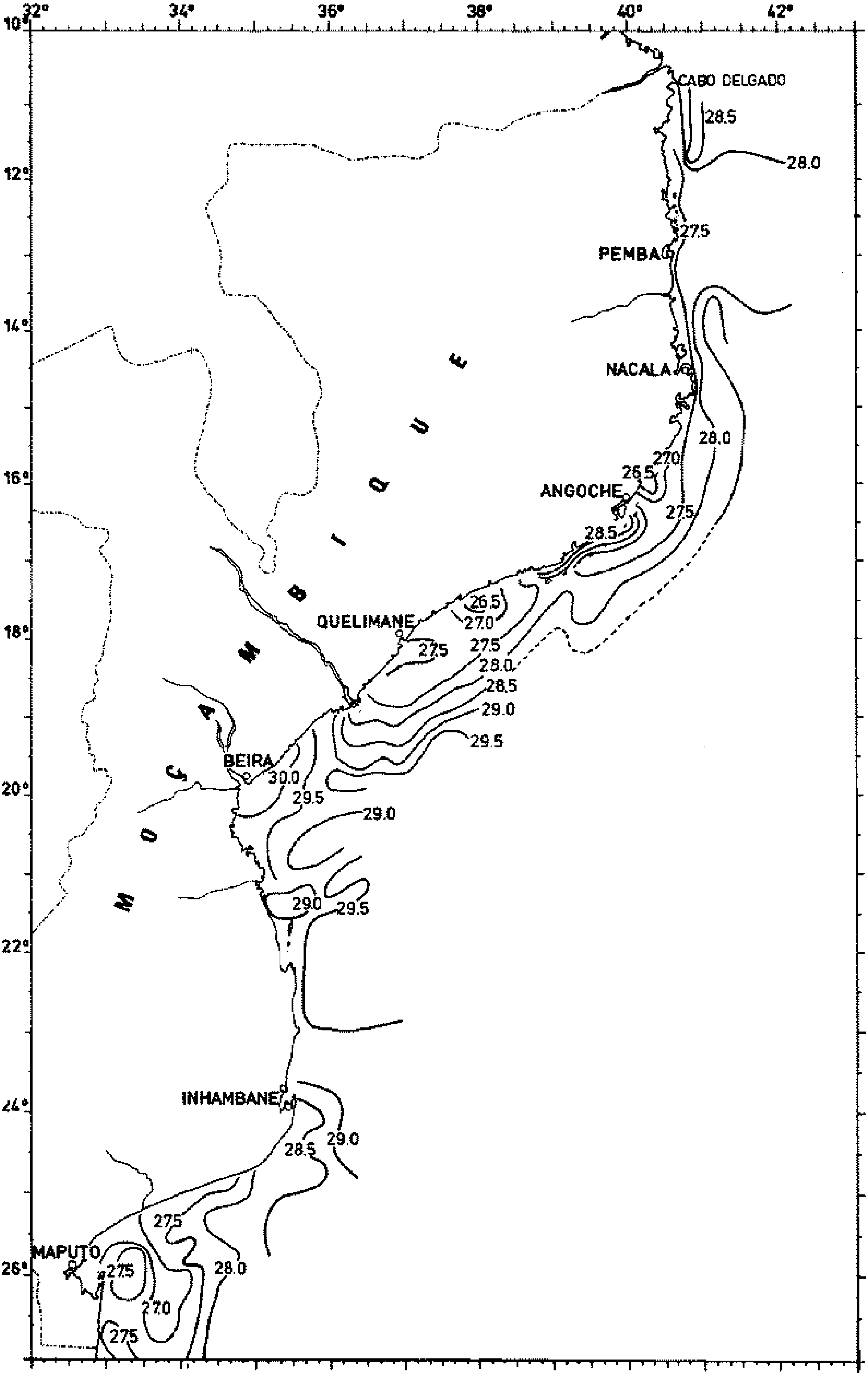


Fig. 5.25. Surface salinity - February - March 1978.

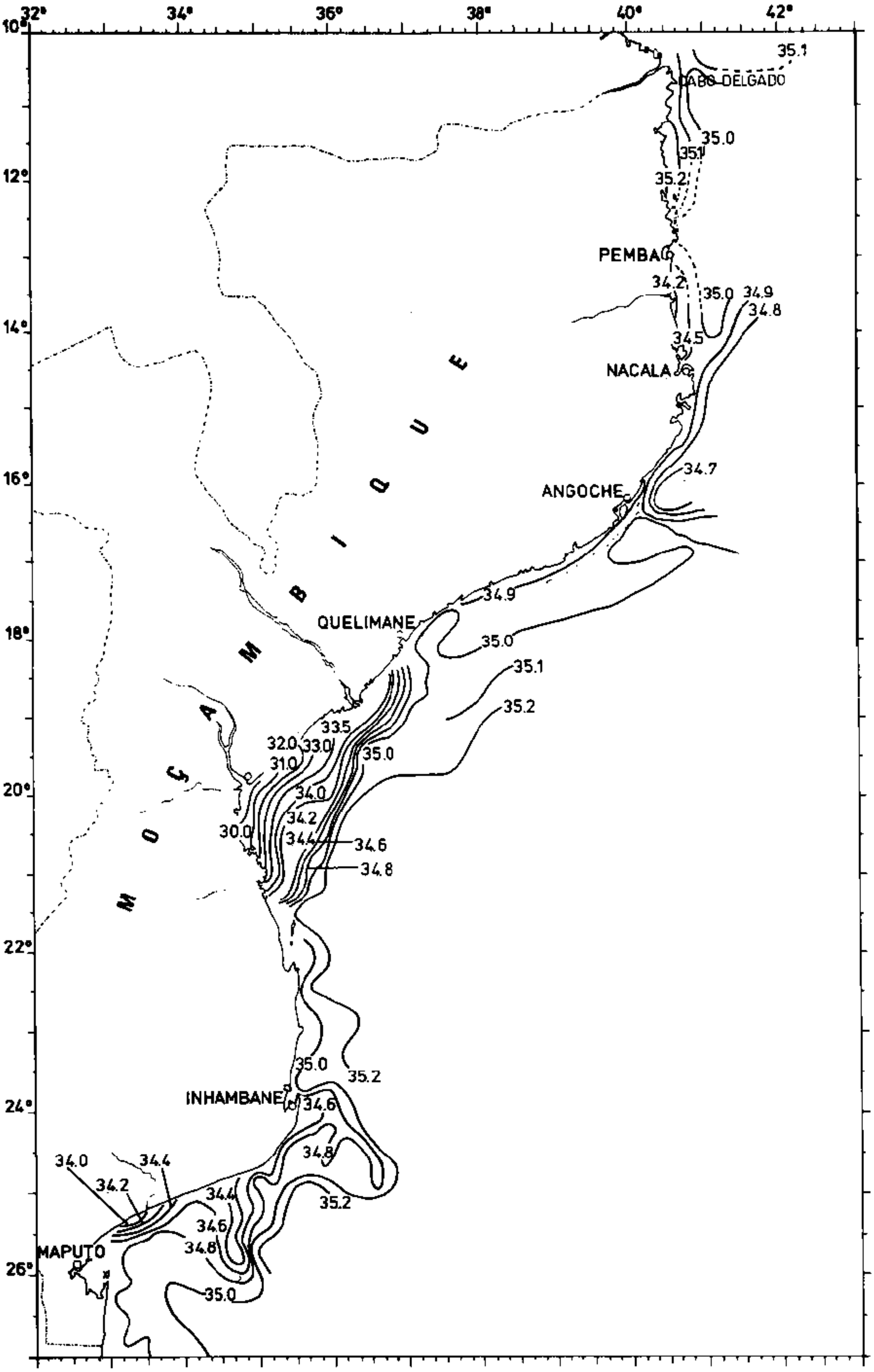


Fig. 5.26. SECTION I - 31 January 1978.

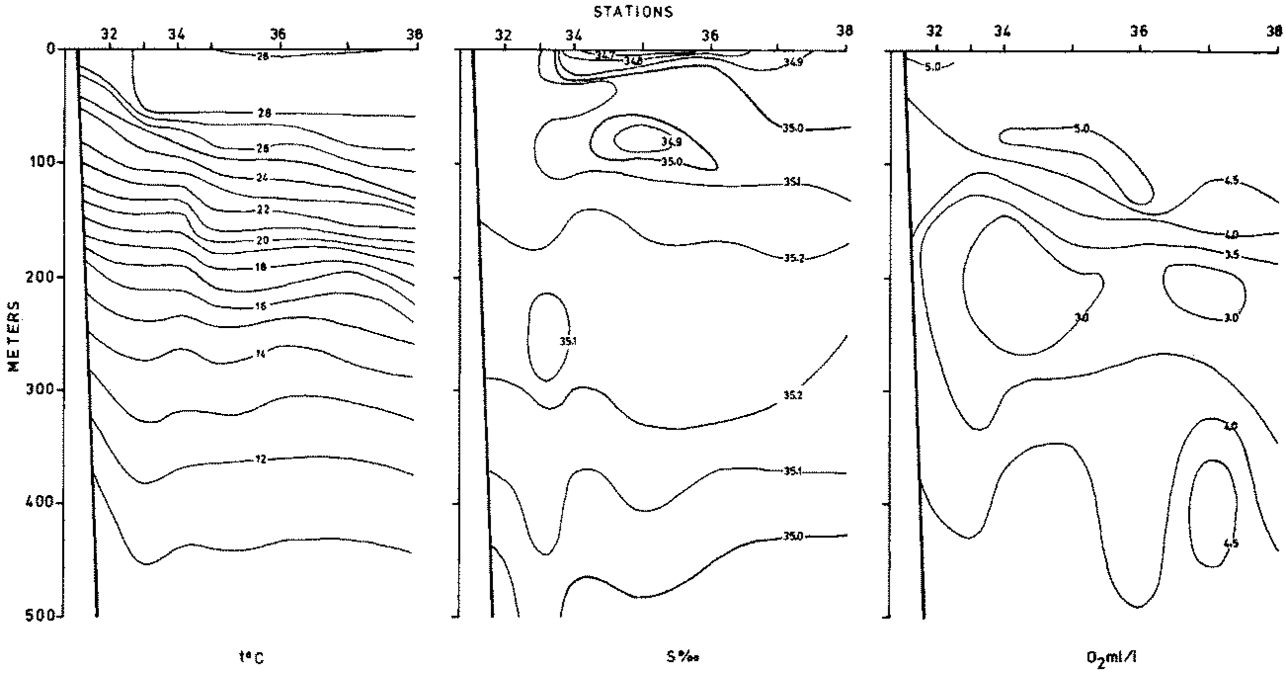


Fig. 5.27. SECTION II - 14 February 1978.

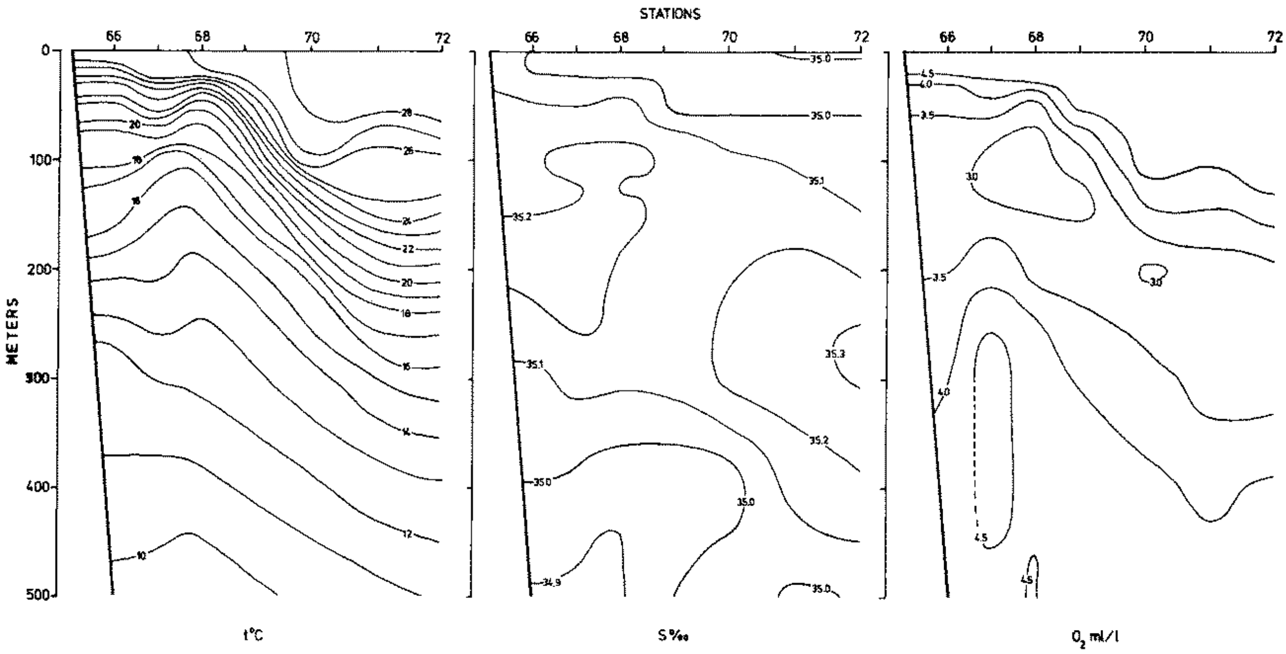


Fig. 5.28. SECTION III - 16 February 1978.

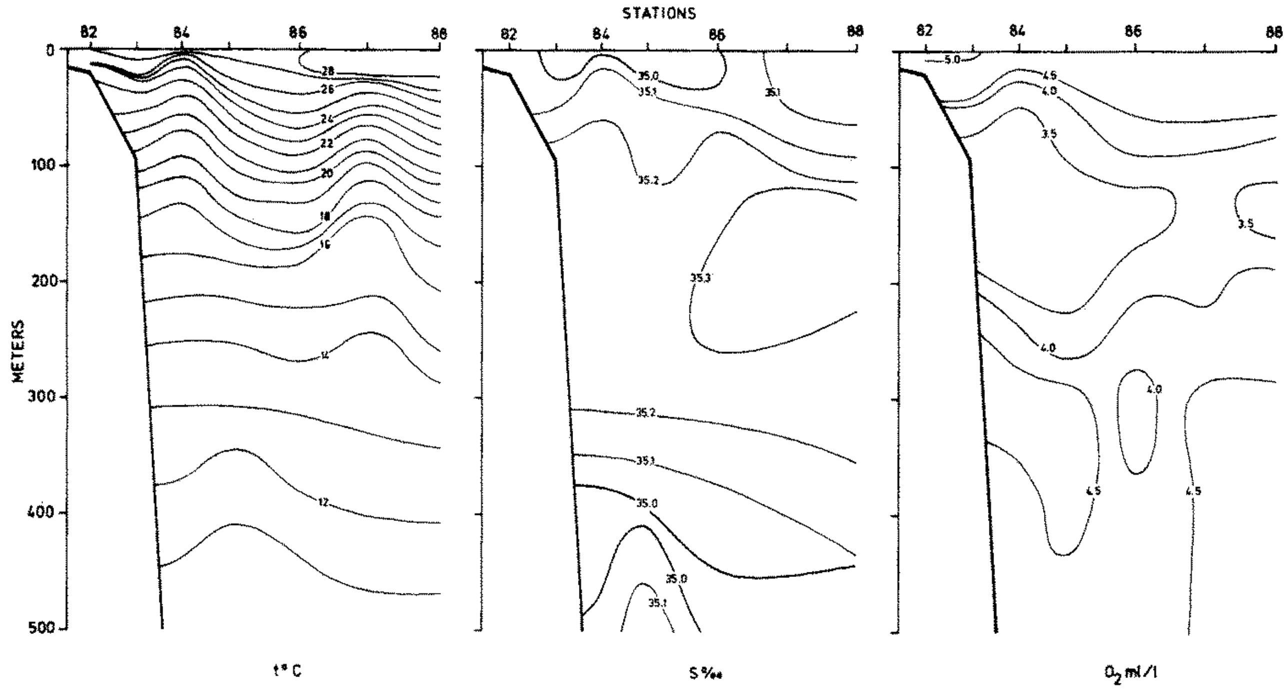


Fig. 5.29. SECTION IV - 23 February 1978.

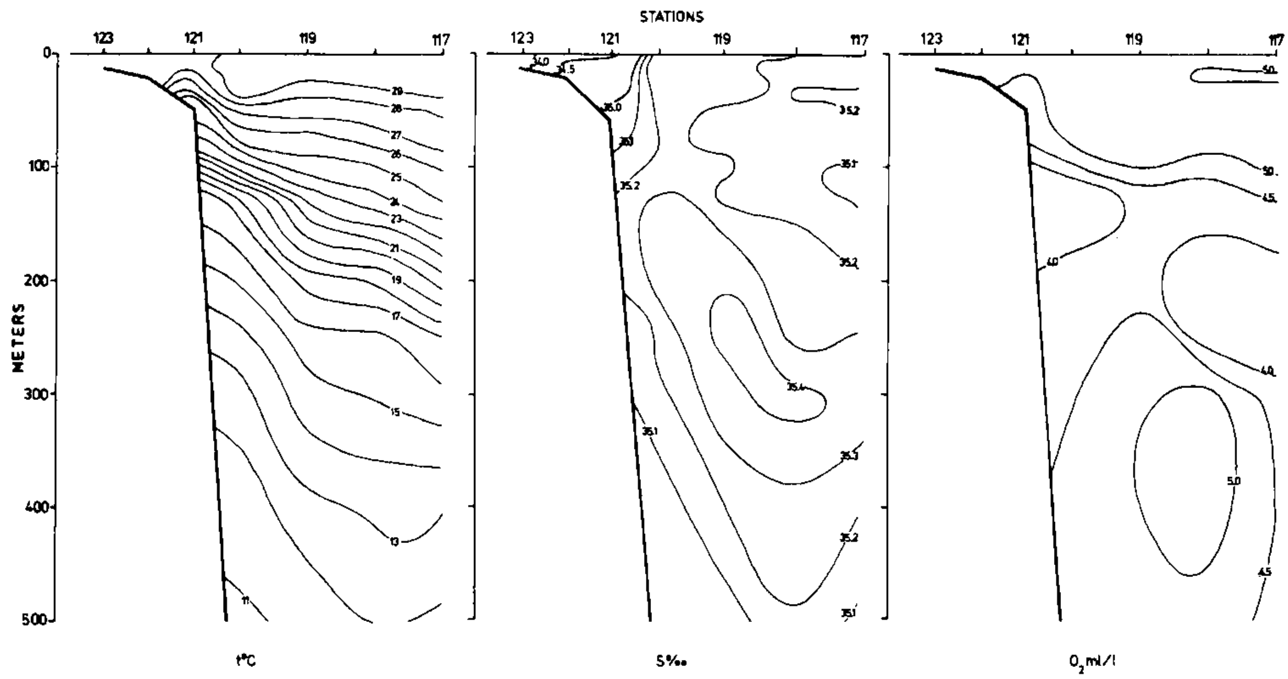


Fig. 5.30. SECTION V - 7 March 1978

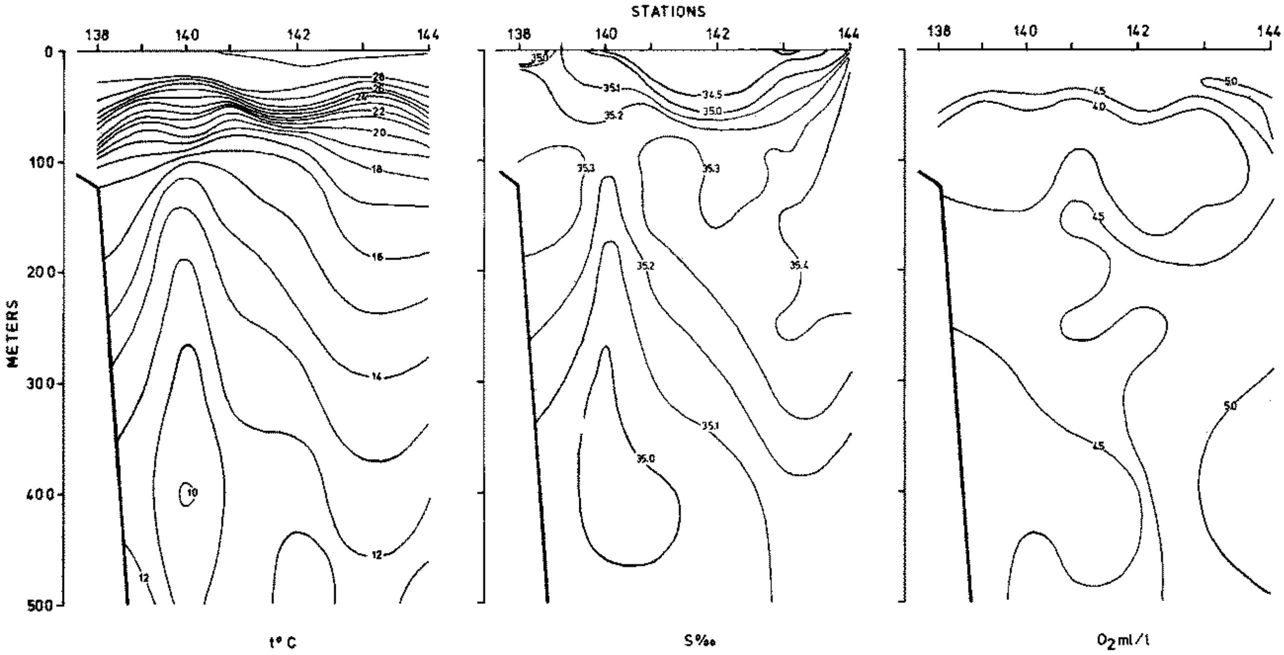


Fig. 5.31. SECTION VI - 13 March 1978.

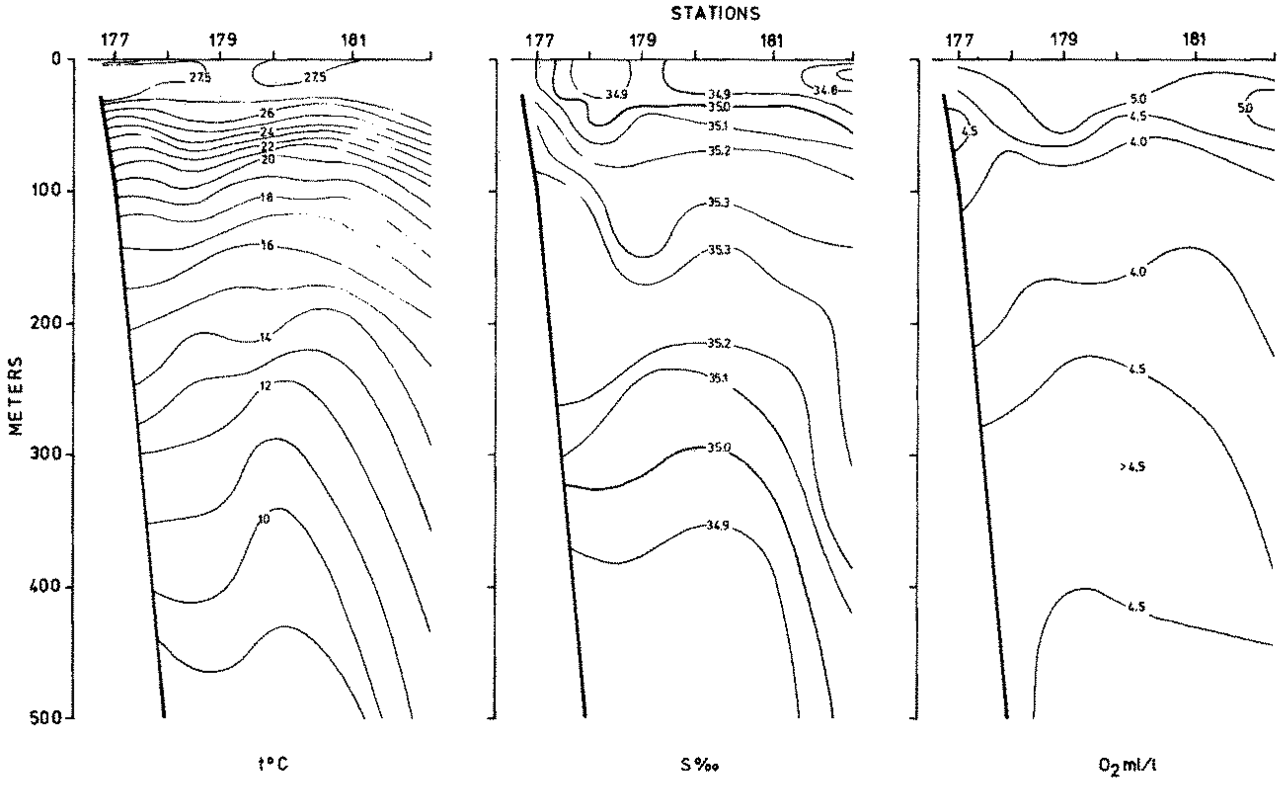


Fig. 5.32. Zambezi section 1-26 January 1978.

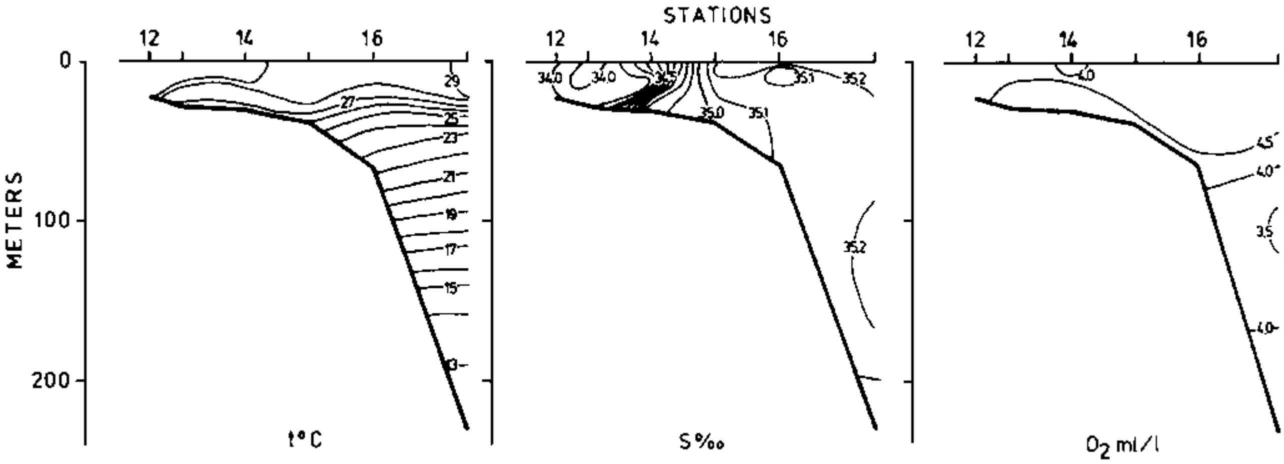


Fig. 5.33. Zambezi section 2-26 January 1978.

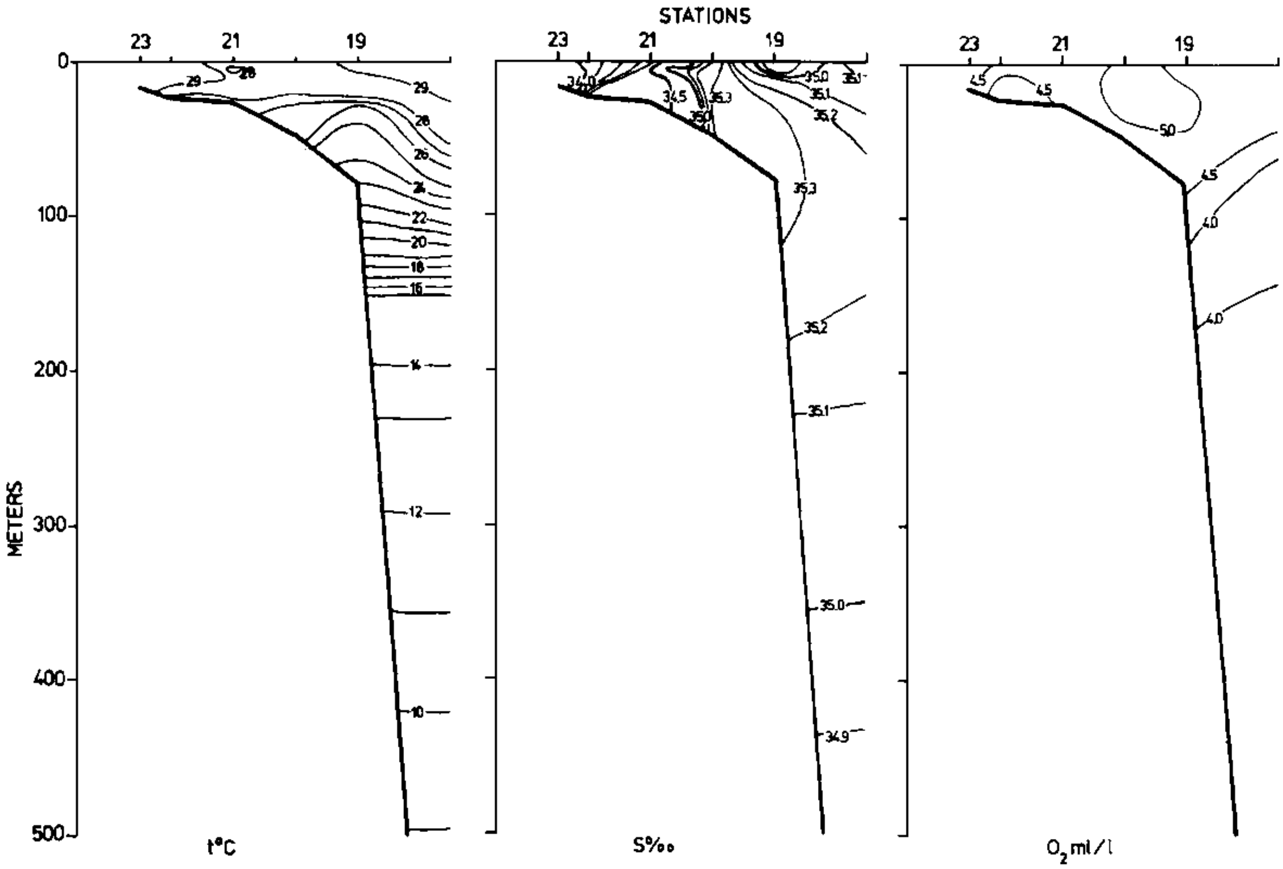


Fig. 5.34. Zambezi section 3 - 23 January 1978.

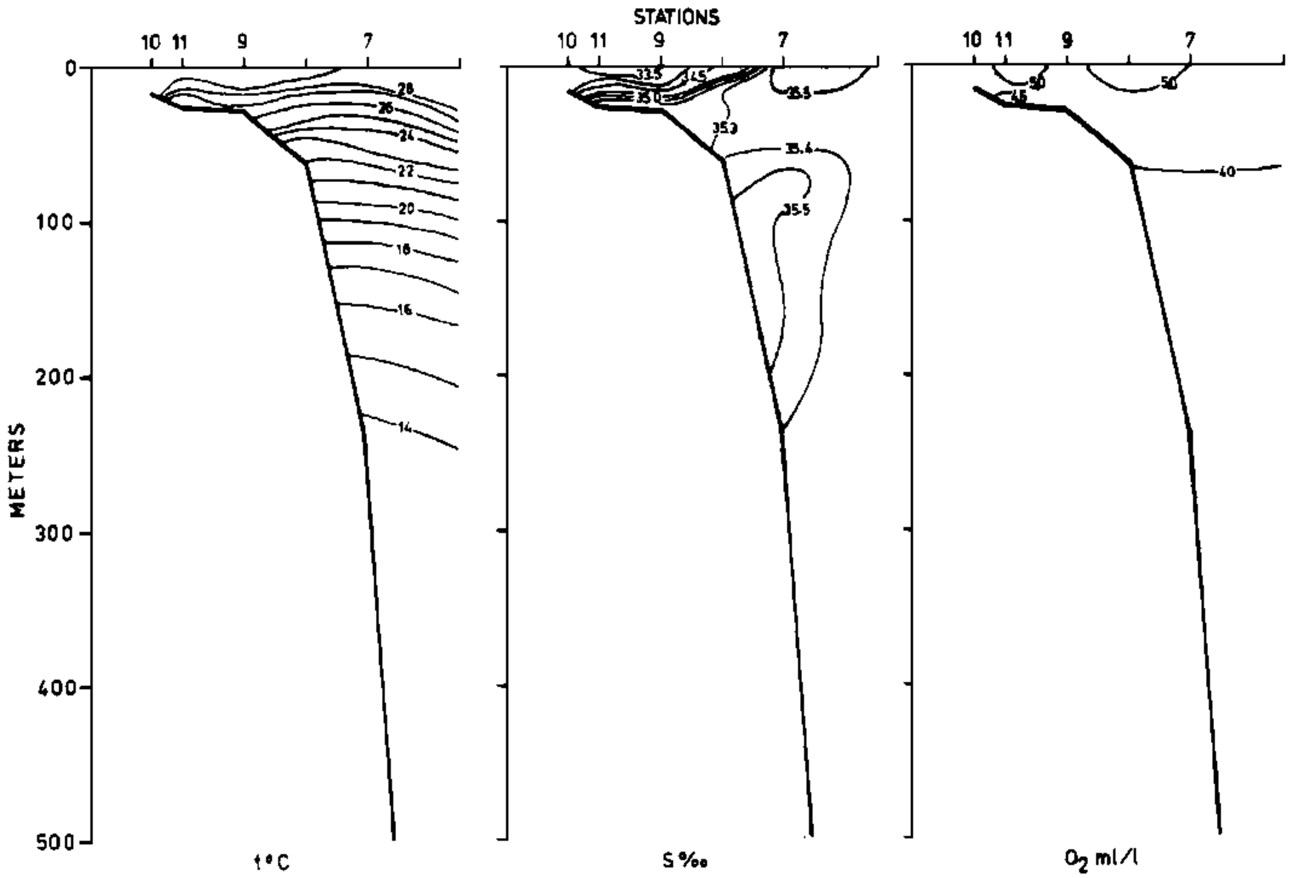


Fig. 5.35. Zambezi section 4-22 January 1978.

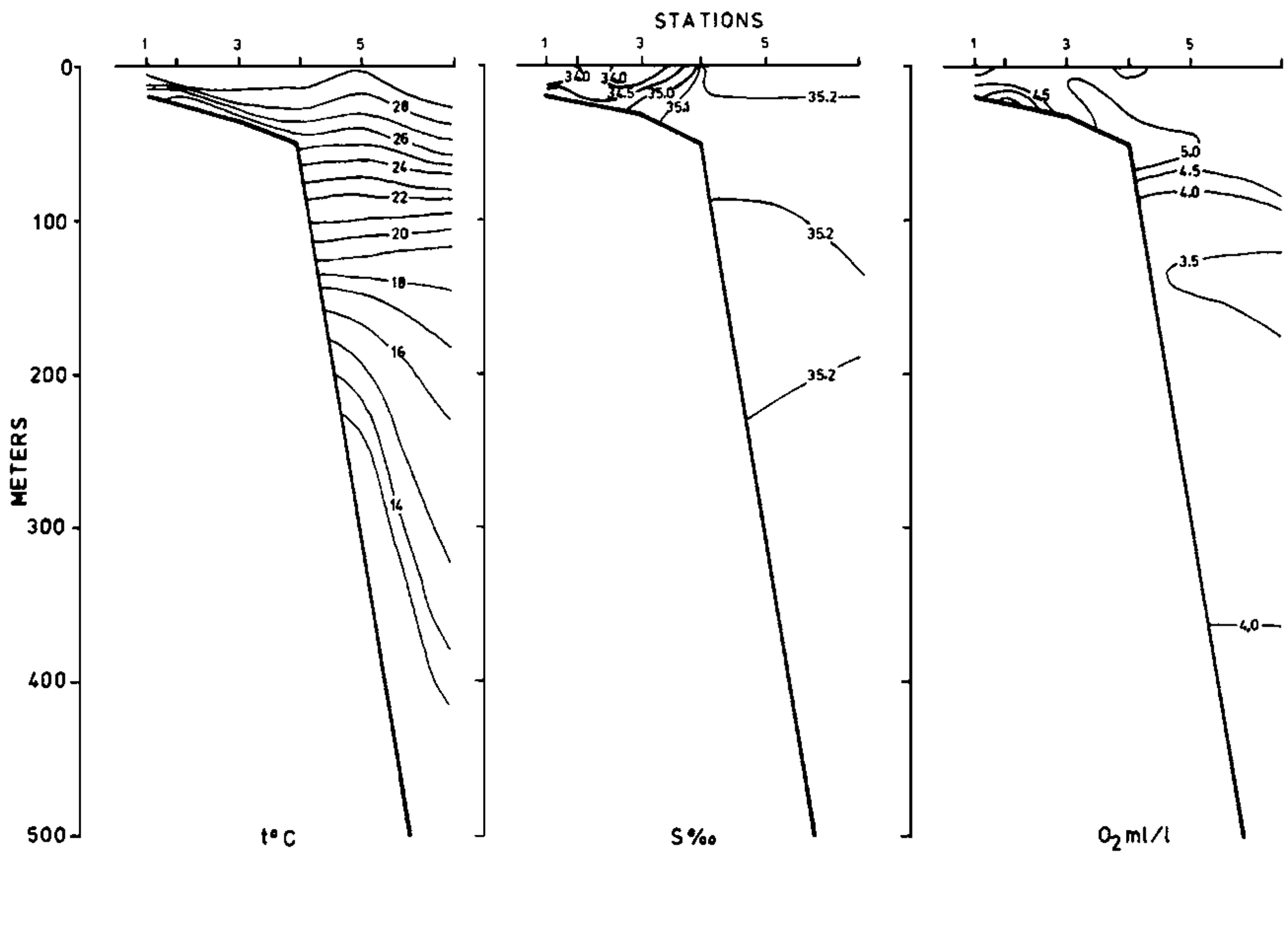


Fig. 5.36. Surface temperature - April - June 1978.

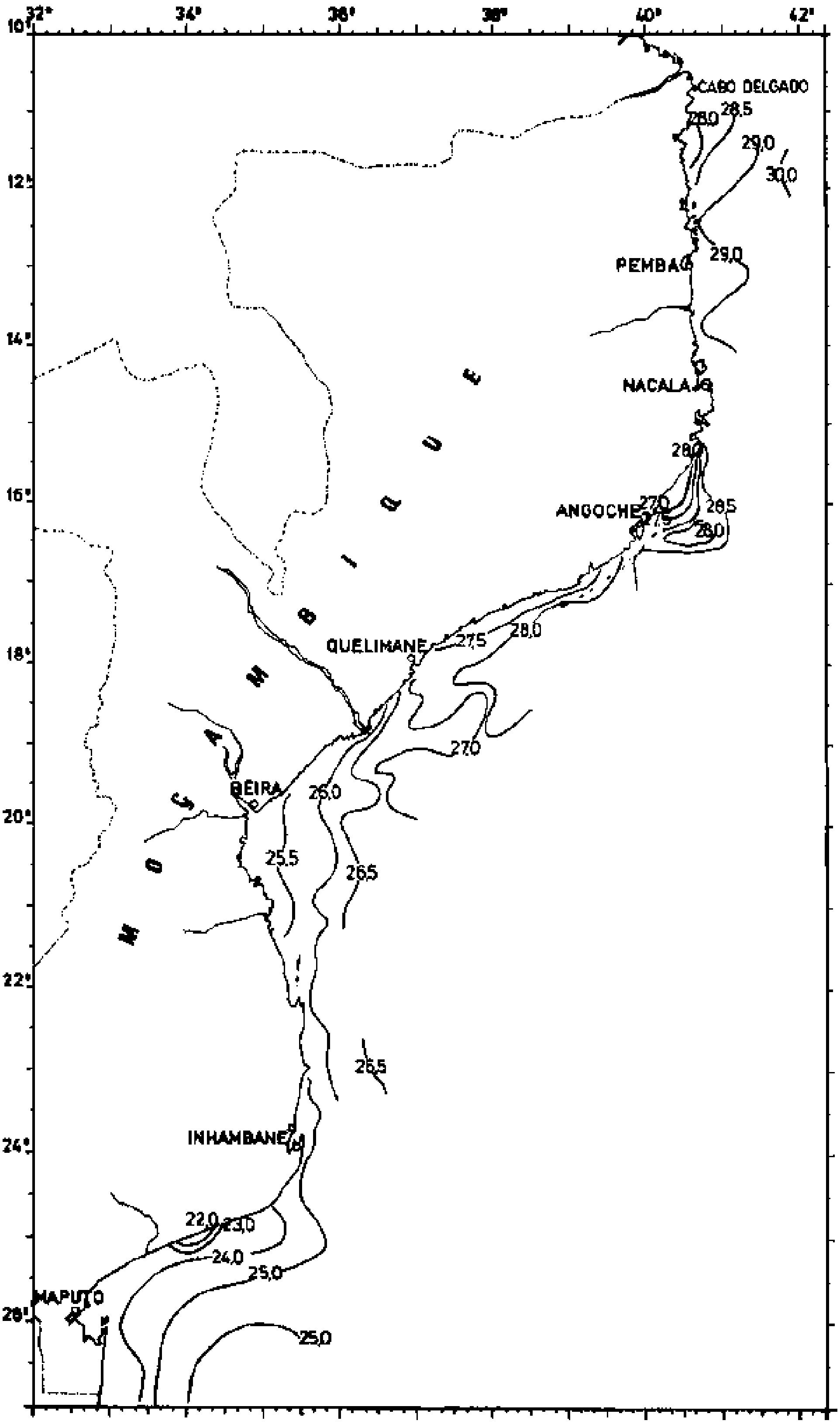


Fig. 5.37. Surface salinity - April - June 1978.

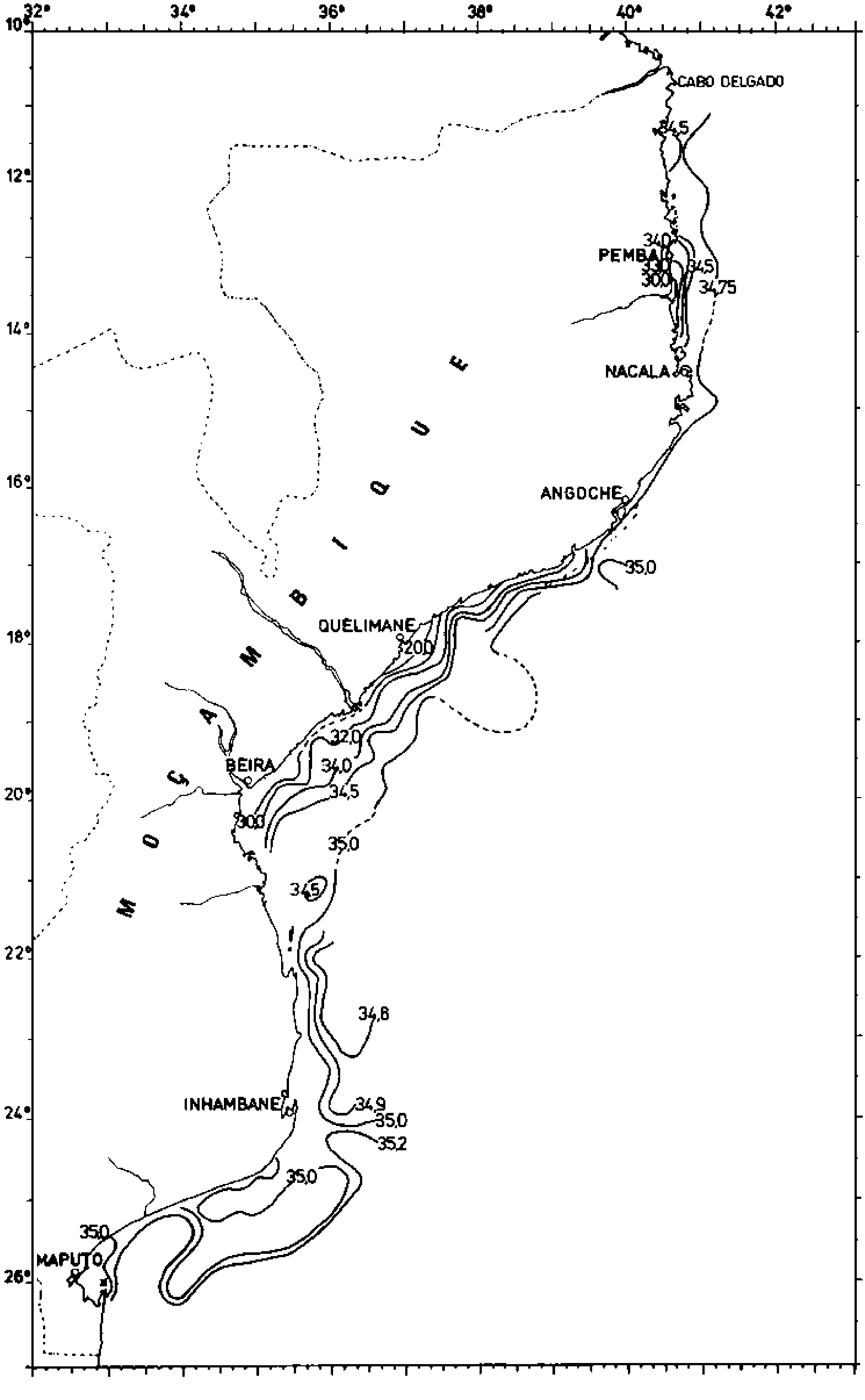


Fig. 5.38. SECTION 1-10 April 1978.

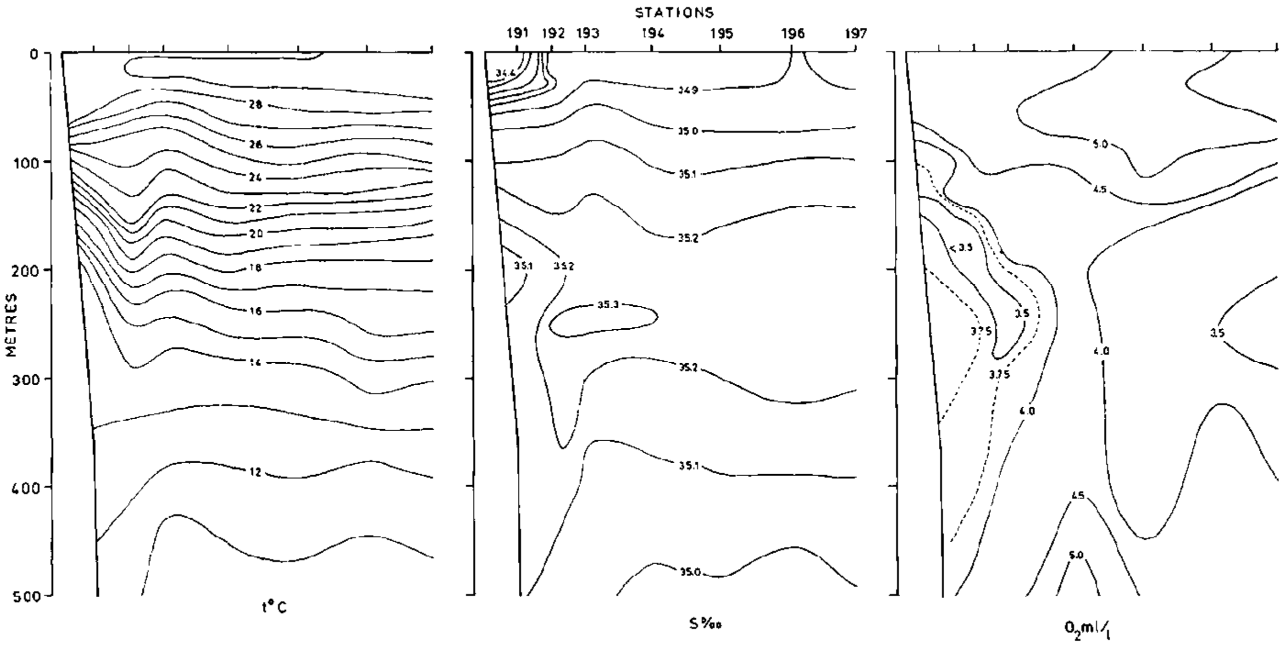


Fig. 5.39. SECTION II - 17 April 1978.

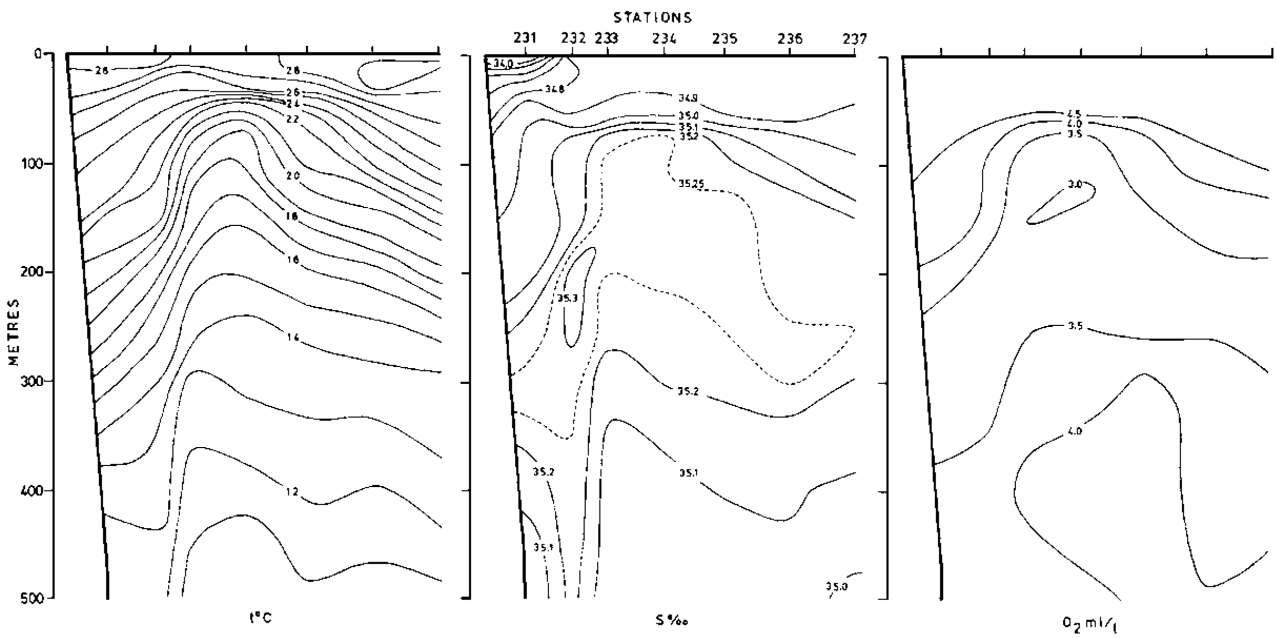


Fig. 5.40. SECTION III - 24 April 1978.

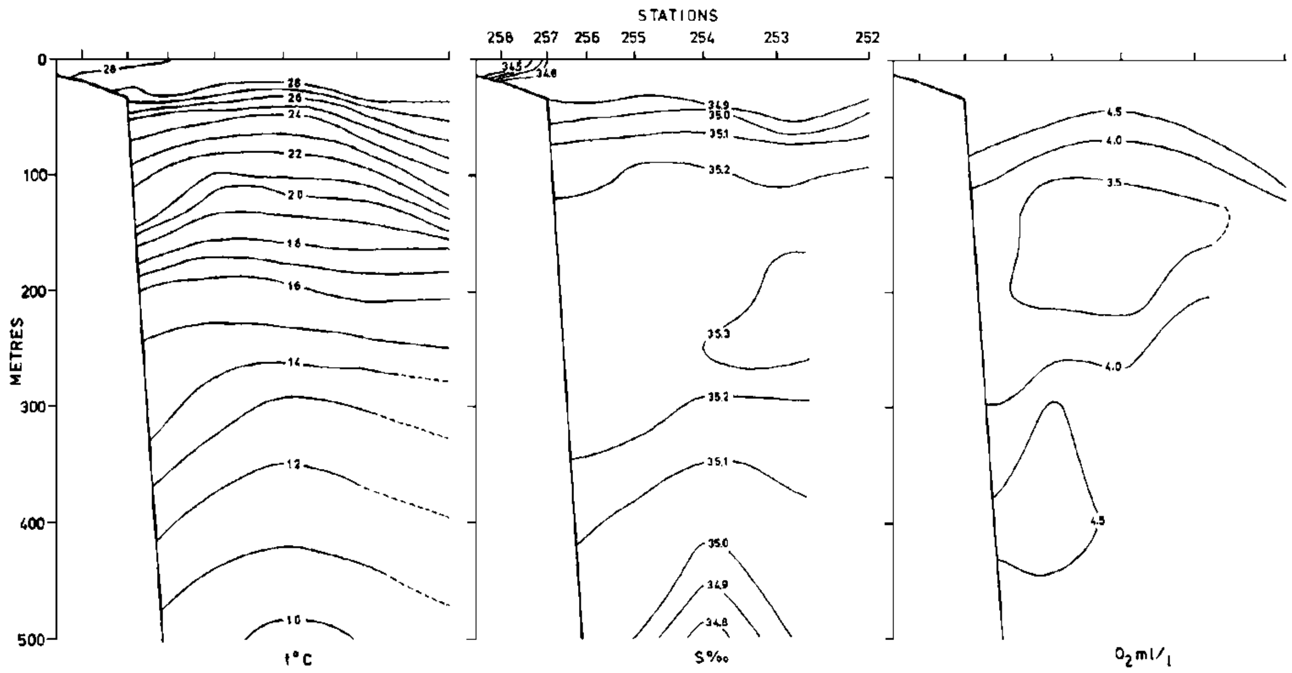


Fig. 5.41. SECTION IV - 18 May 1978.

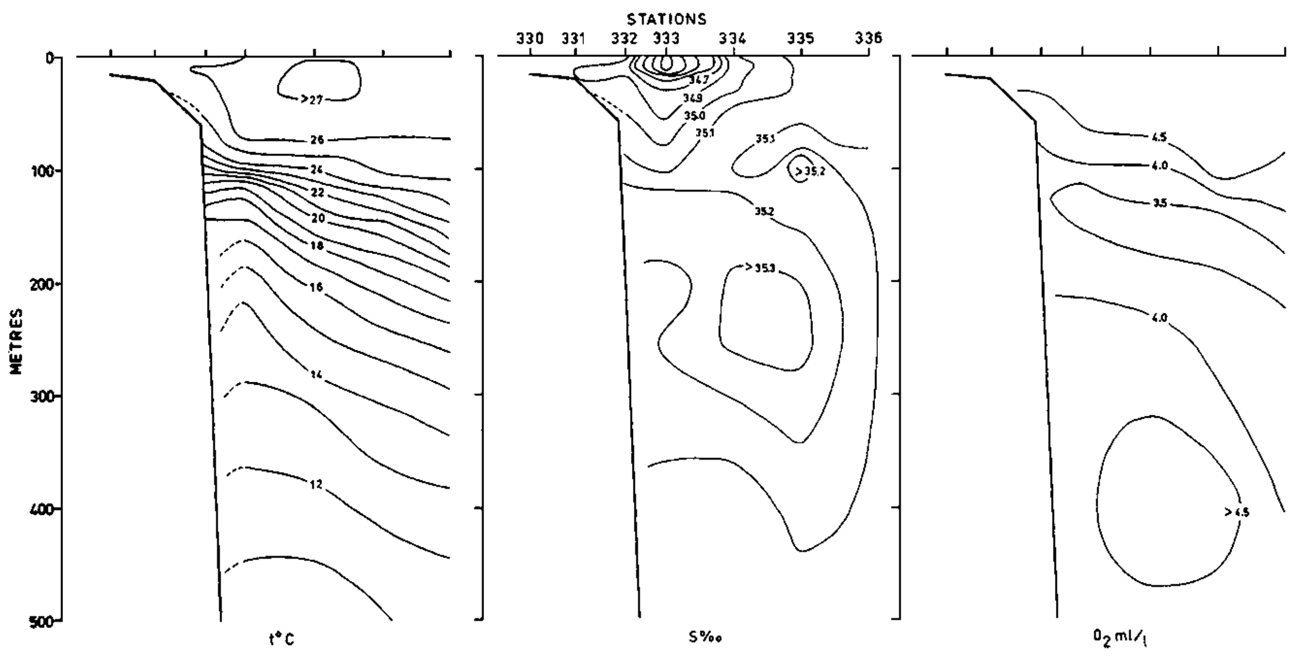


Fig. 5.42. SECTION V - 23 May 1978.

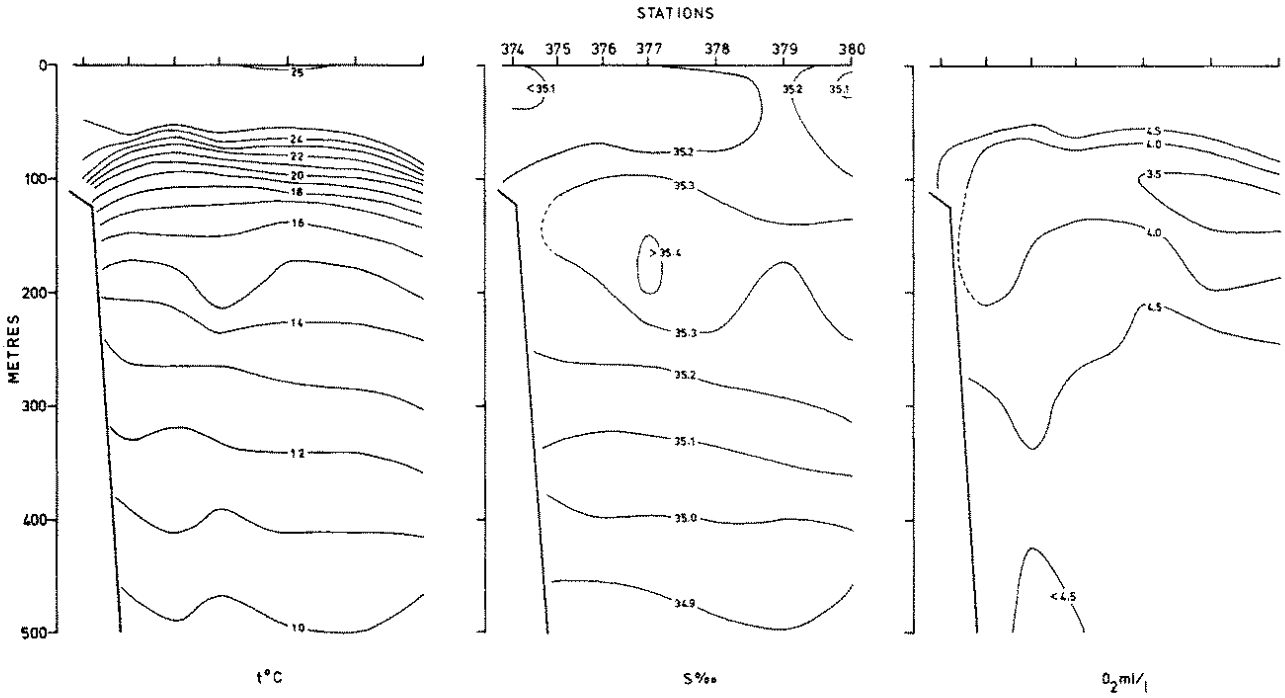


Fig. 5.43. SECTION VI - 25 May 1978.

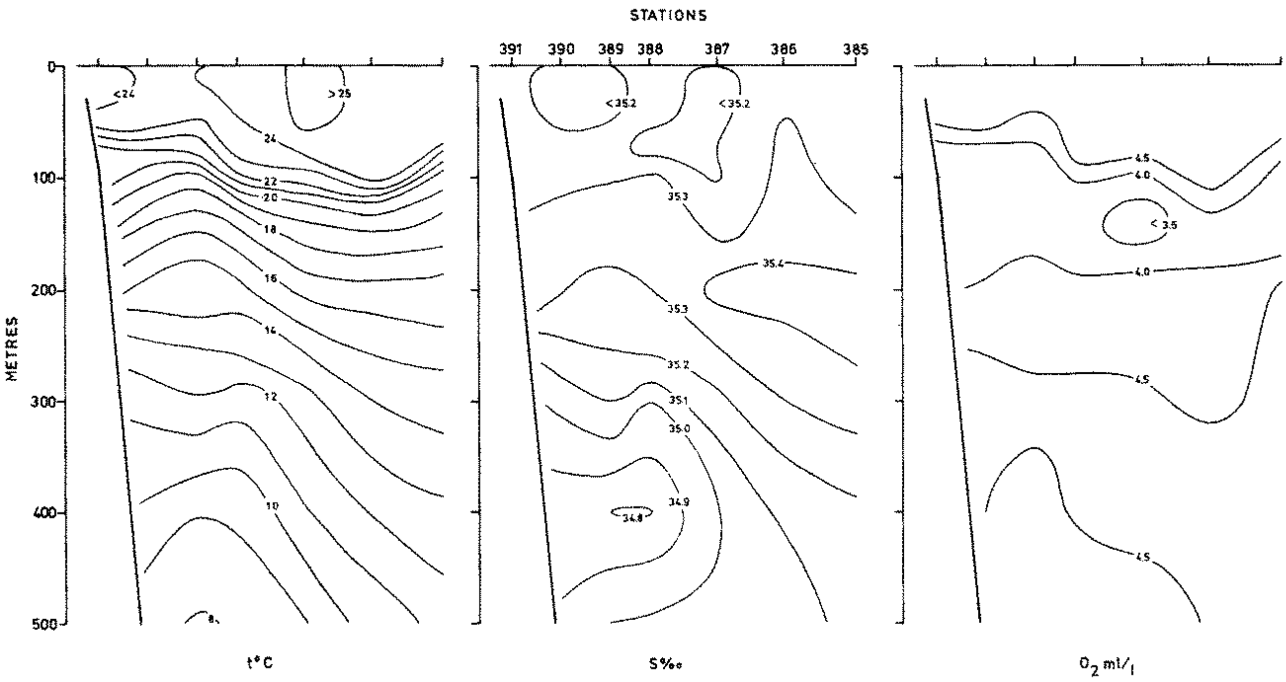


Fig. 5.44. Zambezi section 1-3 May 1978.

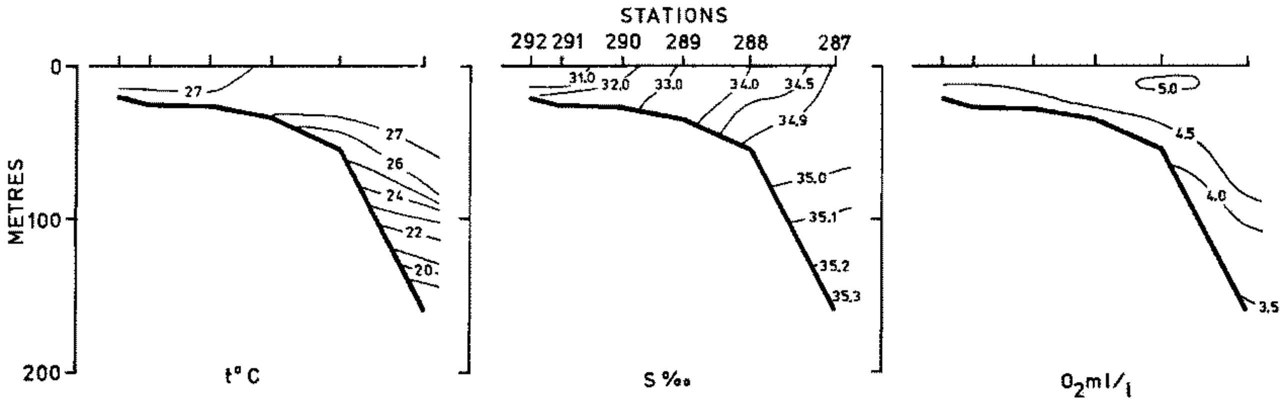


Fig. 5.45. Zambezi section 2-2 May 1978.

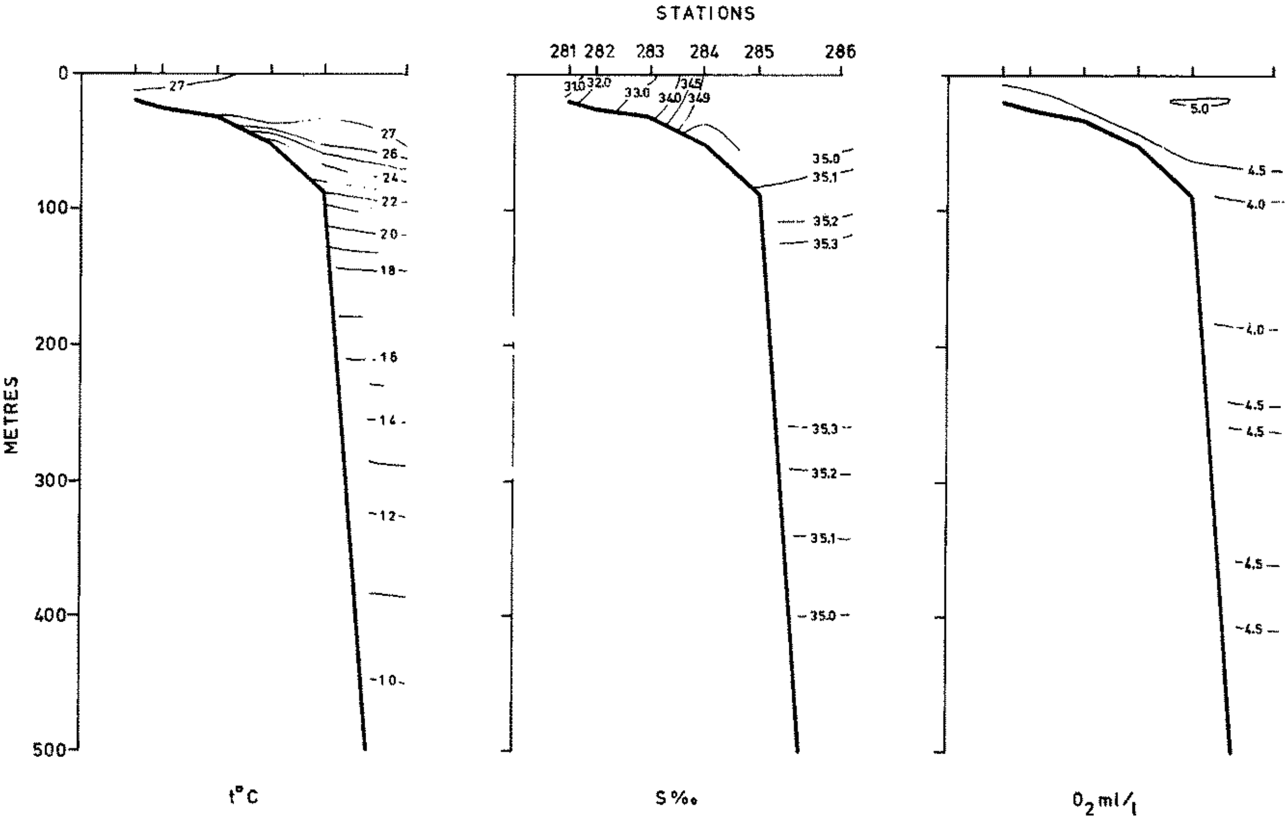


Fig. 5.46. Zambezi section 3-1 May 1978.

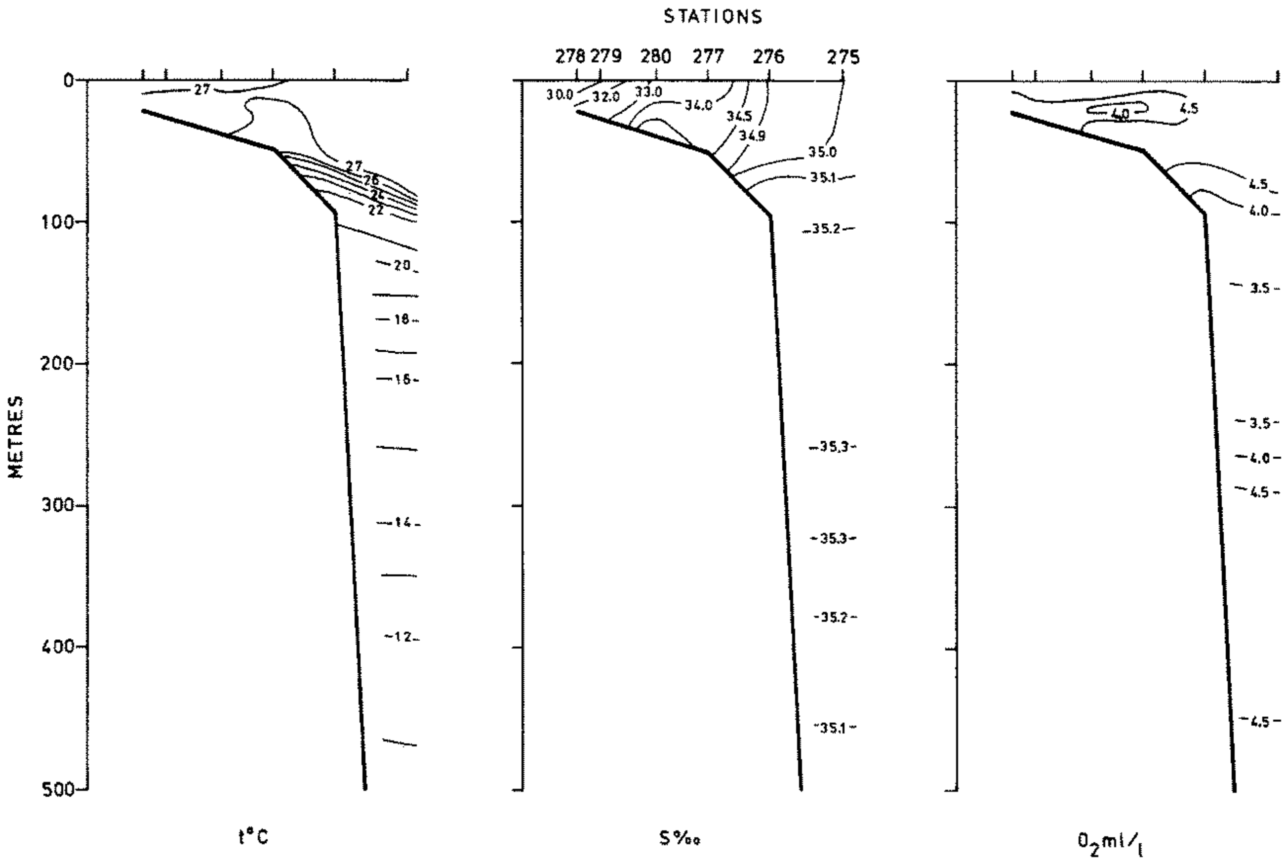


Fig. 5.47. Zambezi section 4-1 May 1978

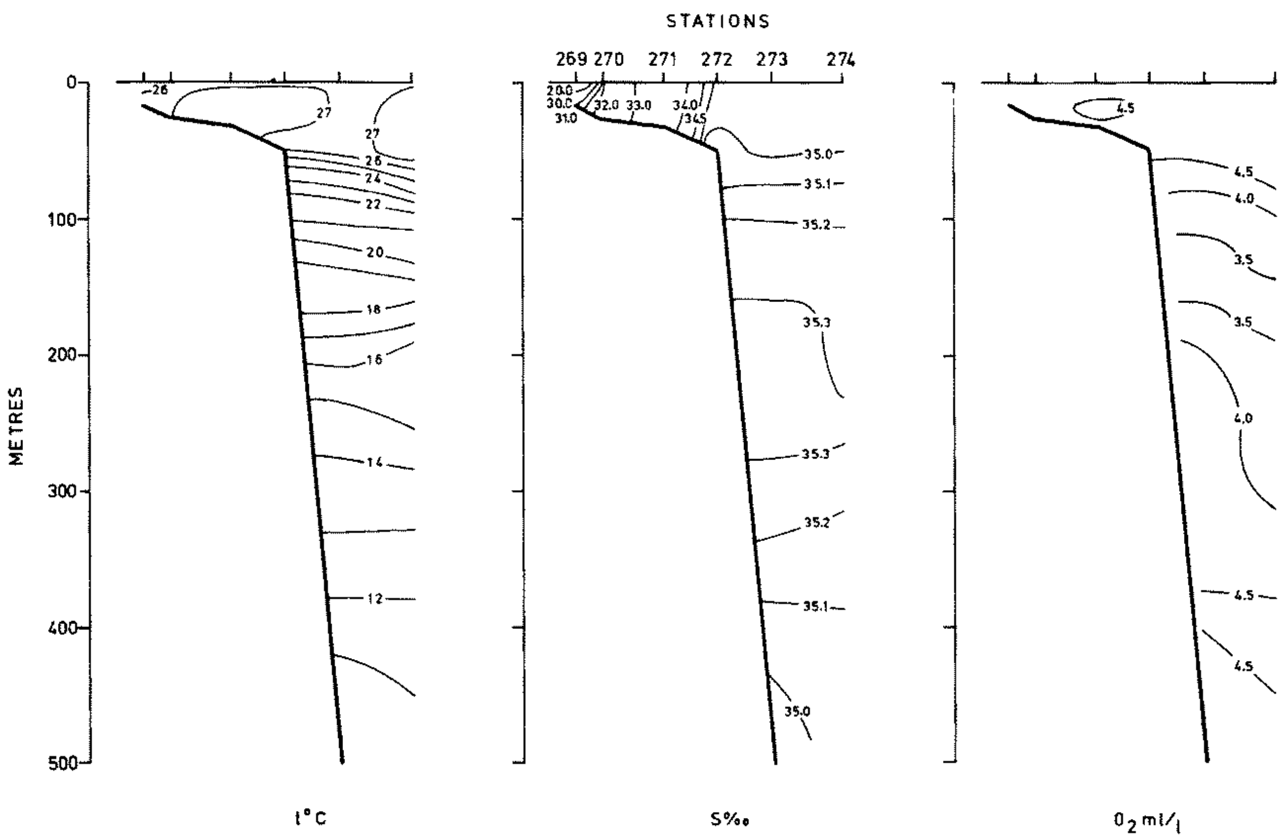
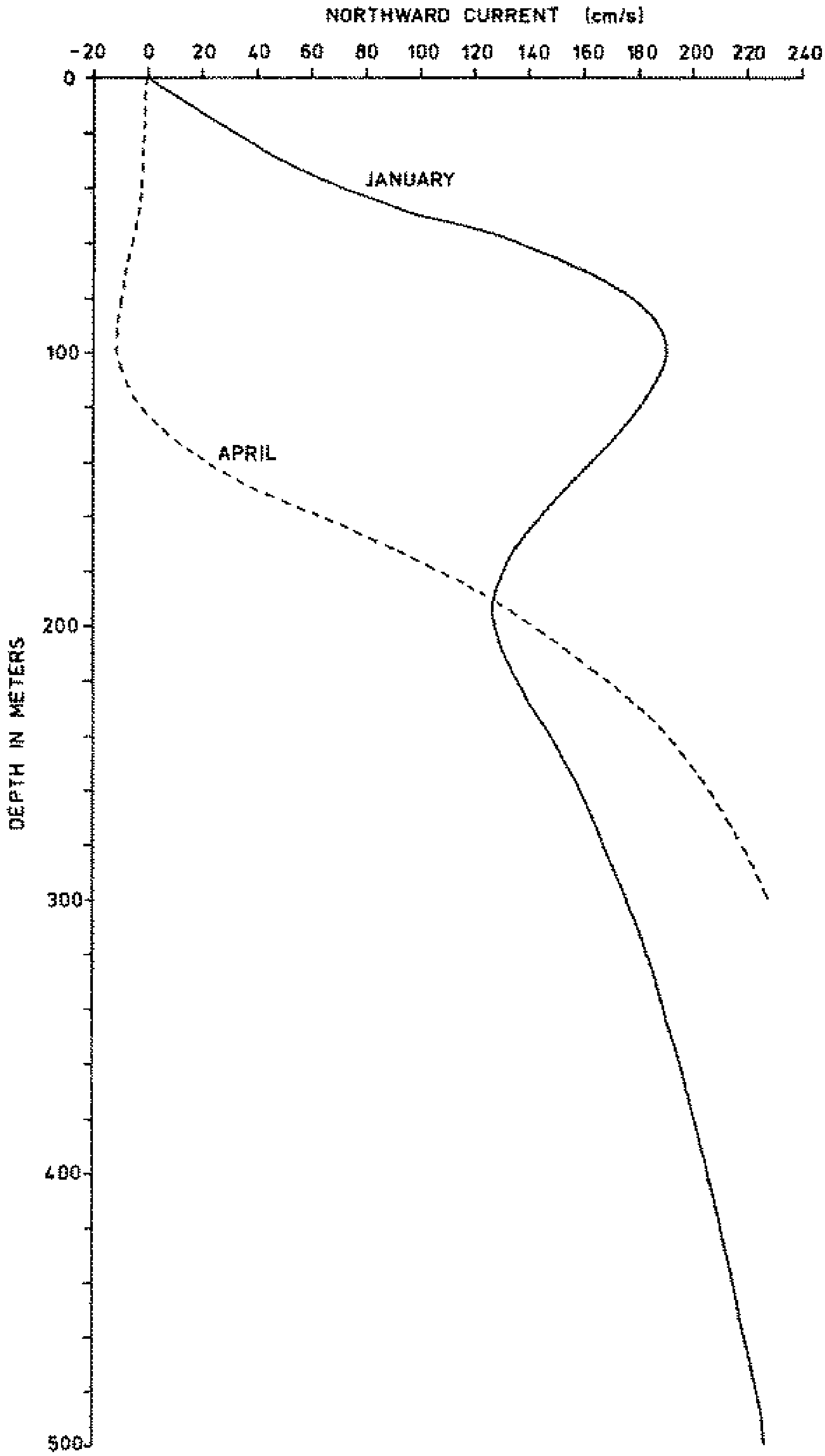


Fig. 5.48. Geostrophic velocity profile relative to the surface in SECTION I during January and April 1978.



6. DEMERSAL FISH

6.1. Species composition and distribution

Demersal fish of commercial interest are mainly confined to the upper 200 m. The splitting of the total catch into main groups and the species composition of the demersal catch from the surveys of “Aelita”, “Kattegat” and “Dr. Fridtjof Nansen” for summer and winter appear in Tables 6.1 and 6.2 respectively. Table 6.3 gives the same for the “Professor Mesyatsev” survey, and Table 6.4 shows the demersal fish composition for some months from the Soviet commercial trawlers. During the period June-November 1978 a survey was carried out by SIP (Servico de Investigacoes Pesqueiras, Maputo) to investigate the species composition of the group “Mixed fish” from these vessels. Some results appear in Table 6.5. As seen, small pelagic fish dominate, mostly scad (Decapterus spp.) below 15 cm. Of demersal fish goatfish and lizard fish are the most important. In general, the fish in the “Mixed fish” group are the smallest fish from the catches.

Table 6.1. Catch composition and composition of demersal catches in bottom trawls from “Aelita” “Kattegat” and “Dr. Fridtjof Nansen” during summer - October to March (% weight).

Area	Sofala			Bazaruto		Delagoa		Inhaca
Depth zones	10-50	50-100	>200	<200	>200	<200	>200	>200
Demersal fish	56.8	32.1	100	65.8	91.9	8.4	63.6	86.7
Pelagic fish	41.1	60.4		32.6	6.5	88.4	18.4	8.7
Sharks/rays	2.1	7.5		1.6	1.6	3.2	18.0	4.6
Breams - SPARIDAE/NEMIPTERIDAE	1.0	2.9		4.9		1.4		
Croakers - SCIAENIDAE	7.0	0.4		3.2	1.8	5.4		
Gurnards/Crocodile fish								
TRIGLIDAE/PERISTEDIIDAE	0.2				0.8		0.8	4.7
Goatfish - MULLIDAE	1.2	4.7		0.8		0.4		0.5
Groupers - SERRANIDAE	0.6	1.7		4.4		0.3		
Grunters - POMADASYIDAE	3.1	1.8		15.5				
Hairtails - TRICHIURIDAE	0.8							
Lizard fish - SYNODONTIDAE	2.4	1.2	25.4	2.0	14.5		14.8	5.5
Snappers - LUTIANIDAE	0.1	0.4		1.0				
Others	40.4	19.0	74.6	34.1	74.8	0.9	48.0	75.9
Number of hauls	100	22	14	13	42	77	114	44

Table 6.2. Catch composition and composition of demersal catches in bottom trawls from “Aelita” and “Dr. Fridtjof Nansen” during winter - April to September (% weight).

Area	Sofala			Bazaruto		Delagoa		Inhaca
Depth zones	10-50	50-100	>200	<200	>200	<200	>200	>200
Demersal fish	53.7	54.0	76.5	33.4	38.8	37.4	76.9	70.2
Pelagic fish	33.1	36.3		61.8	53.2	59.6	13.3	19.9
Sharks/rays	13.2	9.7	23.5	4.8	8.0	3.0	9.8	9.9
Breams - SPARIDAE/NEMIPTERIDAE	2.8	1.6				4.2	0.2	
Croakers - SCIAENIDAE	10.8		7.8	0.8	0.7			
Gurnards/Crocodile fish								
TRIGLIDAE/PERISTEDIIDAE							0.1	4.9
Goatfish - MULLIDAE	0.9							0.2
Groupers - SERRANIDAE	3.5	0.6						
Grunters - POMADASYIDAE	6.3	31.9		8.1	6.9			
Hairtails - TRICHIURIDAE	3.7							
Lizard fish - SYNODONTIDAE	4.6	1.4		1.5	3.3	1.8	12.8	6.2
Snappers - LUTIANIDAE	0.1							
Others	21.0	18.5	68.7	23.0	27.9	31.4	63.8	58.7
Number of hauls	76	11	1	21	63	65	60	24

Table 6.3. Catch composition and composition of the demersal catches in bottom trawls from "Professor Mesyatsev" Jan 76 - Aug 77 (% weight).

Area	Sofala				Delagoa				
	0-50		50-100		25-200		200-300 m		300-530 m
Depth zones	Jan 76	Aug 77	Jan 76	Aug 77	Jan 76	Aug 77	Jan 76	Aug 77	Jan 76 Aug 77
Demersal fish	33.0	45.3	50.4	25.5	47.9	66.8	16.4	94.5	65.3
Pelagic fish	64.4	42.6	45.5	70.9	40.9	18.5	78.0	+	+
Sharks/rays	2.6	12.1	4.1	3.6	11.2	14.7	5.6	5.5	34.7
Breams - NEMIPTERIDAE	2.9	+	+	1.5					
Goatfish - MULLIDAE	+	9.2	+	5.9	2.6	+			
Groupers - SERRANIDA	1.0	+	6.3	+	+	1.9			
Grunters - POMADASYIDAE	1.6	2.4	2.7	0.9					
Lizard fish - SYNODONTIDAE	5.5	6.6	1.7	2.1	9.2	+	6.0	12.8	+
Scavengers - LETHRINIDAE	+	+	+	1.1	1.6				
Snappers - LUTIANIDAE	2.6	+	15.9	1.8	+	8.9			
Others	19.4	27.1	23.8	12.2	34.5	56.0	10.4	81.7	65.3
Number of hauls	24	51	8	24	4	8	6	4	17

+) indicates presence in the catch.

Table 6.4. Catch composition and composition of the demersal catches in bottom trawls from Soviet commercial trawlers, Nov 77 - June 78 (% weight). BUDNICHENKO, 1979 (pers. comm.).

Area	Sofala 25-100 m		Delagoa 48-200 m
Depth zones	Dec 77	Jun 78	Nov 77
Demersal fish	21.6	33.9	13.1
Pelagic fish	60.9	39.3	59.5
Mixed fish	16.8	20.8	26.5
Sharks/rays	0.7	6.0	0.9
Cornet fish - FISTULARIIDAE		8.2	
Croakers - SCIAENIDAE			0.7
Goatfish - MULLIDAE	9.3	21.7	5.0
Grunters - POMADASYIDAE	11.5	3.3	5.4
Lizard fish - SYNODONTIDAE	0.3	0.1	2.0
Snappers - LUTIANIDAE	0.5	0.6	
Hours of trawling	560	948	620

Tables 6.1-6.4 indicate that the proportion of demersal species in the catches is less during summer at Sofala Bank and in Delagoa Bay than during winter. This tendency is especially pronounced in Delagoa Bay, where less than 10% of the total catch is demersal species in summer. In the Bazaruto area this seasonal variation seems to be reversed.

Table 6.5. Composition of the group "Mixed fish" sampled from landings of the Soviet trawlers in 1978 (SOUSA, 1979. Pers. comm.) (% in weight).

Area	Sofala		Delagoa
Depth zones	Jun 78	Nov 78	Aug 78
Demersal fish	52.5	24.8	12.0
Pelagic fish	44.7	72.8	87.3
Other items	2.8	2.4	0.7
Goat fish - MULLIDAE	49.6	6.2	5.5
Lizard fish - SYNODONTIDAE	2.2	18.4	4.4
Breams - PAGELLUS sp.	0.7	0.2	2.1

The northern area of Mozambique is not included in Tables 6.1-6.4. The shelf north of Angoche is narrow and unsuitable for trawling, the demersal fish composition is therefore not satisfactory known. At the St. Lazarus Bank, however, the demersal stock consists nearly exclusively of the two-spot red snapper (Lutjanus bohar). There seems to be an accumulated stock of snapper at this shallow bank. Table 6.6 shows the species composition in the pot catches in January 1978 at St. Lazarus Bank.

Table 6.6. The species composition in the pot catches at St. Lazarus Bank - January 1978. (W = weight - kg, N = numbers.)

Species	W	N	W%	N%
Twospot red snapper Lutjanus bohar	188.7	65	44.8	77.3
Speckled snapper L. rivulatus	6.1	1	1.5	1.2
Humpback red snapper L. gibbus	0.9	1	0.2	1.2
Moontail seabass Variola louti	5.5	2	1.3	2.4
Mottled brown seabass Promicrops lanceolatus	93.5	3	22.2	3.6
Epinephelus andersoni	11.8	1	2.8	1.2
Mud grouper E. brunneus	16.5	1	3.9	1.2
Squaretail seabass Plecopterus truncatus	17.6	1	4.2	1.2
Mooray eel Lycodontis tesselata	14.5	1	3.4	1.2
Mooray eel L. flavomarginatus	22.4	2	5.3	2.4
Orange spotted emperor Lethrinus kallopterus	2.5	1	0.6	1.2
Longface emperor L. miniatus	7.4	3	1.8	3.6
Shark Carcharinus tjutjot	34.2	2	8.0	2.3
	421.6	84	100	100

The upper 200 m

At Sofala Bank the most important demersal species of commercial value are croakers, grunters and lizard fish. The most abundant species of the first group are Johnius belangerii, J. dussumieri and Otholithes ruber. Of the second group the blotched grunt (Pomadasys maculatus) and the lined silver grunt (P. hasta) dominate. The catches of lizard fish consisted nearly exclusively of the brushtooth lizard fish (Saurida undosquamis). From Tables 6.3 and 6.4 it can be seen that goatfish, of which Upeneus vittatus dominate, are abundant during winter.

Table 6.7. The most important demersal species observed above 200 m during the cruises of "Dr. Fridtjof Nansen".

Area	Northern				Sofala				Bazaruto				Delagoa			
Cruise	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
LUTIANIDAE																
Lutjanus bohar x)	x	x	x	x				x								
Lutjanus sanguineus							x									
Lutjanus gibbus						x										
MULLIDAE																
Upeneus vittatus x)						x	x	x							x	
Upeneus sulfureus								x								
Parupeneus bifasciatus												x				
NEMIPTERIDAE																
Nemipterus delagoa x)							x	x							x	
POMADASYIDAE																
Pomadasys hasta					x	x		x								
Pomadasys maculatus x)						x	x	x								
Pomadasys olivaceum															x	
SCIAENIDAE																
Johnius belangerii x)					x	x	x	x								
Johnius coitor					x											
Johnius dussumeria					x	x										
Otholithes ruber x)					x	x	x	x						x	x	x
SERRANIDAE																
Epinephelus clorostigma			x				x									
Epinephelus morhua							x								x	
Epinephelus tauvina						x										
SPARIDAE																
Pagelus natalensis x)											x		x		x	
Polysteganus coeruleopunctatus									x			x				
Chrysoblephus anglicus													x			
Pterogymnus laniarius											x				x	
Argyrops spinifer												x				
Argyrops filamentosus												x				
Chrysoblephus lophus												x				
Evynnis cardinalis																x
Sparus major																x
SYNODONTIDAE																
Saurida undosquamis x)					x	x	x	x	x	x	x	x	x	x	x	x
Trachinocephalus myops							x	x			x	x			x	

x) The most abundant species.

In the Bazaruto area the most abundant species are grunts. During summer breams such as Nemipterus delagoa and Argyrops spp. and croakers also make a significant contribution. The number of trawl stations, however, is too small to establish the demersal species composition with the desirable degree of certainty.

In Delagoa Bay, breams dominate in winter, and croakers during summer. The number of trawl hauls in the upper 200 m off Inhaca were very few, due to the rough bottom. The species composition of this depth zone has therefore been deleted. Table 6.7 lists the most abundant commercially important species observed during the survey of "Dr. Fridtjof Nansen".

Table 6.8. Dominant families observed below 200 m.

x) Commercially most important, either by species or by abundance.

Common name	- FAMILY	Dominant species
Smelt	- ARGENTINIDAE x	Argentina sphyraena
Flounder	- BOTHIDAE	
Snake mackerel	- GEMPYLIDAE x	Thyrsitoides marleyi
Trumpet fish	- MACRORHAMPHOSIDAE	Macrorhamphosus sp.
Rat tail	- MACROURIDAE	Coelorhynchus spp.
Crocodile fish	- PERISTEDIIDAE	Peristedion adeni
	- SCOMPROPIDAE x	Neoscombrops annectens
Spiny shark	- SQUALIDAE x	Squalus acanthias
Lizard fish	- SYNODONTIDAE x	Saurida undosquamis
Gurnard	- TRIGLIDAE	

Depths below 200 m

The main part of the ichthofauna below 200 m consists of the families listed in Table 6.8. The Myctophidae has been deleted, as this family will be treated separately under the chapter MESOPELAGIC FISH. It is difficult to establish any geographical distribution as only a few deep trawl hauls were carried out north of Bazaruto. Snake mackerel, however, were abundant between Nacala and Pemba and seem to be distributed along the whole coast. Spiny sharks were caught at depths between 30 and 450 m, but were especially abundant at 250-300 m off Inhaca. The most abundant species of commercial value seemed to be Neoscombrops annectens.

6.2. Biological characteristics

Figs. 6.1 and 6.2 give the mode and range of length as well as some observations on maturity stages for the most important demersal species.

Lutianidae

The most important species of this family was the two-spot red snapper (Lutjanus bohar) which dominated the stock of the shallow St. Lazarus Bank. The length of the fish varied between 33 and 79 cm with most being in the range 55 to 70 cm (Fig. 6.1). Spawning specimens were not observed.

Blood snappers (L. sanguineus) 55 to 70 cm were found between Angoche and Pebane and at the southern part of Sofala Bank at about 50 m in February 1978. In the same area, humpback red snappers (L. gibbus) 33 to 74 cm were caught in November 1977 at depths of about 50 m.

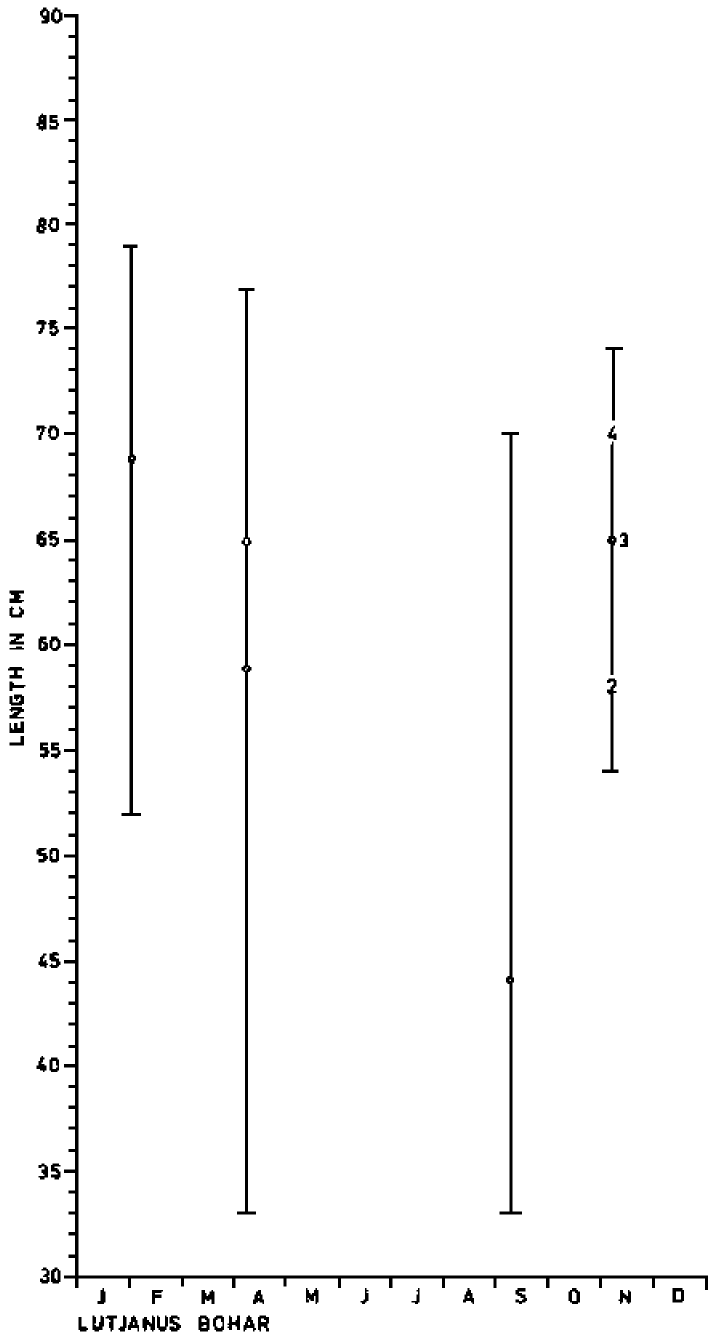
Mullidae

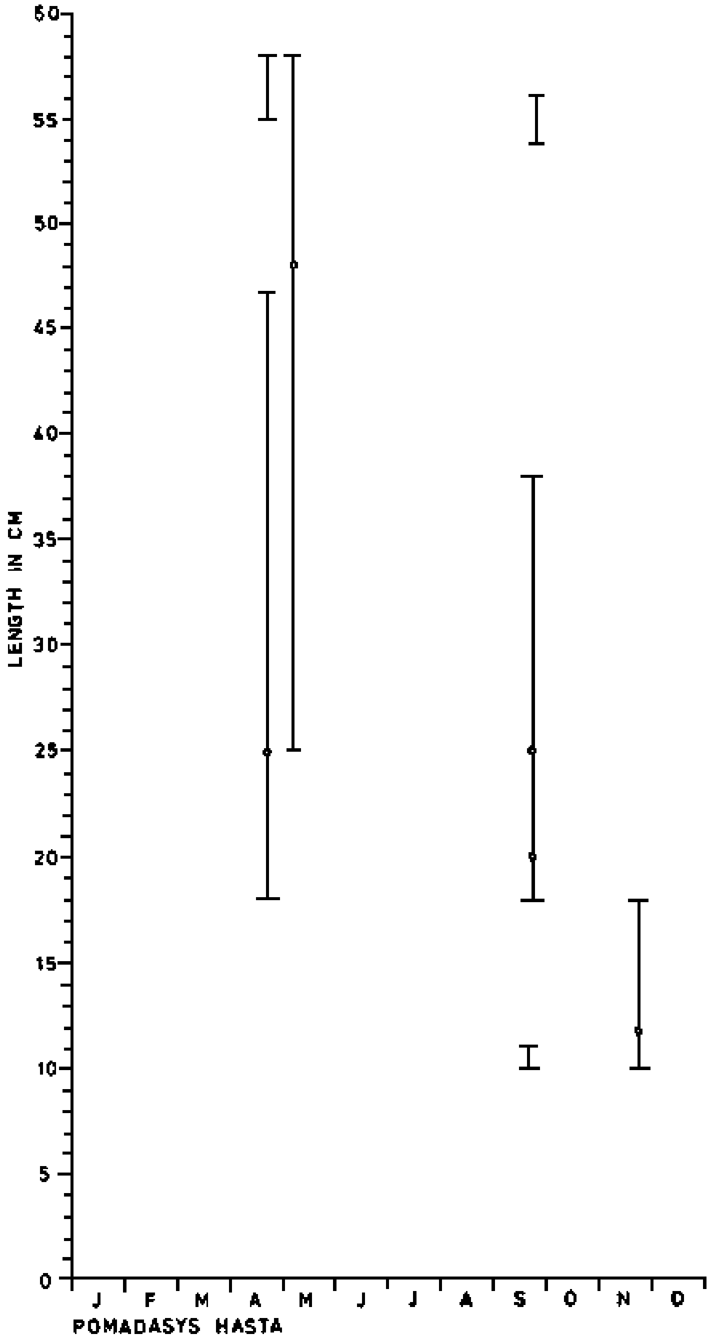
The yellow-striped goatfish (Upeneus vittatus) was the most abundant species from this family. It occurred frequently in trawl catches from 10-100 m at Sofala Bank. From the length distribution in Fig. 6.1 it can be seen that specimens from 6 to 24 cm were recorded. The main part of the stock, however, seemed to be between 10 and 15 cm. The smallest individuals were observed in April.

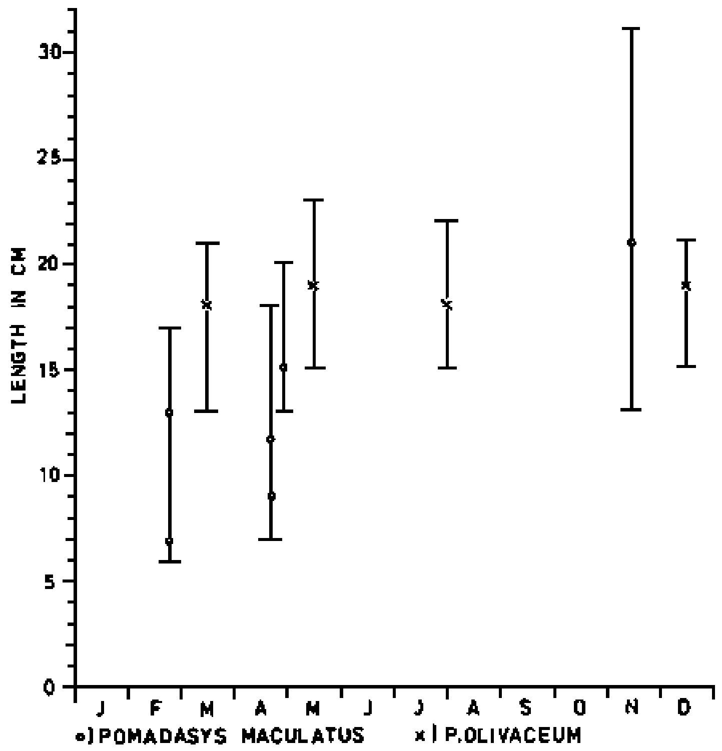
Nemipteridae

This family was represented in the catches by one species only, namely the Delagoa threadfin bream (Nemipterus delagoa) of lengths 13 to 28 cm, most being between 18 and 22 cm. There are some indications of a peak in the spawning activity in December-January.

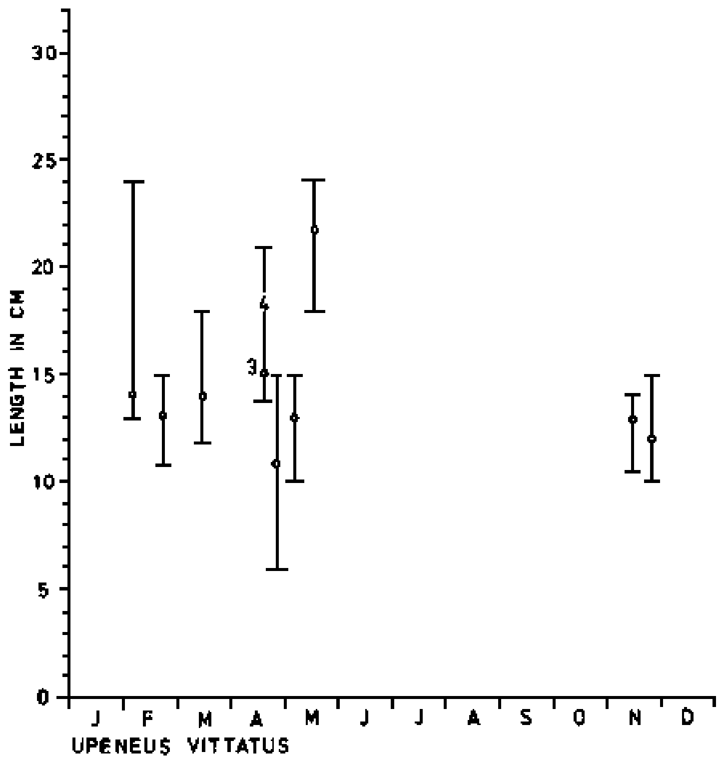
Fig. 6.1. Distribution of modal length and range for some demersal species




LENGTH IN CM
60
55
50
45
40
35
30
25
20
15
10
5
0
J F M A M J J A S O N D
POMADASYS HASTA



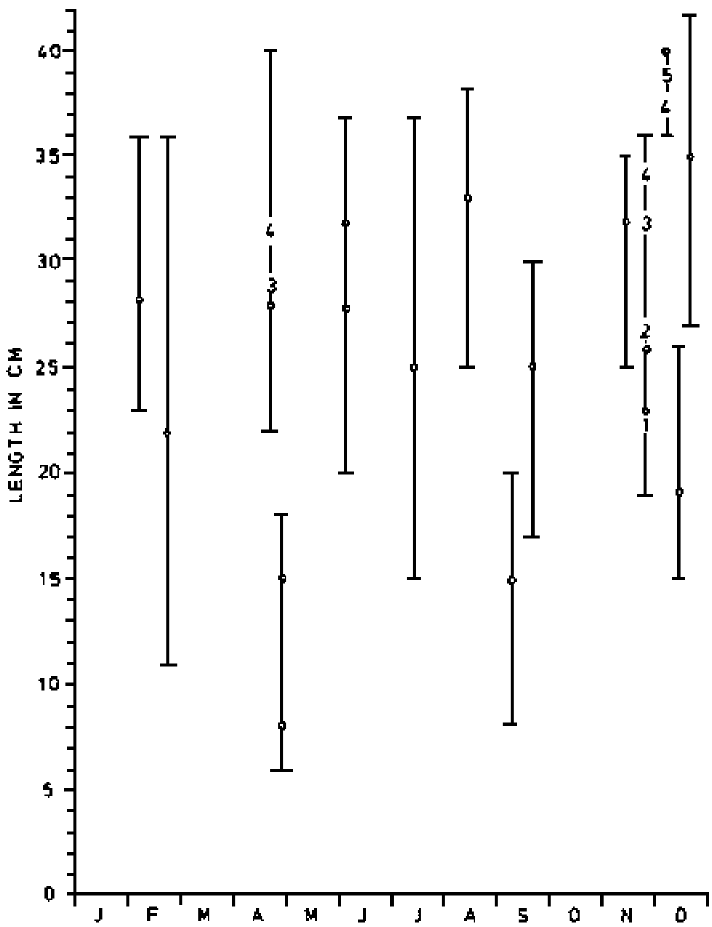
LENGTH IN CM
0
5
10
15
20
25
30
J F M A M J J A S O N D
o) POMADASYS MACULATUS
x) P.OLIVACEUM



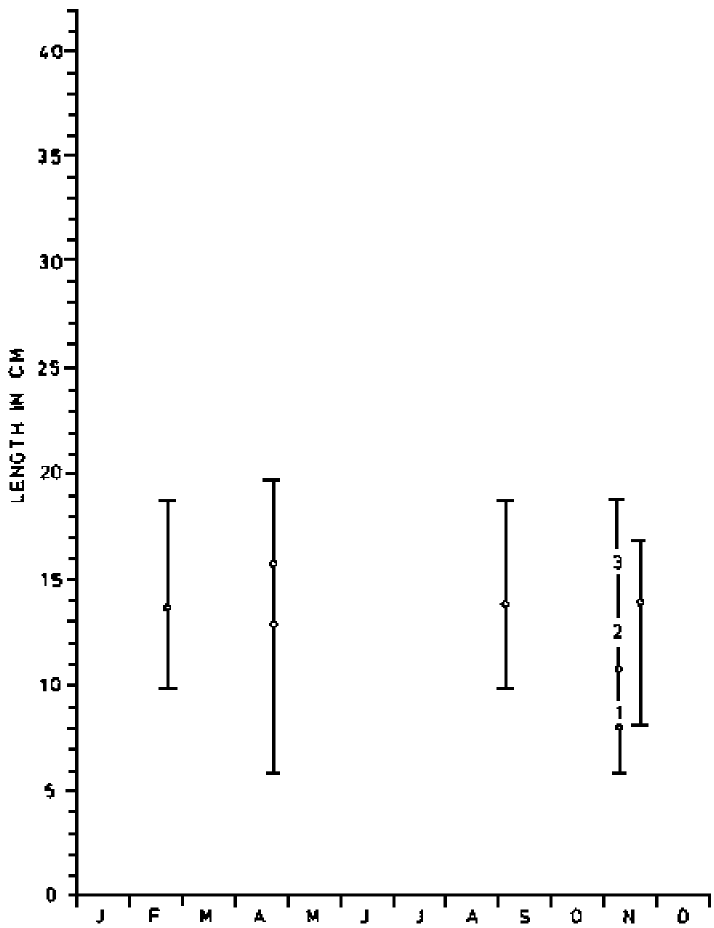
LENGTH IN CM
0
5
10
15
20
25
30
4
3
J F M A M J J A S O N D
UPENEUS VITTATUS

Fig. 6.2. Distribution of modal length and range for some demersal species.

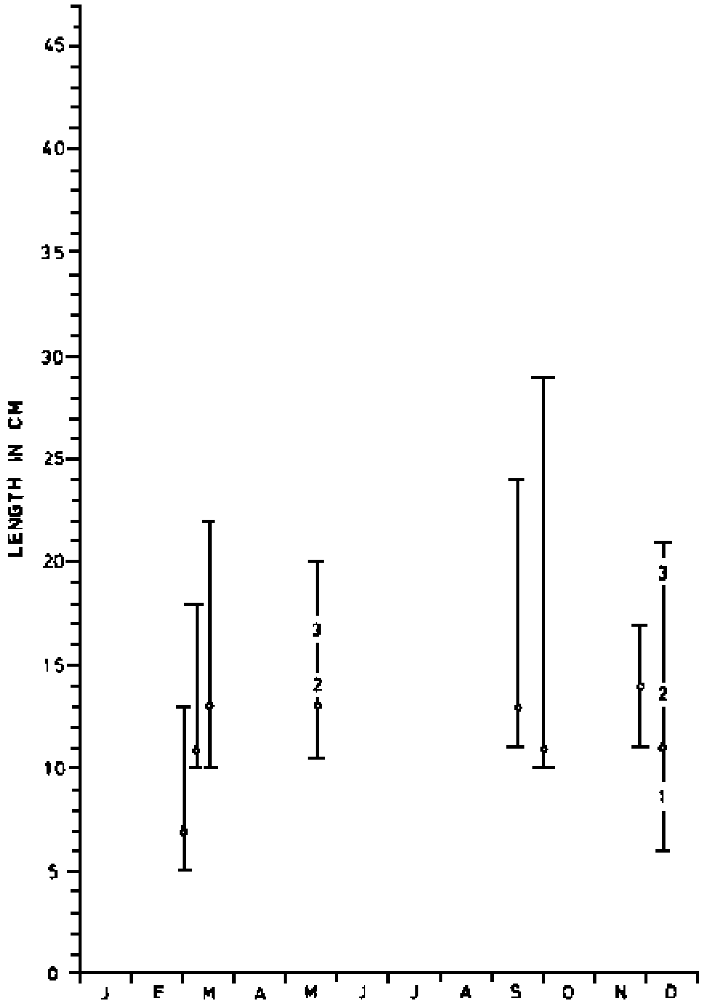
OTHOLITHES RUBER



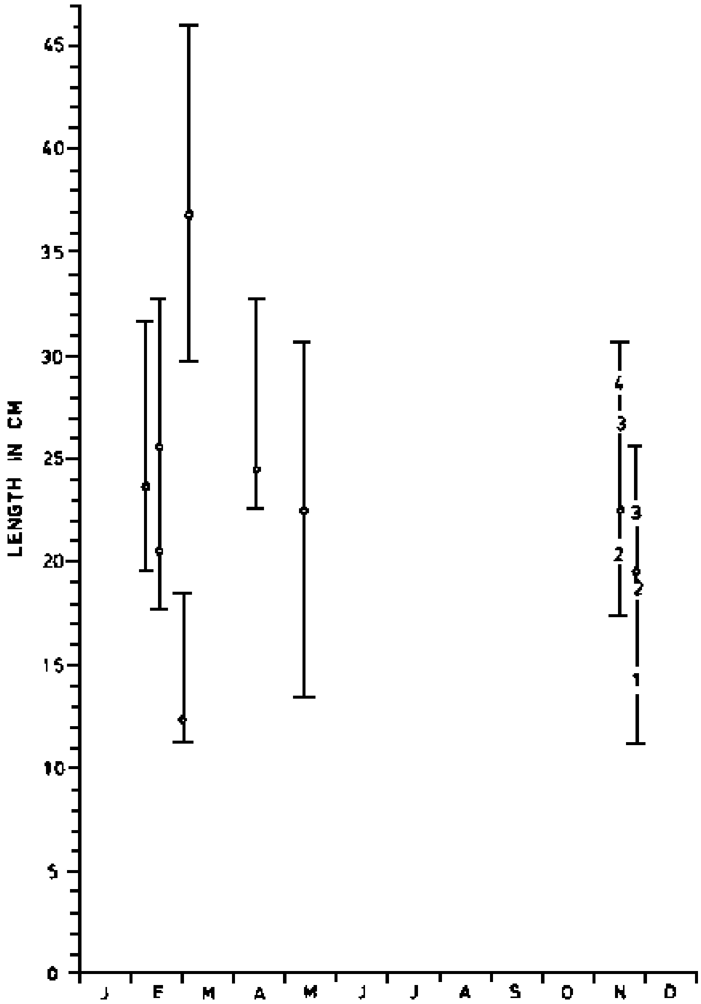
JOHNIUS BELANGERII



NEOSCOMBROPS ANNECTENS



SAURIDA UNDOSQUAMIS



Pomadasyidae

The blotched grunt (Pomadasys maculatus) was observed at lengths between 6 and 31 cm. The smallest individuals were observed during summer and the length distribution gives some support for the assumption of a spawning period in December-January.

Lined silver grunts (Pomadasys hasta) had lengths between 10 and 58 cm, with the smallest individuals occurring in September-November. The samples in April-May with very wide length range suggest the presence of at least two year-classes.

Rock grunts (Pomadasys olivaceum) have a length of 18-22 cm. A peak in the spawning activity seems to occur between August and December, according to the maturity observations of “Aelita”, (BUDNICHENKO et al, 1977).

Sciaenidae

The length of the Belangers croaker (Johnius belangerii) was between 6 and 20 cm. The smallest specimens were found in November. No observations of any spawning were made.

The tiger-toothed croaker (Otholithes ruber) was observed at lengths between 6 and 42 cm. The majority was between 25 and 35 cm. Observations on maturity taken both on “Dr. Fridtjof Nansen” and the “Aelita” (BUDNICHENKO et al, 1977) indicate a peak spawning in December-January and maybe another in June-July. With some boldness one might construct the growth curves of Fig. 6.1, showing a growth to 25-30 cm 6-7 months after spawning.

Synodontidae

The dominant species in this group, the brush-tooth lizard fish (Saurida undosquamis), had a length between 12 and 46 cm. The majority were between 17 and 27 cm. They seemed to be widely distributed over most of the shelf and slope area and were found at depths between 40 and 400 m. The length distribution seemed to be different between males and females. There also appeared to be an increase in length with depth.

Pre-spawning or spawning females were never caught at depths shallower than 200 m, and spent or recovering individuals were always below 300 m. This indicates a vertical migration associated with the reproduction cycle. The ripe and spent fish were found in November and January, suggesting a peak in sexual activity in September to November.

These observations are in reasonable good accordance with the investigations into S. tumbil in Philippine waters where the temperature conditions are approximately the same as along the Mozambican coast TIEWS, MINES and RONQUILLO, 1968).

6.3. Abundance

If the average fish density is known for a given area, the size of the stock may then be calculated. Table 6.9 gives the result of such calculations split into areas, depth zones and seasons. The fish density is obtained from the mean catch rate and the area swept by the trawl. The latter is the distance between the trawl wings multiplied by the length of the tow. All the trawl hauls from the surveys of the research vessels “Aelita”, “Dr. Fridtjof Nansen”, “Kattegat” and “Professor Mesyatsev” were applied. For each vessel the demersal fish density was calculated according to the specification of her trawl net, trawl speed and catch rate. The average density was obtained as a weighted mean for all the vessels. The efficiency coefficient of the trawls was taken as 1, i.e. all the fish ahead of the trawl were caught. The areas of the different depth zones are found in Table 3.1.

In order to reach a reliable result by these “swept area” calculations, the following conditions must be fulfilled:

- The estimation of the efficiency coefficient of the trawl must be correct.
- Random chosen fishing localities should be used.

The last condition is believed to have been approximately satisfied for demersal species, as the aimed trawlings were mainly carried out on pelagic recordings.

Table 6.9. Mean density of demersal fish and standing stock size in thousand tonnes estimated by using the catch rates of bottom trawls. Numbers in brackets are extrapolated values.

Area	Inhaca			Delagoa			Bazaruto			Sofala			
Depth	Density kg/km^2	No.of hauls	Stock	Density kg/km^2	No.of hauls	Stock	Density kg/km^2	No.of hauls	Stock	Density kg/km^2	No.of hauls	Stock	
SUMMER													
0- 50	[100]	-	0.03	3739	56	17.00	510	10	2.20	1456	124	55.10	
51-100	120	1	0.03	524	12	1.60	387	3	0.50	1554	28	11.40	
101-150	[100]	-	0.02	711	7	0.90	77	1	0.07	135	1	0.06	
151-200	115	1	0.02	162	3	0.20	58	1	0.06	[150]	-	0.07	
201-400	462	42	0.40	1120	93	8.80	941	31	3.90	696	10	1.40	
Total			0.5			28.5			6.7			68.0	103.7
WINTER													
0- 50	[100]	-	0.03	4258	11	19.40	176	2	0.7	714	128	27.0	
51-100	[100]	-	0.03	4527	28	13.7	882	2	1.2	1191	35	8.8	
101-150	[100]	-	0.02	1291	6	1.7	2041	3	2.0	[150]	-	0.07	
151-200	[100]	-	0.02	712	2	0.9	2385	17	2.3	[150]	-	0.07	
201-400	1043	23	1.00	1209	45	9.5	2130	62	8.7	204	2	0.40	
Total			1.1			45.2			14.9			36.3	97.5

As seen in Table 6.9, the demersal fish stock during summer was 103 700 tonnes and in winter 97 500 tonnes. In winter the stock at Sofala Bank decreased, and increases along the rest of the coast. BIRKETT (1978) presents similar calculations based on the data from "Professor Mesyatsev" alone (Table 1.5). Except for Delagoa Bay in winter, when he reached a stock size less than half of our calculations, there is an astonishing degree of correspondance.

Table 6.10 shows the acoustic abundance estimates of demersal fish from "Dr. Fridtjof Nansen". During Cruise II in November the coverage was not as good as on the other cruises, due to lack of time. As a result of this, the acoustic estimate is probably too high, due to overvaluation of the area of the acoustic recordings. The most likely acoustic estimate of the demersal resources will be 250-300 000 tonnes.

Table 6.10. Acoustic abundance estimates of demersal fish from "Dr. Fridtjof Nansen" (thousand tonnes).

	Inhaca	Delagoa	Bazaruto	Sofala	Northern	St. Lazarus	Total
September-October 1977	36	2	31	194	19	9	291
November 1977	-	111	29	260	5	9	414
April-June 1978	3	12	52	166	4	11	248

An acoustic estimate of demersal fish will usually be an underestimate, due to the limitation of the echo sounder and integrator in making recordings very close to the bottom. An investigation by BURCZYNSKI (1976) at Sofala Bank indicates that an average catch rate of 100 kg/trawl hour could be expected even if there are no recordings on the echo sounder. This catch rate is equivalent to about 100 000 tonnes of demersal fish for the whole shelf area of Mozambique. If we add this to the acoustic estimate the total demersal stock will be 350-400 000 tonnes.

The discrepancy between of the two different abundance estimates of demersal fish, 100 000 versus 350-400 000 tonnes, seems to be unreasonably large. If the last figure is correct, it follows that the efficiency coefficient of the bottom trawls used is about 0.3, which appears to be suspiciously low for demersal species. A reasonable assumption is then that the conversion factor between the integrator reading and the density of fish per unit area is too high. Therefore, as a first approximation of the abundance of the demersal stock off Mozambique, 200 000 tonnes is suggested. This means that the efficiency coefficient of the trawls will be approximately 0.5.

The formula of GULLAND (1970), $Y_{max} = 0.5 \cdot M \cdot B_O$, can be used to estimate the potential annual yield. M is the natural mortality rate and B_O the virgin or unexploited stock. Considerable differences in natural mortality are to be expected between species. There is a lack of estimates of M for the fish of the region. Investigations from other areas, however, suggest that M = 0.5 is reasonable for the demersal stock as a whole (ANON, 1979, PAULY, 1978). For the snapper at St. Lazarus Bank this value probably is too high, and therefore M = 0.2 has been applied to this species. A value of 0.2-0.3 seems to be common for the larger slow-growing species (MUNRO, 1969-1973, PAULY, 1978). Using these figures, the potential annual yield of the demersal stocks is about 50 000 tonnes. For the St. Lazarus Bank the annual yield will be about 1000 tonnes.

The by-catch of demersal fish in the shrimp fishery at Sofala Bank is probably about 20 000 tonnes. As the confidence interval of the abundance estimate is so large, this catch, as well as the catch from the Soviet trawlers, has not been included in the calculations.

There is lack of information on the fishery going on in the coral reef areas as well as in more inshore waters. The coast between Cabo Delgado and Angoche is just such a typical reef area. Along the southern part of the Tanzania coast the trap fishery from the reef area has a current annual yield of 4.8 tonnes/km^2. Investigations from other areas in the region suggest that the maximum yield from the coral reefs is about 5 tonnes/km^2 (ANON, 1979). The area of the reefs along the northern Mozambican coast is of the order 1-2000 km^2, which gives an annual potential production of 5-10 000 tonnes.

By inshore fishery we mean fishing at depths less than 10 m. The area of the inshore waters is 2-5000 km^2, depending of the method of calculation. GULLAND (1970) suggests a potential annual yield of 2.5 tonnes/km^2 for areas of intermediate productivity in the Indian Ocean. Under these assumptions the expected potential yield of the inshore waters will probably be of the same order as that of the reef fishery.

7. SMALL PELAGIC FISH

7.1 Species composition

This group consists of the smaller schooling fish with a diurnal vertical migration pattern, and includes the following species:

ANCHOVY	- Stolephorus spp.
BARRACUDA	- Sphyreana spp.
DRIFTFISH	- Ariomma spp.
JACK	- Alepes sp., Carangoides spp., Caranx spp.
MACKEREL	- Rastrelliger spp., Scomber sp.
PONYFISH	- Leiognathidae
SARDINE	- Dussumieria sp., Etrumeus sp., Hilsa keelee, Pellona ditchela, Sardinella spp., Thryssa spp.
SCAD	- Decapterus spp., Trachurus sp.

Due to the deviation both in behaviour and biology of the Stolephorus spp. from the rest of the Engraulidae and Clupeidae families, these species have been put into a separate group, the ANCHOVY.

Along the whole coast of Mozambique the recordings of small pelagic fish were mainly confined to the shelf area, i.e. at depths less than 200 m.

To establish the pelagic species composition in an area based on catch data alone is rather dubious, due to the large space and time variations both in abundance and composition. Most of the pelagic species carry out regular vertical migrations. During daytime they occur as schools close to, or a few meters above, the bottom, and are during that time accessible to bottom trawls. At night the pelagic species disperse in the water column and are hence not caught with bottom trawls. This feature has been clearly demonstrated by BIRKETT (1978). By comparing the catches of pelagic fish in bottom trawls during day and night at Sofala Bank he shows that the night catch was only 2-5% of the day catch. The small night-time catches were probably accidental catches made during the few minutes the trawl was in mid-water.

Table 7.1. Pelagic species composition in the bottom trawls of “Aelita” and “Professor Mesyatsev” 20-100 m (% weight).

Vessel	Aelita						Prof. Mesyatsev					
Area	Sofala		Bazaruto		Delagoa		Sofala		Bazaruto		Delagoa	
Species	Jun-Aug 76	Oct-Dec 76	Apr 77	Jun 77	Dec-Jan 77	Apr-Jun 77	Jan 76	Aug 77	Jan 76	Aug 77	Jan 76	Aug 77
Barracudas - SPHYRAENIDAE			15.6	80.6		36.6	1.8	0.5		66	0.4	
Driftfish - ARIOMMIDAE	2.3	34.5		5.3	1.9	35.9	17.7	4.2				59.5
Mackerel - SCOMBRIDAE	26.8	12.2					20.8	14.8			4.5	18.5
Ponyfish - LEIOGNATHIDAE		4.3			26.1	9.7	5.8	3.6				
Sardines - CLUPEIDAE/ENGRAULIDAE	29.3	0.4					16.6	14.2				1.2
Scads/Jacks - CARANGIDAE	41.6	48.6	84.4	14.1	72.0	17.8	37.3	62.7	100	34	95.1	20.8

Table 7.1 shows the pelagic species composition in the bottom trawls of the “Aelita” and “Professor Mesyatsev” survey. Table 7.2 gives the same for the Soviet commercial trawlers for some months from which the data seems reliable. As can be seen, the most important pelagic group seems to be the CARANGIDAE, of which the two species round scad (Decapterus maruadsi) and horse mackerel (Trachurus trachurus) are dominant at Sofala Bank and Delagoa Bay respectively. In Delagoa Bay the horse mackerel is most abundant during summer and significantly less so in winter.

Table 7.2. Pelagic species composition in bottom trawl catches from a Soviet commercial trawler, 25-100 m (% weight).

	Sofala		Delagoa
	Dec 77	**Jun 77**	**Nov 77**
Barracudas - SPHYRAENIDAE	7.9	0.8	8.9
Driftfish - ARIOMMIDAE	19.9	-	4.8
Mackerel - SCOMBRIDAE	1.7	8.1	0.3
Sardines - CLUPEIDAE/ENGRAULIDAE	0.9	17.4	5.3
Scads/Jacks - CARANGIDAE	69.6	73.7	80.7
Hours of trawling	550	948	620

The sardine group consists mainly of the two species Indian pellona (Pellona ditchela) and orangemouth thryssa (Thryssa vitrirostris). They seem to be more frequent in bottom trawl catches during winter. The same pattern is shown by ponyfish (Leiognathus spp.) and barracuda (Sphyraena spp.). The latter species is especially dominant in the Bazaruto area. Driftfish (Ariomma sp.) contribute significantly to the catches at Sofala Bank in summer and in Delagoa Bay in winter.

Table 7.3. Pelagic species composition in trawl catches from Sofala Bank, 10-50 m (% weight).

Vessel	**KATTEGAT (Summer)**		**F. NANSEN (Summer)**		**F. NANSEN (Winter)**	
Gear	**Bottom trawl**	**Pelagic trawl**	**Bottom trawl**	**Pelagic trawl**	**Bottom trawl**	**Pelagic trawl**
Anchovies - STOLEPHORUS SP.				69.3		81.0
Barracudas - SPYRAENIDAE						2.9
Mackerel - SCOMBRIDAE	5.9	43.0	7.2	26.7	4.0	2.6
Sardines - CLUPEIDAE/ENGRAULIDAE	32.7	49.4	92.8		76.6	9.9
Scads - DECAPTERUS SPP.	29.0	0.6		0.8	1.9	3.5
Jacks - CARANGOIDES SP.	32.4	7.0		3.2	17.5	0.1

Table 7.3 shows the pelagic species composition at Sofala Bank in both pelagic and bottom trawls from “Kattegat” and “Dr. Fridtjof Nansen”. As can be seen, the composition of the catch from the two different gears deviates considerably. Some of this discrepancy can be explained by the distribution of day and night hauls. The anchovy (Stolephorus sp.), however, never occurred in bottom trawls. The reason why it did not occur in the pelagic trawl of “Kattegat” is probably due to misidentification, so the species has been put in the sardine group. Anchovies appear to be one of the major pelagic resources off Mozambique. As seen from Tables 7.1 - 7.3, a bottom trawl survey will not include this important species.

In order to reach a better estimate of the pelagic species composition, the catch data and the acoustic abundance data from “Dr. Fridtjof Nansen” were combined. The pelagic species composition in each trawl catch was regarded as representative for a sub-area. The pelagic echo abundance was split according to this composition and summed up for larger areas. The result is shown in Table 7.4. Table 7.5 lists the main pelagic species recorded by “Dr. Fridtjof Nansen”.

Fig. 7.1. Small pelagic fish distribution in September 1977.

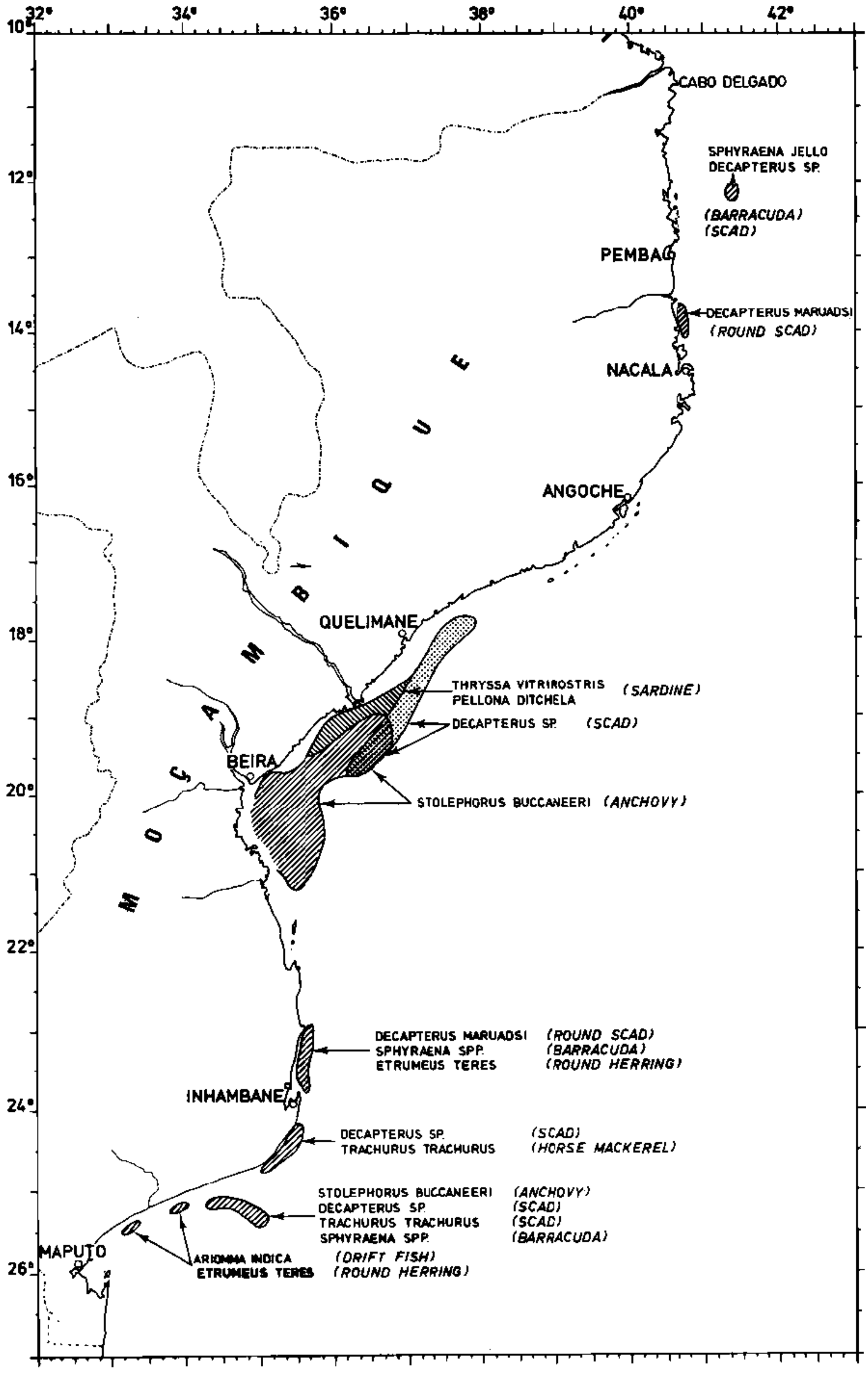


Fig. 7.2. Small pelagic fish distribution in November 1977.

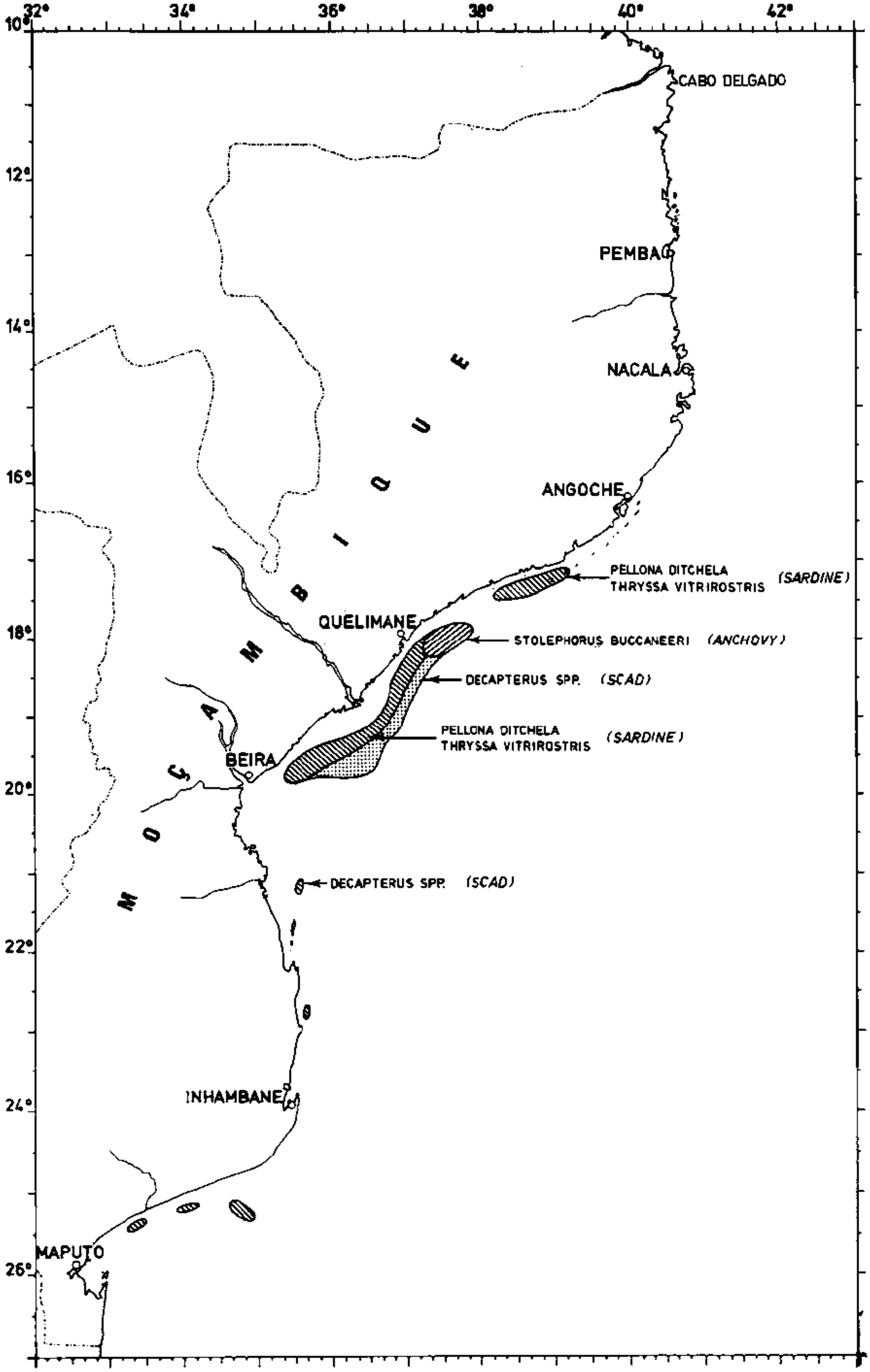


Fig. 7.3. Small pelagic fish distribution in February -March 1978.

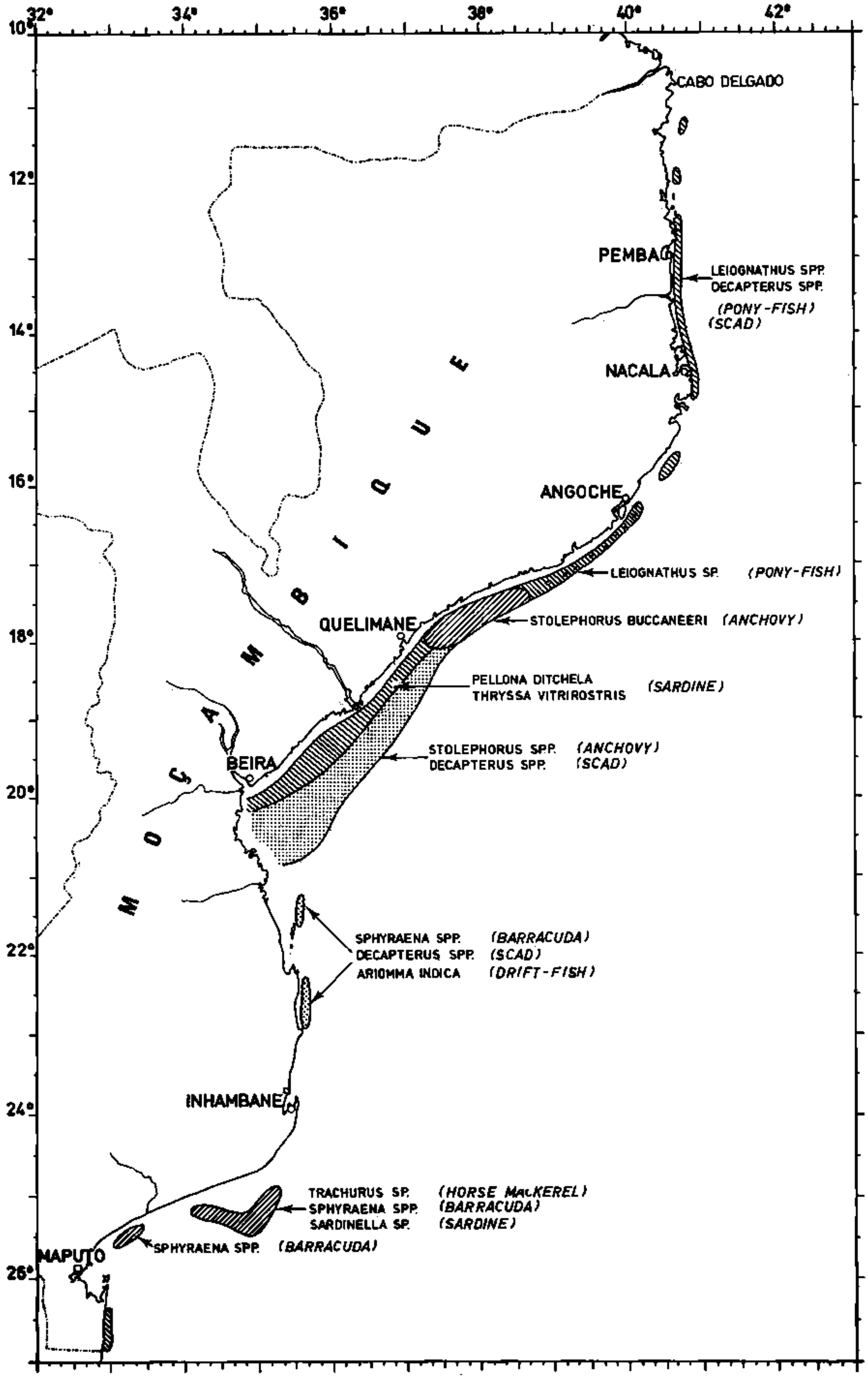


Fig. 7.4. Small pelagic fish distribution in April -June 1978.

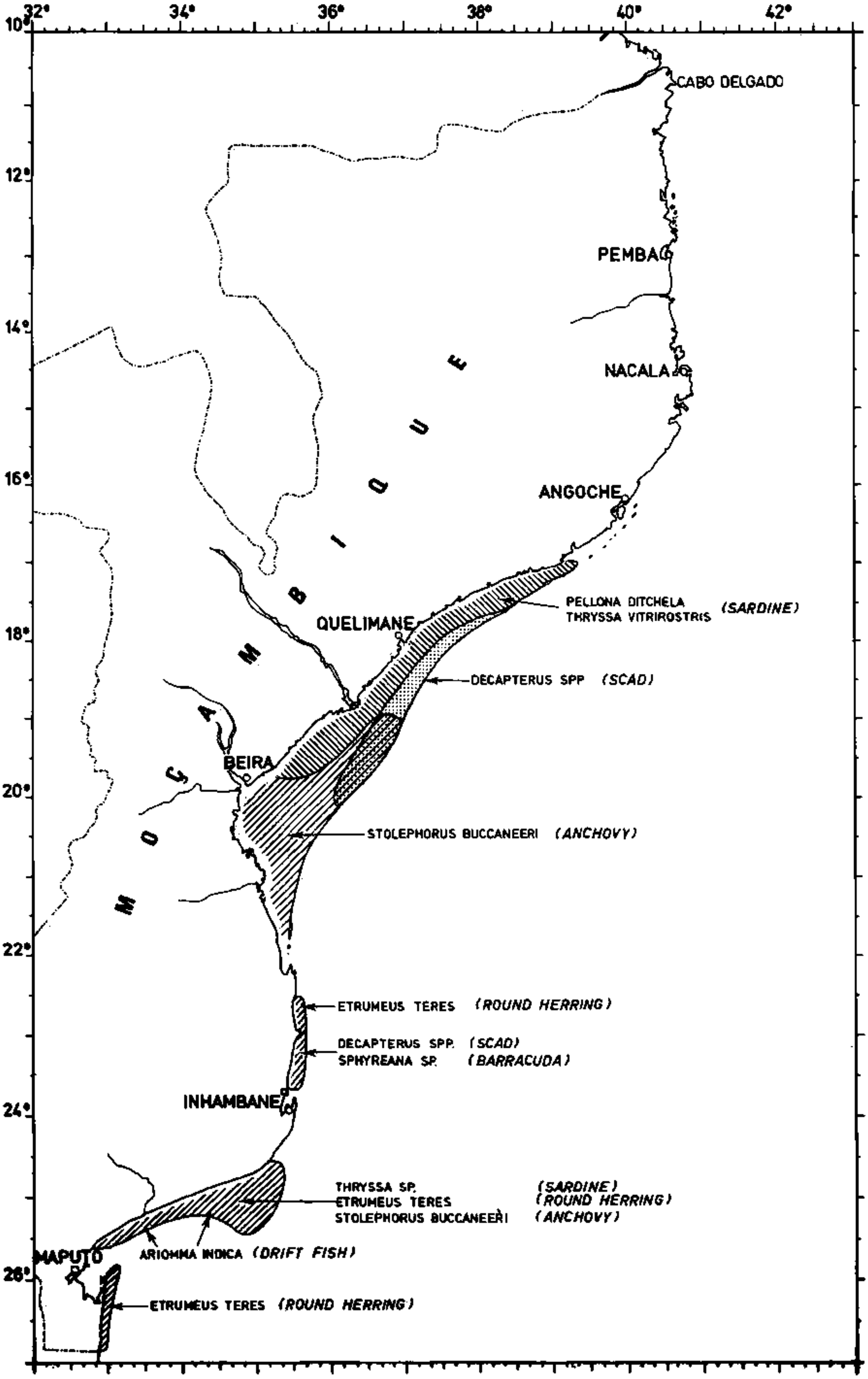


Table 7.4. Pelagic species composition from combined catch and acoustic data of the "Dr. Fridtjof Nansen" survey (% weight).

Area	Sofala			Bazaruto			Delagoa		
Species	Sep 77	Oct/Nov 77	Apr/Jun 78	Sep 77	Oct/Nov 77	Apr/Jun 78	Sep 77	Oct/Nov 77	Apr/Jun 78
Anchovies - STOLEPHORUS SP.	70	20	40	33					9
Barracudas - SPHYRAENIDAE				10		5	32		
Driftfish - ARIOMMIDAE						5			35
Mackerel - SCOMBRIDAE									
Ponyfish - LEIOGNATHIDAE			10			10			
Sardines - CLUPEIDAE/ENGRAULIDAE	20	60	40	3		10	10		39
Scads/Jacks - CARANGIDAE	10	20	10	54	100	70	58	100	17

7.2 The distribution

Figs. 7.1-7.4 show the distribution of the most important small pelagic species during the four cruises of "Dr. Fridtjof Nansen".

Northern area

At St. Lazarus Bank schools of banded barracuda (Sphyraena jello) and scad (Decapterus sp.) were observed in September 1977. North of Nacala, round scad (Decapterus maruadsi) were found along the bottom at about 200 m at the same time (Fig. 7.1). In February 1978 round scad and ponyfish (Leiognathus sp.) were found in the same area (Fig. 7.3). "Professor Mesyatsev" in January 1976 had a good catch of round scad from 186 m, just north of Nacala. As also pointed out by BIRKETT (1978), this may indicate that there is a continuous distribution of scad along the whole coast of Eastern Africa. In October 1977 "Kattegat" observed schools of scad in the area between Angoche and Pemba (ANON, 1978 e), which seem to confirm this. In November 1977 and in April 1978, however, there were no similar recordings (Figs. 7.2 and 7.3).

Table 7.5. Small pelagic species from the cruises of “Dr. Fridtjof Nansen”.

Area	Northern				Sofala				Bazaruto				Delagoa				Inhaca			
Cruise	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
<u>ARIOMMIDAE</u>																				
Ariomma indica *					x						x		x		x	x				
<u>CARANGIDAE</u>																				
Alepes djeddaba								x												
Carangoides chrysophrys							x								x					
Carangoides malabaricus			x				x								x	x				
Decapterus macrosoma *						x		x					x							
Decapterus maruadsi *	x				x	x		x	x			x								
Megalaspis cordyla *																x				
Selar crumenopthalmus						x		x												
Trachurus trachurus *													x		x					
<u>CLUPEIDAE</u>																				
Dussumeria acuta					x			x												
Etrumeus teres *									x			x	x			x				x
Hilsa kelee					x															
Pellona ditchela *					x	x	x	x												
Sardinella melanura								x												
Sardinella gibbosa								x					x		x					
Sardinella sirm					x			x												
<u>ENGRAULIDAE</u>																				
Thryssa setiorostris					x															
Thryssa vitrirostris *					x	x	x	x								x				
Stolephorus buccanerii *					x	x	x	x					x							
<u>LEIOGNATHIDAE</u>																				
Gazza minuta							x								x					
Leiognathus elongathus												x								
Leiognathus equulus *							x													
Secutor ruconius						x														
<u>SCOMBRIDAE</u>																				
Rastrelliger kanagurta					x			x												
Rastrelliger brachysoma															x					
<u>SPHYRAENIDAE</u>																				
Sphyraena forsteri					x															
Sphyraena jello	x																			
Sphyraena japonica	x										x				x					
Sphyraena obtusata *					x		x	x	x				x							

*) The most abundant species.

<u>Sofala Bank</u>

At Sofala Bank the following species were dominant: Buccaneer anchovy (<u>Stolephorus</u> <u>buccanerii</u>), Indian pellona (<u>Pellona</u> <u>ditchela</u>), orangemouth thryssa (<u>Thryssa</u> <u>vitrirostris</u> and round scad (<u>Decapterus</u> <u>maruadsi</u>). Orangemouth thryssa and Indian pellona shared a common distribution area and were not usually found in deeper water than 40 m. The orangemouth thryssa seemed to have a more near-shore distribution, as this species was dominant in catches from shallower depths than 20 m, while Indian pellona contributed most at depths between 20 and 40 m. Scad were mainly observed at depths between 40 and 100 m and anchovies between 20 and 60 m.

There seemed to be a migration to the northern part of Sofala Bank of anchovies from November to February. In April anchovies again had approximately the same distribution area as in September.

Bazaruto area

In this area the pelagic recordings were usually made up by the following species: Round scad, barracuda (Sphyraena japonica, S. obtusata) and round herring (Etrumeus teres). In addition, some driftfish (Ariomma indica) occurred in March. Off Imhambane concentrations of porcupine fish (Diodon maculifer) were observed as schools during all four cruises. This contribution to the acoustic pelagic recordings has been deleted as this species is of no commercial value.

Delagoa Bay

The most abundant Carangidae in this area were horse mackerel (Trachurus trachurus) which were only rarely observed further north. At Boa-Paz Bank schools of layang scad (Decapterus macrosoma) were observed in September 1977. Also barracuda (Sphyraena obtusata, S. japonica) and Indian driftfish (Ariomma indica) were abundant during winter at depths more than 100 m.

Fig. 7.5. Distribution of modal length and range for some small pelagic species. (A)

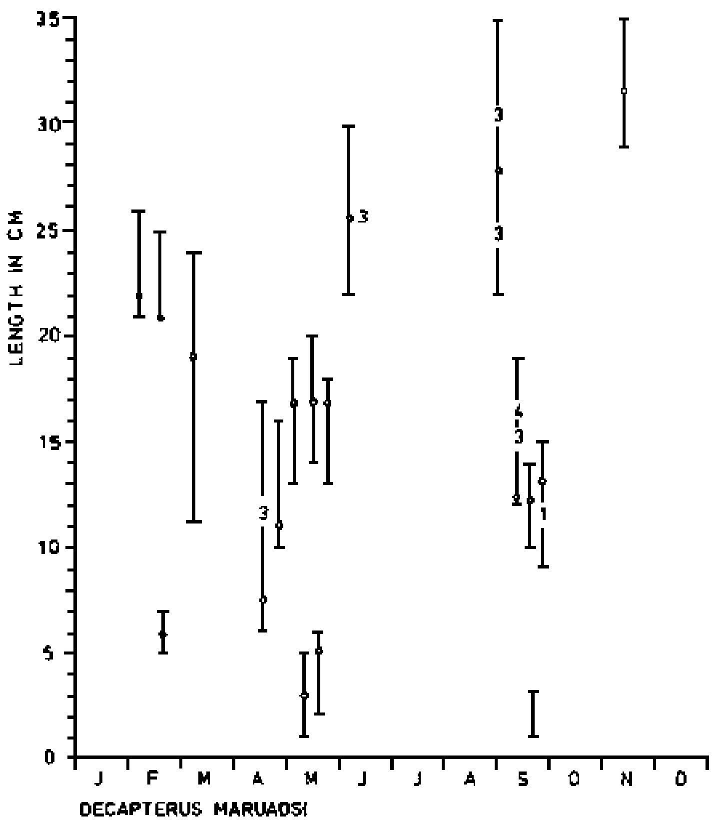


Fig. 7.5. Distribution of modal length and range for some small pelagic species. (B)

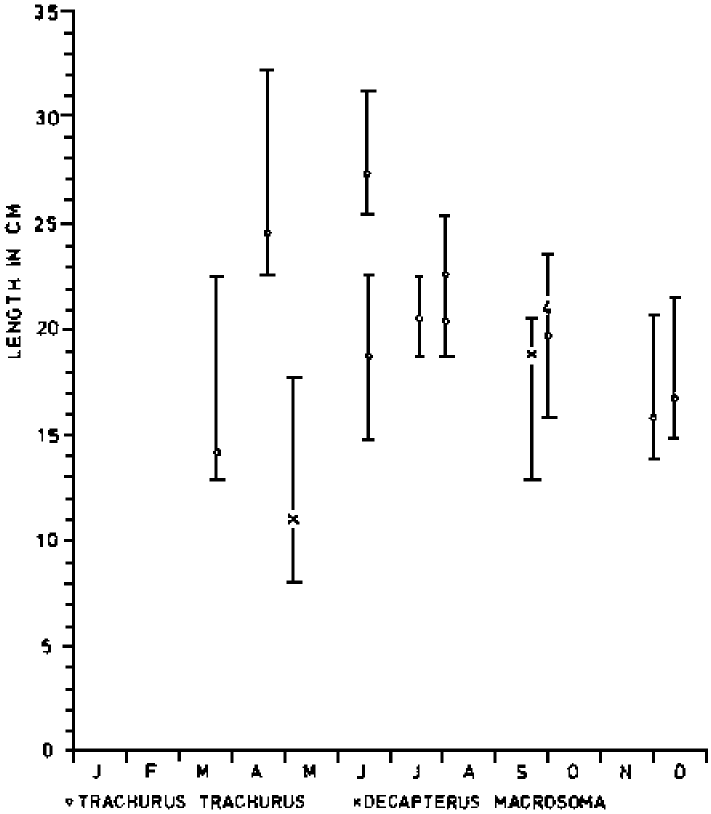


Fig. 7.5. Distribution of modal length and range for some small pelagic species. (C)

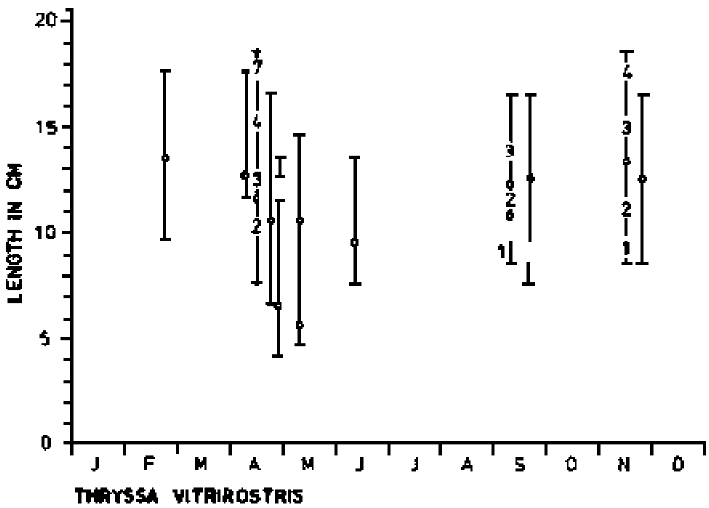


Fig. 7.5. Distribution of modal length and range for some small pelagic species. (D)

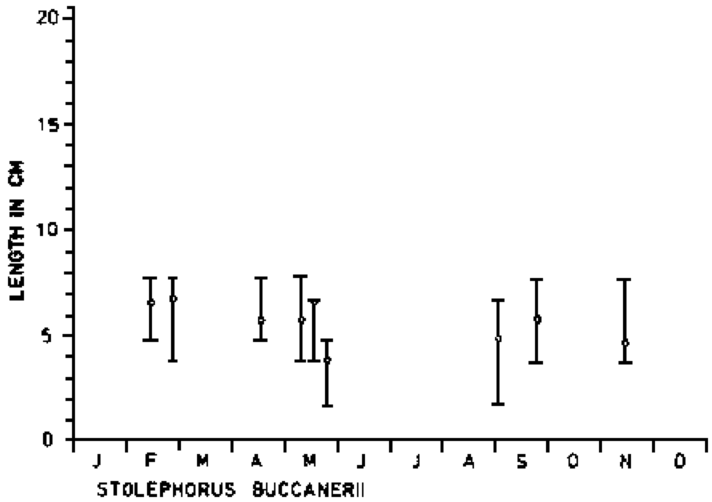


Fig. 7.5. Distribution of modal length and range for some small pelagic species. (E)

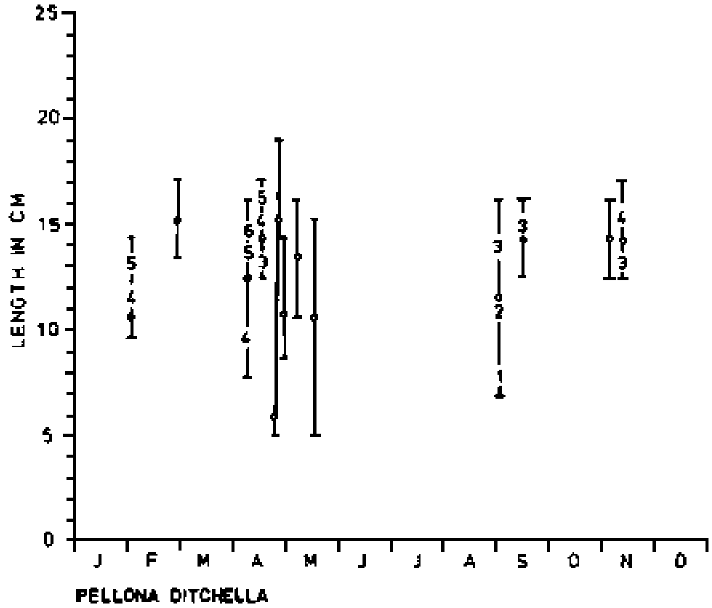


Fig. 7.5. Distribution of modal length and range for some small pelagic species. (F)

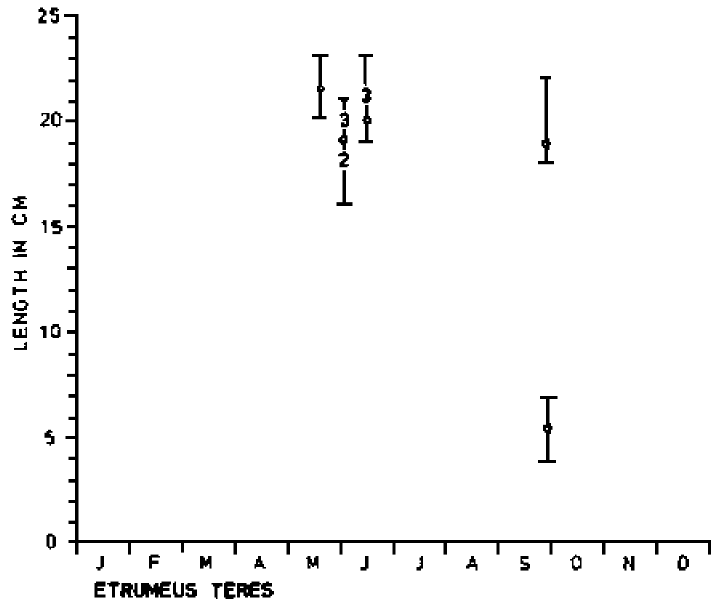


Fig. 7.6. Distribution of modal length and range for some small pelagic species. (A)

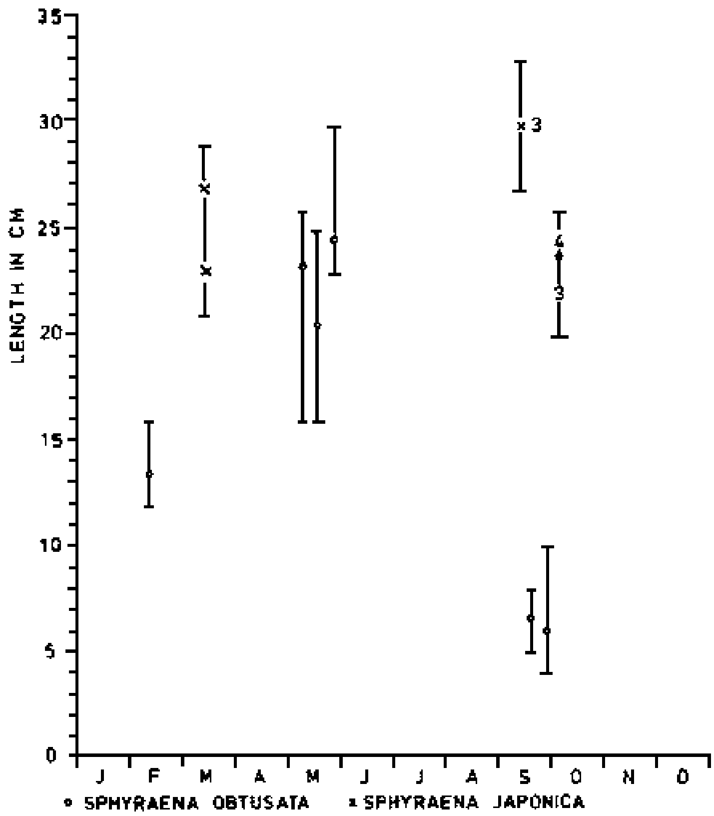


Fig. 7.6. Distribution of modal length and range for some small pelagic species. (B)

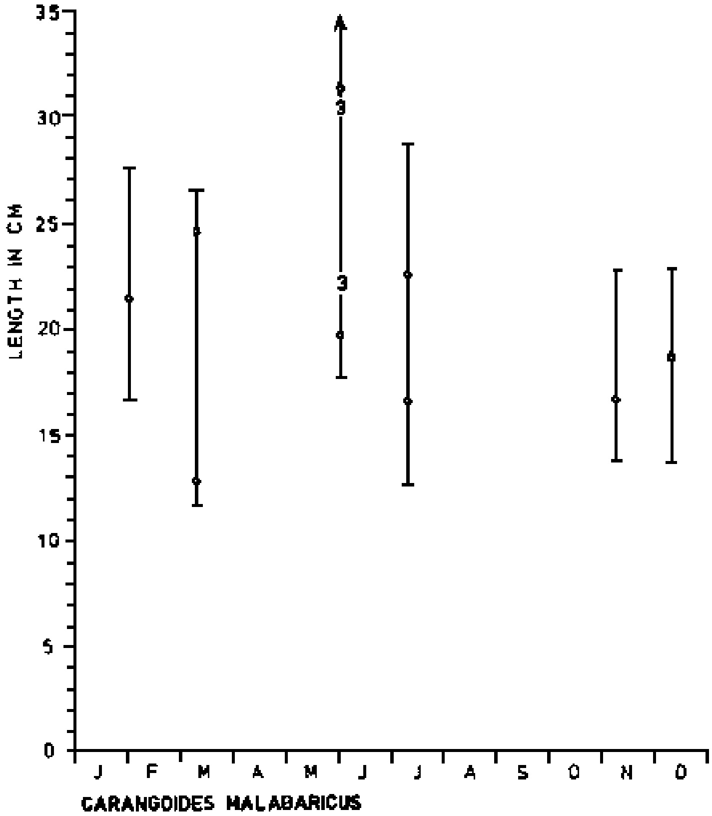


Fig. 7.6. Distribution of modal length and range for some small pelagic species. (C)

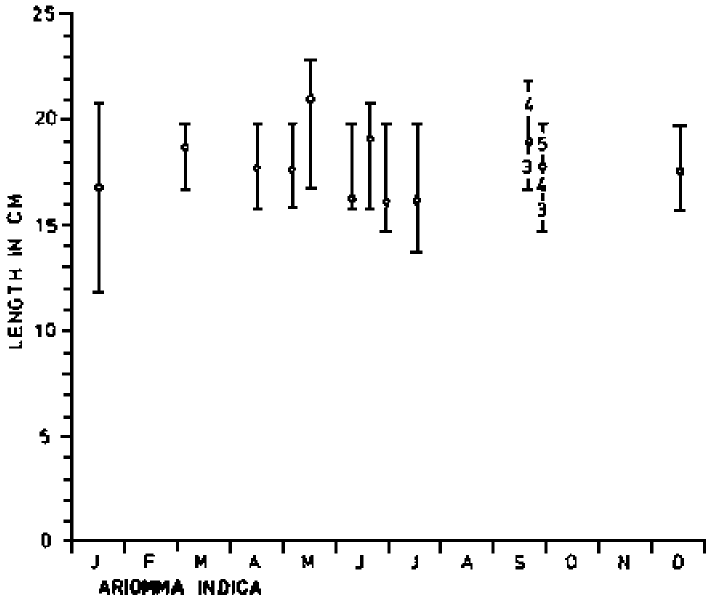
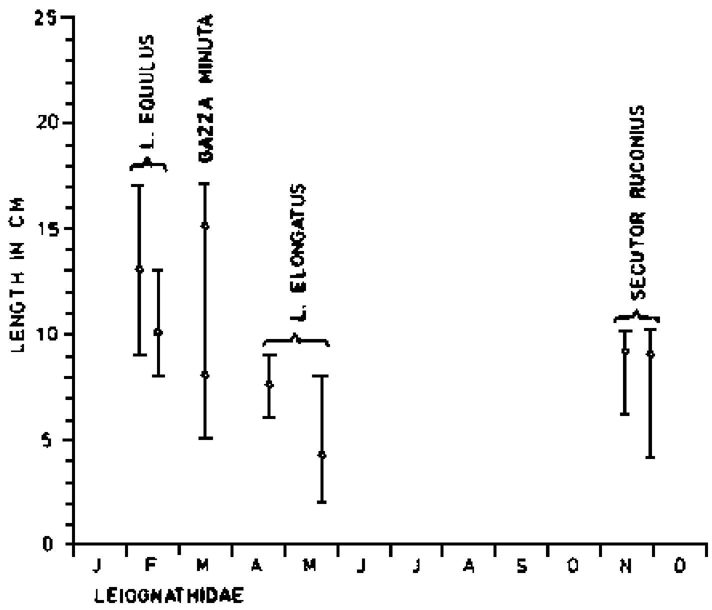


Fig. 7.6. Distribution of modal length and range for some small pelagic species. (D)



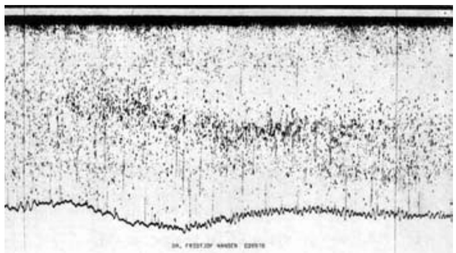
Inhaca

The only pelagic species observed in this area was round herring, in June 1978.

7.3 Biological characteristics

Figs. 7.5 and 7.6 give the mode and range of the length as well as observations on maturity stages for the most important pelagic species.

Fig. 7.7. Night recording of buccaneer anchovy.



Anchovy

This group was exclusively made up of the buccaneer anchovy (Stolephorus buccaneerii). During night-time the anchovy was dispersed more or less in the whole water column, as seen in Fig. 7.7. During daytime, however, it formed schools in mid-water (Fig. 7.8) and not close to the bottom as did most of the other pelagic species. As seen in Fig. 7.5, the smallest individuals occurred in May and September, thus indicating the main spawning periods to be April and August. Observations from India (ANON., 1976 a) show that some closely related species have very rapid growth and that the adult size is reached after about 6 months. The temperature conditions off the western Indian coast and off Mozambique are approximately the same, and therefore the same growth pattern should be expected along the coast of Mozambique. The apparent migration of this species on Sofala Bank is most likely associated with the main spawning which seemed to take place at the southern part of Sofala Bank at depths of 30-60 m.

Fig. 7.8. Day recording of buccaneer anchovy.

Barracuda

This family includes the four species listed in Table 7.5 of which obtuse barracuda (Sphyraena obtusata) were the most abundant. Barracuda seemed to form commercial concentrations at 200-250 m depths, during April-July in the Bazaruto area. Fig. 7.9 shows an echo recording of Sphyraena japonica off Bazaruto in March at 260 m depth, resulting in a catch rate of about 2 tonnes/hr. The modal length distribution in Fig. 7.6, together with the maturity observations from “Aelita” (BUDNICHENKO et al., 1977), suggests a main spawning period in June-August for the obtuse barracuda.

Driftfish

The Indian driftfish (Ariomma indica) was found at depths between 30 to 350 m but mainly at 50-100 m. There seemed to be a migration of driftfish from Delagoa Bay to Sofala Bank in September-October and back again in February-March. The species composition in Tables 7.1 and 7.2 supports this view. The modal length distribution in Fig. 7.6 gives no indications as to any preferred spawning period. However, spent females were observed in the Bazaruto area in January and maturity observations from “Aelita” (BUDNICHENKO et al., 1977) indicate another spawning in July-August.

Fig. 7.9. Echo recording of barracuda at the bottom.

Ponyfish

This group consists of the following species: Secutor insidiator and S. ruconius, Gazza minuta, Leiognathus elongatus and L. equulus, of which the latter is the most abundant. The ponyfish showed typical pelagic fish behaviour and can occur in large schools at the bottom during daytime, as can be seen in Fig. 7.10, catch rates of up to 3.5 tonnes/hour can be achieved. The modal length distribution in Fig. 7.5 gives some support for a spawning in April for L. elongatus. The observation of small juvenile Leiognathus sp. 1-5 cm long in April might mean that others of the ponyfish group were also spawning at the same time.

Sardine

Spawning females of the Indian pellona (Pellona ditchela) were observed in April, the smallest individuals being noted in April-May (Fig. 7.5). The main spawning season therefore seemed to be in March-May. Most likely there was also a secondary peak in the spawning activity from August to November. During daytime the pellona formed schools close to the bottom, as seen in Fig. 7.11.

Fig. 7.10. Echo recording of ponyfish at the bottom during day time.

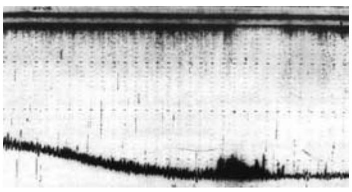
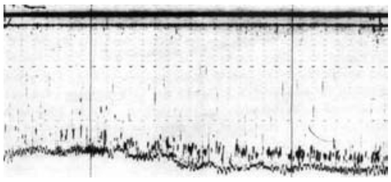


Fig. 7.11. Day recording of Indian pellona.



The Indian pellona was usually found together with orangemouth thryssa (Thryssa vitrirostris) which seemed to have a peak spawning period in March-May (Fig. 7.5).

The round herring (Etrumeus teres) was only observed south of Sofala Bank. Juveniles 4-7 cm long were observed in September and a few spawning females in May.

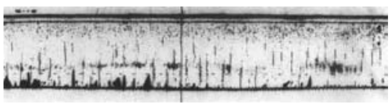
A few catches of kelee shad (Hilsa kelee) were made at Sofala Bank, but this species had probably a very near-shore distribution and was therefore rarely observed by the research vessels. A fishery on this species is carried out in shallow water in the bays of Maputo and Beira.

Scad/Jack

The most abundant species of this group was round scad (Decapterus maruadsi). It was often recorded together with layang scad (Decapterus macrosoma). As can be seen in Fig. 7.5 the smallest individuals of round scad were found in May and September. This, in addition to the observation of spawning females in April by “Aelita”, (BUDNICHENKO et al., 1977) indicates peak spawning periods in April and September. Round scad probably migrate to deeper water for spawning. This agrees with the observations on the Californian Jack mackerel (Trachurus symetricus) which spawns in offshore deeper grounds (FREY, 1971).

Support to this theory is also given by the reduction of catch in the 0-50 m layer, with a corresponding increase from 50-100 m during March-May by the Soviet commercial trawler. “Professor Mesyatsev” observed the same tendency in August 1977 compared to January 1976 (BIRKETT, 1978). In October 1977 “Professor Mesyatsev” recorded substantial concentrations of round scad at the Mahé plateau (BIRKETT, 1978), but in July 1978 mainly juveniles were observed (ANON, 1978 d). Of the few recordings of adults, about 20% were in maturity stages 5 and Fig. 7.12 shows a typical day recording of round scad. As can be seen, they were observed as schools at the bottom while the sardine schools were usually found a few meters above the bottom. During night-time they were dispersed in the upper part of the water column.

Fig. 7.12. Day recording of round scad.



Layang scad seemed to have a different spawning time to the round scad. Observations from “Aelita” (BUDNICHENKO et al., 1977) showed that more than 50% of the females were in maturity stage 5 in December 1976. In April the majority of the females were in stages 1-3, and in June 100% were in stage 3. Though perhaps somewhat dubious, this could indicate only one main spawning period in January-February, which also seems to fit the distribution of modal length in Fig. 7.5.

The malabar cavalla (Carangoides malabaricus) (Fig. 7.6) was found along most of the coast at depths between 20 and 100 m. No spawning or near-spawning females were observed on any of the cruises.

The horse mackerel (Trachurus trachurus) is not usually observed north of Bazaruto, and is most abundant at Boa-Paz Bank. It occurred at depths between 30 and 150 m, with the greatest concentrations at about 50 m. A main spawning season seemed to take place in September-October.

7.4 Abundance

Table 7.6 shows the acoustic abundance estimates of the main pelagic stocks. As can be seen, the most important species was the buccaneer anchovy, amounting to about 300 000 tonnes, followed by scad, Indian pellona and orangemouth thryssa.

Table 7.6. Acoustic estimates of the main pelagic stocks from "Dr. Fridtjof Nansen" (thousand tonnes.)

Time	Species	St. Lazarus-Delgado	Sofala Bay	Bazaruto	Delagoa	Inhaca	Total
Sep 1977	Decapterus spp.	32	41	32	5	-	110
	Etrumeus sp.			2	2		4
	Sphyreana spp.	5		6	6		17
	Stolephorus sp.		290	20			310
	Pellona sp.		62				62
	Thryssa sp.		20				20
	Trachurus sp.				6		6
	Total	37	413	60	19	-	529
Oct-Nov 1977	Decapterus spp.		30	1	5		36
	Stolephorus sp.		30				30
	Pellona sp.		50				50
	Thryssa sp.		50				50
	Trachurus sp.				4		4
	Total		160	1	9		170
Apr-Jun 1978	Decapterus spp.		25	26			51
	Stolephorus sp.		95		5		100
	Sphyreana spp.			2			2
	Etrumeus sp.			4	5	5	14
	Pellona sp.		45				45
	Thryssa sp.		45		16		61
	Leiognathus sp.		25	4			29
	Ariomma sp.			2	17		19
	Trachurus sp.				5		5
	Megalaspis sp.				5		5
	Total		235	38	53	5	331

BIRKETT (1978) presents abundance estimates for pelagic fish from the "Professor Mesyatsev" investigation (Table 1.5). For Sofala Bank he gives 94 500 and 42 400 tonnes for January and August respectively. For Delagoa Bay the corresponding figures are 40 200 and 4600 tonnes. These estimates are much lower than those presented in Table 7.6. Birkett's values were obtained by "the swept area" method. Only day hauls were used, and the efficiency coefficient of the trawl was taken as 1.

The main sources of error in such calculations are the efficiency coefficient and the necessary assumption that the trawl hauls are representative of the general fish density within the surveyed area. The supposition of 1 as the efficiency coefficient will for pelagic species result in a underestimate of the fish density, as echo recordings have shown that even during daytime a proportion of the pelagic population is situated well above the headline height. It is also likely that some of the pelagic and fast-swimming species ahead of the trawl are able to avoid the net.

If the trawl hauls are going to be representative for the whole surveyed area, random chosen fishing localities should be used. The trawl hauls of "Professor Mesyatsev" did not fully satisfy this condition for the pelagic species. However, the distribution of trawl stations at Sofala Bank (BIRKETT, 1978) indicates that this source of error is of minor importance off Mozambique. The assumption of 1 as the efficiency coefficient is probably more important, and thus the estimates of BIRKETT (1978) are most likely undervalued.

By removing from Table 7.6 the Stolephorus sp. at Sofala Bank which were not recorded by "Professor Mesyatsev", the total pelagic stock estimate of "Dr. Fridtjof Nansen" in this area varies between 123 000 and 140 000 tonnes. This means that one has to multiply Birkett's estimate by a factor between 1.3 and 3.3 in order to reach the pelagic stock estimates made by "Dr. Fridtjof Nansen".

BURCZYNSKI (1976) presents a pelagic fish stock evaluation based on the echo survey of "Professor Mesyatsev" in January 1976 (Table 1.4). The results are based on calibration of the echo integrator by means of sample hauls. At Sofala Bank he arrived at a pelagic stock size of 65 000 tonnes and in Delagoa Bay 11 000 tonnes. Burczynski believs the last figure to be an underestimate due to bad weather conditions which dispersed the stock and an unsatisfactorily grid pattern.

Some additional information on the acoustic survey of "Professor Mesyatsev" was brought forward during the FAO/IOP Workshop on the Fishery Resources of the Western Indian Ocean south of the Equator held in the Seychelles 23 October - 4 November 1978 (ANON, 1979). According to the Soviet calculations the pelagic stock at Sofala Bank was 90 000 and 62 000 tonnes in January and February 1976 respectively, and only 5000 tonnes in August 1977. In Delagoa Bay the pelagic stock both in January 1976 and in August 1977 amounted to 7000 tonnes.

As can be seen, the echo survey results from "Professor Mesyatsev" give lower values for the pelagic stocks off Mozambique than those from "Dr. Fridtjof Nansen". This is believed to be due to the following reasons:

- The anchovy (Stolephorus sp.) is not included in the estimates from "Professor Mesyatsev".

- The tendency of "Professor Mesyatsev" to only count concentrations of pelagic fish and not to attempt to include also the dispersed distribution.

- The calibration procedure of the echo integrator aboard "Professor Mesyatsev" by using the trawl catches as a measure of absolute density.

The objections to the last point are the same as those previously mentioned in relation to the calculations of BIRKETT (1978).

Also the final report of the "Aelita" investigation (BUDNICHENKO et al., 1977) includes some abundance estimates based on the "swept area method" (Table 1.6). The catches have not been split into demersal and pelagic species, and the calculation was carried out only for a proportion of the total fishable areas. The results presented therefore give the total fish abundance and are quite obviously an underestimate.

To estimate the potential annual yields of the pelagic stocks in the area, the formula of GULLAND (1970), $Y_{max} = 0.5 \cdot M \cdot B_O$, was applied. M is the natural mortality rate and B_O the virgin or unexploited stock. If fishing is significant some modification is needed. In this case the equation $Y_{max} = 0.5\ (C + MB_1)$ max was used, where C is the present catch and B_1, the exploited stock. For the sardine, ponyfish and scad, which are caught as by-catch in the shrimp fishery at Sofala Bank, the last formula was applied.

The natural mortality coefficient for the fish in the region is not satisfactorily known. Estimates for similar species in other regions make it reasonable to use M = 2 for the anchovy and M = 1 for the rest of the pelagic species (PAULY, 1978). The results of these calculations appear in Table 7.7. For B_O or B_1, the maximum stock size recorded was used. The results of Y_{max} in Table 7.7 therefore presuppose that the most optimum fishing pattern is used.

If the anchovy is subtracted, the maximum potential annual yield in Table 7.7 amounts to 162 000 tonnes. The pelagic stock excluding the anchovy varied between 140 000 and 231 000 tonnes, as seen in Table 7.6. If one estimates the average stock to be 200 000 tonnes, and the present catch to be 40 000 tonnes as a by-catch in the shrimp fishery, this will give a potential annual yield of 120 000 tonnes.

Table 7.7. Maximum potential annual yield of pelagic stocks (thousand tonnes).

Species	B_{max}	C_B	C_S	M	Y_{max}
Anchovies	310	-	-	2	310
Barracudas	17	-	0.5	1	8
Driftfish	19	-	0.5	1	9
Mackerel	-	2	0.5	1	-
Ponyfish	29	10	-	1	20
Sardines	120	10	0.5	1	65
Scads	116	4	4.5	1	60

B_{max} = Maximum stock size
C_B = Estimated by-catch in shrimp fishery
C_S = Estimated Soviet catches Sep. 77 - Jun. 1978
M = Instantaneous mortality rate
Y_{max} = Maximum potential yield

8. LARGER PELAGIC SPECIES

The lack of data makes it difficult to go into details for this group. During the surveys of “Dr. Fridtjof Nansen” and “Kattegat” little attention was paid to the larger pelagic species. However, on both vessels visual sightings of surface schools were recorded, and these appear in Fig. 8.1. The schools were not usually detected by the sonar as they were confined to very near the surface. Some of the surface school observations consisted of species belonging to the group “small pelagic species”, mostly scad.

Table 8.1. Composition of the long-line catches of “Aelita” (% weight).

TUNAS	44.7	
Thunnus albacores		34.1
T. obesus		6.1
T. alalunga		4.0
BILLFISH	27.3	
Makaira ampla		24.0
Xiphias gladius		3.0
Makaira mazara		0.3
SHARKS	23.0	
Prionace glauca		8.5
Carcharhinus limbatus		5.9
Alopias vulpinus		2.8
Carcharhinus longimanus		2.1
C. melanopterus		1.4
C. albimarginatus		1.3
C. leucas		0.6
C. brevipinna		0.4
OTHERS	5.0	

In August and November 1976 and in June-July 1977 “Aelita” carried out 29 long-line stations over depths between 500 m and 2800 m. More than half of the stations were carried out between Bazaruto Island and Angoche. Table 8.1 gives the composition of the catches. The average catch rate was 146 kg/-100 hooks. As seen in Table 8.1 tuna contributed 44.7%, billfish 27.3% and sharks 23%. Of the tunas the yellowfin tuna (Thunnus albacares) was the dominant species. Also bigeye tuna (Thunnus obesus) contributed significantly. The best catches of tuna were obtained off Sofala Bank in June, where the bottom depths were 1200-2000 m and the depth to the thermocline 60-80 m.

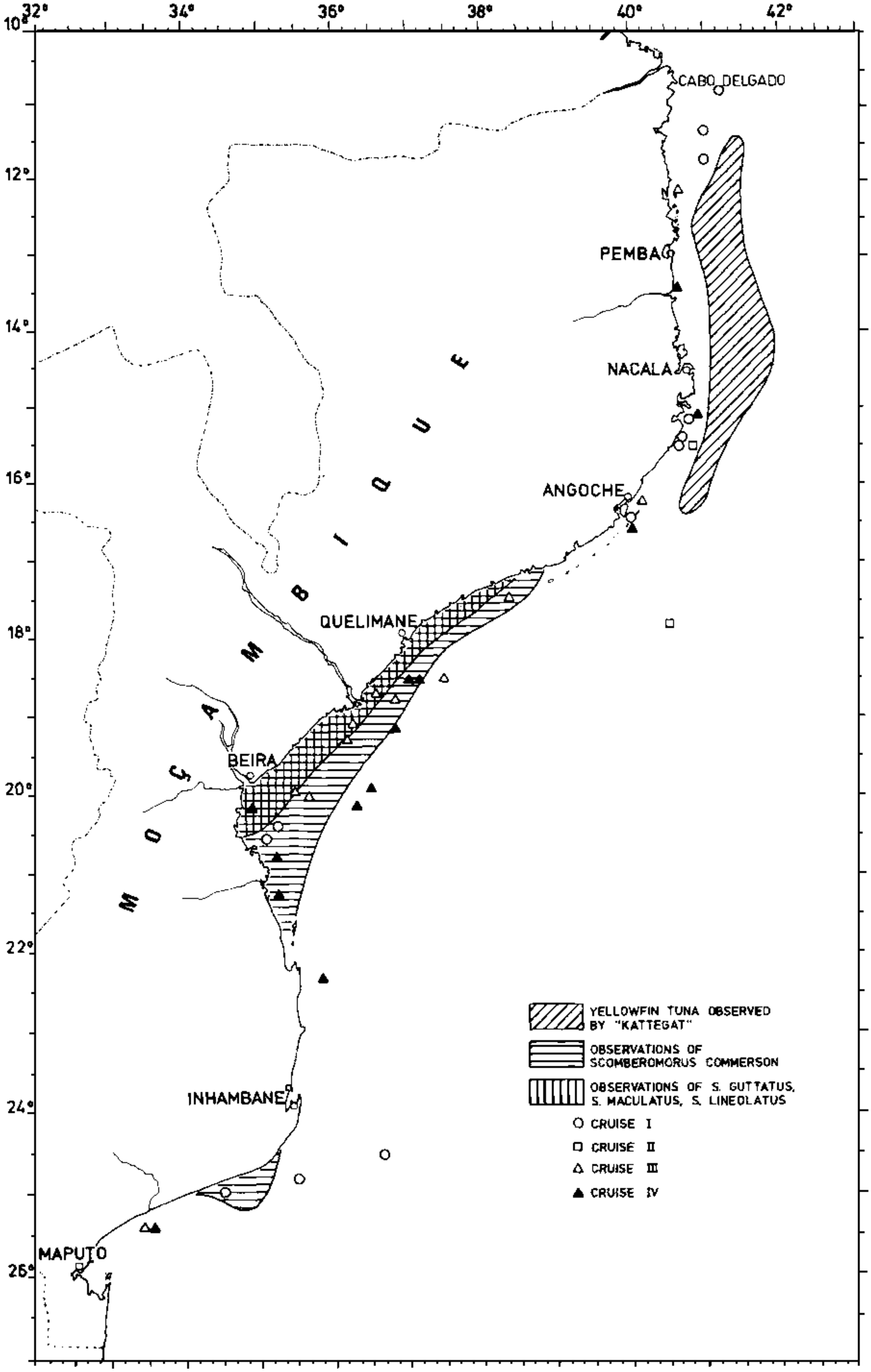
Among the billfishes the marlin (Makaira ampla) dominated the catches. Also for these species the best catches were taken off Sofala Bank. The most important sharks caught were the blue shark (Prionace glauca) and grey shark (Carcharhinus limbatus).

Spanish mackerel

The most abundant of these species caught on the “Dr. Fridtjof Nansen” surveys was the narrow-barred Spanish mackerel (Scomberomorus commerson). It occurred frequently as by-catch both in bottom and pelagic trawls and catches up to 60 kg/hour were obtained. “Professor Mesyatsev” had catches up to 137 kg/hour at Sofala Bank in July. The distribution area of the narrow-barred Spanish mackerel is indicated in Fig. 8.1. It was only recorded in water shallower than 50 m at Sofala Bank and at the Boa-Paz Bank. Other Spanish mackerel, such as S. guttatus, S. maculatus and S. lineolatus, were only caught at Sofala Bank and appeared to have a more near-shore distribution than S. commerson; this can be seen in Fig. 8.1. These species were not usually observed in water deeper than 30 m. The major part of the surface schools recorded over the shallower part of Sofala Bank probably consisted of Spanish mackerel. These schools were frequently seen in the distribution area of the buccaneer anchovy on which they feed.

Juvenile Spanish mackerel of about 2-3 cm were found in April off Cabo Delgado. In May and September specimens of 5-7 cm were caught at Sofala Bank. These observations indicate two peaks in the spawning activity, namely in April and August.

Fig. 8.1. Observations of larger pelagic species and surface schools.



Sharks

Table 8.2 lists the most important sharks identified on the cruises of "Dr. Fridtjof Nansen". They were accidentally caught in trawl hauls and some very good catches were obtained by gill-net and longline. Sharks were frequently observed swimming at the surface and were especially abundant off the mouth of the Zambezi River. There is without doubt a significant resource of sharks which at present are only lightly exploited. They are caught as by-catch in the shrimp fishery and in the bottom trawl fishery of the Soviet trawlers.

Table 8.2. Sharks identified on the cruises of "Dr. Fridtjof Nansen".

Area	Northern				Sofala				Bazaruto				Delagoa			
Cruise	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
CARCHARHINIDAE																
Carcharhinus brachyurus								x								x
C. brevipinna							x				x					
C. falsiformis*						x		x				x				x
C. limbatus								x								
C. longimanus							x				x					
C. melanopterus					x		x									
C. obscurus*	x						x				x	x			x	
C. sealei			x					x								
Galeorhinus galeus						x										
Hypogaleus hyugaensis																x
Mustelus manato*								x				x			x	x
M. mustelus							x									
Rhizoprionodon acutus						x										x
SPHYRNIDAE																
Sphyrna lewini					x			x								x
S. mokarran							x									
S. zygaena*							x	x					x			
MOBULIDAE																
Mobula diabolus								x								

Tunas

A significant proportion of the surface schools observed by "Dr. Fridtjof Nansen" in more offshore waters probably consisted of tuna. "Kattegat" in November-December 1977 made several sightings of surface schools of yellowfin tuna in the area from Angoche to north of Pemba (Fig. 8.1).

Others

Talang queenfish (Scomberiodes commersonianus) and cobia (Rachycentron canadus) were caught in small numbers at some trawl stations on the shallower part of Sofala Bank. In the same area there were also a few accidental catches of the eastern little tuna (Euthynnus affinis) and the oriental bonito (Sarda orientalis).

9. MESOPELAGIC FISH

9.1 Species composition and distribution

The species composition in the catches was only fully studied during a cruise in April-June 1978, and partly during January-March 1978. A list of species caught on these cruises is given in Table 9.1. Provisional identification carried out at sea during the other cruises suggests, however, that the dominant species were the same.

Table 9.1. Species identified during cruises 3 and 4 of "Dr. Fridtjof Nansen".

AREA	NORTHERN			SOFALA BANK				BAZARUTO		DELAGOA		INHACA			
St.no.	91	93	96	41	100	135	137	142	143	56	182	64	62	152	151
Benthosema fibulatum		+	+			1	2	1		2			1	1	+
B. pterotum											1				
Hygophum hygomi				+											
Myctophum spinosum	+														
M. obtusirostrum			+												
M. asperum				+											
M. aurolaternatum				+											
Symbolophorus evermanni	1		+												
Diaphus garmani			1			2	+	+		+					
D. nielseni		1	+		2		+								
D. watasei				1					2	1		1		2	1
D. suborbitale			+												
D. thiollierei		+			+					+					
D. perspicillatus		2	2	2	1	+	+								
Lampanychtus sp.	2		+												
Maurolicus muelleri							1	+	1						2
Polymetme corythaeola														+	

1 and 2 indicate first and second species in abundance respectively, + indicates presence in sample.

Benthosema fibulatum was caught all over the area studied and it was dominant at most stations south of 20°S. It was caught both in bottom trawls and in pelagic trawls. B. fibulatum is abundant in the north-western Indian ocean (GJØSÆTER, 1978) and KOTTHAUS (1972) caught specimens as far south as about 5°S. GRINDLEY & PENRITH (1965) report occurrence of B. fibulatum off the Natal coast. Based on these records and the present observations, B. fibulatum seems to be present in coastal waters along the whole of east Africa.

B. pterotum was caught at one station (25°14'S 34°33,5'E), where it was the only species caught. The catch was about 7 kg. Previously, B. pterotum is known in the Arabian Sea south to about 3°N off east Africa (GJØSÆTER, 1978). The present record seems to be the first from the southern Indian Ocean.

The specimens could not be distinguished from B. pterotum from the Arabian Sea in their distribution of photophores, but they had a lower number of gill rakers on the first gill arch with a mean of 23.10 versus 26.56. Although the difference in this single character does not justify description of a new species, it warrants further studies on the taxonomy of B. pterotum stocks along the east coast of Africa.

Hygophum hygomi was caught at one station, about 20°S. This species apparently has a bipolar distribution (BEKKER, 1965). NAFPAKTITIS and NAFPAKTITIS (1969), caught this species between about 20° and 35°S in the Indian Ocean.

Myctophum spinosum and M. aurolaternatum were caught at one station each, both between 13° and 15°S. NAFPAKTITIS and NAFPAKTITIS (1969) caught both species southwards to 10°S in the Indian Ocean.

M. asperum and M. aurolaternatum were caught at one station, about 20°S. NAFPAKTITIS and NAFPAKTITIS (1969) caught these species between 10°N and 10°S and between 5°N and 10°S respectively, in the Indian Ocean.

Symbolophorus evermanni was the dominant species at one station at about 13 S and was present at one about 16°S. Previously NAFPAKTITIS and NAFPAKTITIS (1969) recorded this species south to about 15°S in offshore waters.

Diaphus garmani was caught between 16°S and 26°S. It was the most abundant species in a night haul at 50 m depth at about 16°S. It ranged second in a bottom trawl haul at 50 m depth. The records fall within the known range for this species as described by NAFPAKTITIS (1978).

D. nielseni was caught from about 15°S to 21°S. At about 15°S it was the dominant species. This species was only caught with pelagic trawls. D. nielseni is also previously known from this area (NAFPAKTITIS, 1978).

D. watasei was caught between about 22° and 26°S, where it ranged first or second in three bottom trawl hauls at depths between 265 and 460 m. It was never caught with pelagic trawls. NAFPAKTITIS (1978) recorded this species between about 5°S and 28°S.

D. perspicillatus was caught at five stations between 14°S and 21°S, at one station (14°S) it was the dominant species, and at two it ranged second. It was caught with both pelagic trawls and bottom trawls. NAFPAKTITIS (1978) also recorded D. perspicillatus from the same area.

D. suborbitale and D. thiollierei were caught at one and two stations respectively between 14°S and 17°S. Neither of them were abundant. D. suborbitale has previously been recorded between 7°N and 8°S in the Indian Ocean (NAFPAKTITIS 1978, GJØSÆTER 1978), therefore the present catch locality (17°S) seems to be a southern extention of the range of this species. D. thiollierei has also been previously recorded from this area.

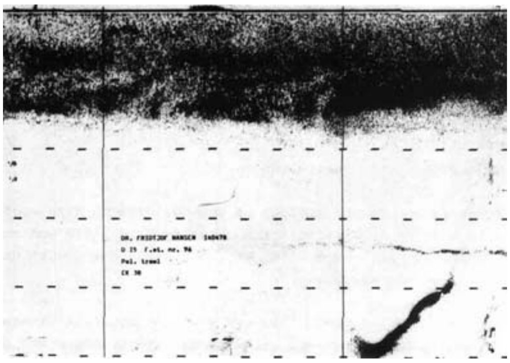
Maurolicus muelleri was caught at four stations between 21°S and 27°S. At two of these stations it was the dominant species and at one it ranged second. It was caught both with pelagic and bottom trawls. M. muelleri has a world-wide distribution; it has been caught off South-Africa (GREY 1964), but apparently not off Mozambique before.

Polymetme corythaeola was caught in a bottom trawl at one station (26°S). This species is previously known from the Indian Ocean off Natal (about 29°-30°S) and in the northern Indian Ocean south to about 5ºS off Zanzibar. The present record suggests that it may be distributed continously along the east African coast.

9.2 Behaviour

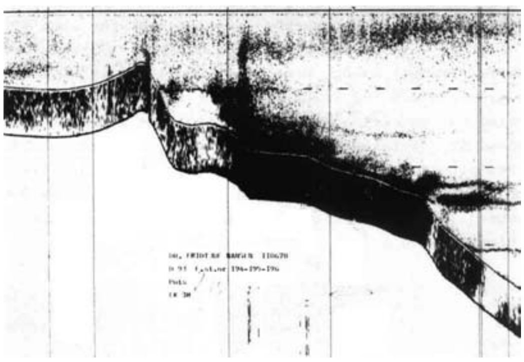
Mesopelagic fish were observed over most of the area studied. In offshore waters a deep scattering layer (DSL) was usually observed in deep water. Sometimes this layer was found below 500 m, which was the lower limit for the echo integration carried out to estimate fish abundance. At sunset the DSL, or part of it, migrated towards the surface and during night-time it was situated in the upper 100 m (Fig. 9.1). Usually the DSLs consisted of dispersed fish and schools were seldom observed. Generally, the fish density was highest close to the continental slope.

Fig. 9.1. Mixture of plankton and mesopelagic fish during night-time.



Along most of the coast, a scattering layer was found above the bottom at depths between 300 and 350 m, while sometimes mesopelagic species were also observed close to the bottom in more shallow waters (Fig. 9.2). Diaphus watasei was found in this bottom layer both day and night. During daytime Benthosema fibulatum and Maurolicus muelleri were also caught in this layer.

Fig. 9.2. Recording of mesopelagic fish along the continental slope.



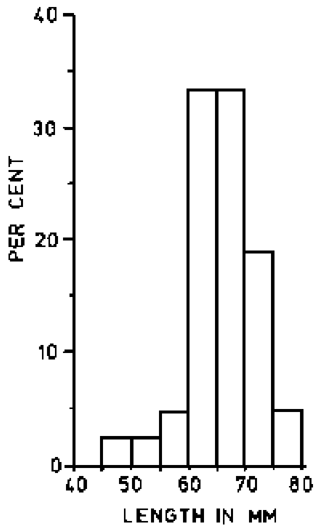
9.3 Biological observations

Observations on the biology of the mesopelagic fish species were made on the cruise during January-March 1978 and on the one during April-June 1978. Fig. 9.3 gives the length distribution of the species.

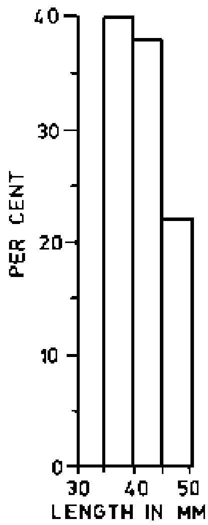
Benthosema fibulatum, which was the most abundant species, ranged in length between about 30 and 90 mm. There was no difference in size distribution between samples from March and May 1978. Primary growth zones in the otoliths which are supposed to be formed daily were studied in a few fish, and the results seem to confirm the conclusion that B. fibulatum reaches its maximum size in about one year (GJØSÆTER, 1978).

Fig. 9.3. Length distribution of mesopelagic fish.

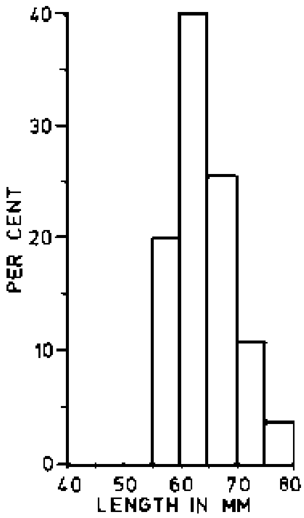
BENTHOSEMA FIBULATUM - MARCH 1978



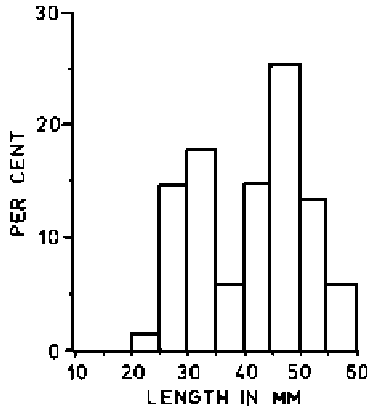
BENTHOSEMA PTEROTUM



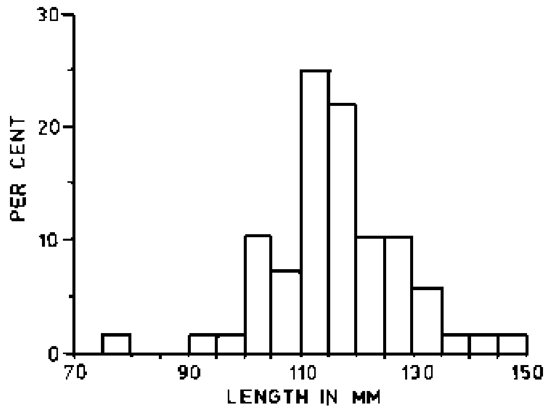
BENTHOSEMA FIBULATUM - MAY 1978



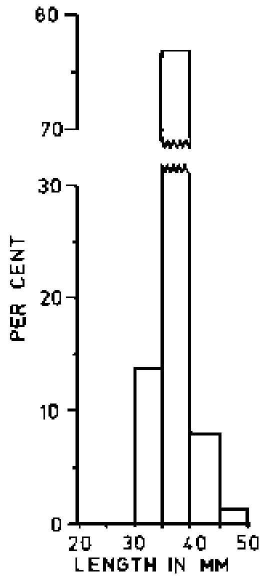
DIAPHUS PERSPICILLATUS



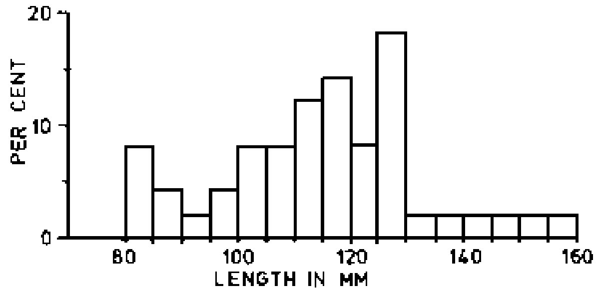
DIAPHUS WATASEI - MARCH 1978



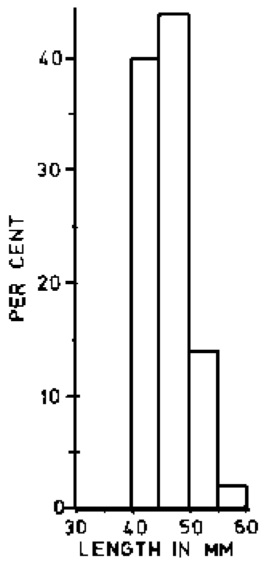
DIAPHUS NIELSENI



DIAPHUS WATASEI - MAY 1978



MAUROLICUS MUELLERI



Gonads were studied in a sample from March 1978, and most of them were mature or ripe. Stomach contents were studied in the same samples, copepods and euphausids appearing to be the most important food items.

The catch of B. pterotum consisted of large adult fish only. A few gonads were studied, and they were all maturing or ripe. There therefore seems to be little doubt that the species spawn in the area. The biology of these two species is further discussed by GJØSÆTER (1978).

Ranging after Benthosema fibulatum, Diaphus perspicillatus was the most abundant species in the area. The length of this species ranged between about 20 and 60 mm. NAFPAKTITIS (1978) found mature eggs in females ranging between 48 and 54 mm in the Indian Ocean. CLARK (1973) suggests that the species reach maturity after one year in Hawaiian waters.

D. nielseni was also fairly common in the catches. This species ranged in length between 30 and 50 mm with a mode between 35 and 40 mm. NAFPAKTITIS (1978) found that three females measuring 32-36 mm were gravid.

Diaphus watasei was often abundant in bottom trawl catches. This very large species ranged in length between 80 and 170 mm. Fish caught during March 1978 had a slightly lower modal length than those caught during May 1978. The gonads were studied in one sample from March 1978. Only females were caught and they were, with few exception, ripe. The smallest ripe females measured between 124 and 157 mm in the same area. Stomachs contained euphausids, prawns, small squids and cope-pods. Myctophids were also observed in one stomach, but the species could not be identified due to advanced digestion. D. watasei is usually caught in gears fishing on or close to the bottom. Juveniles are, however, supposed to live pelagicly.

Maurolicus muelleri was fairly common in parts of the area studied. Only adult specimens ranging in size between 40 and 60 mm were caught.

9.4 Abundance

The abundance of mesopelagic fish has been calculated from acoustical data and length composition in the catches. As length data are only available from two cruises, and no significant difference could be observed between these, the same lengths, 40 mm for the area north of 18°S and 50 mm for the area south of 18°S - were used for all surveys. The results are shown in Table 9.2.

Table 9.2. Abundance estimates (in million tonnes) of mesopelagic fish in zones of 0-30 n.miles and 30-200 n.miles off the 200 m depth contour off Mozambique.

Cruise	South of 18°S		North of 18°S		Total
	0-30 n.miles	30-200 n.miles	0-30 n.miles	30-200 n.miles	
1	1.2	1.0	0.02	0.3	2.5
2	0.4	2.9	0.8	1.7	5.8
3	0.9	5.9	0.2	1.5	8.5
4	1.1	1.2	0.5	2.7	5.5
Mean	0.9	4.5	0.4	1.6	5.6

The estimate obtained from the first cruise is probably an underestimate as the source level of the acoustic equipment at that time was lower than on the latter cruises. Although this is partly compensated for in the calculations, the detection threshold would have been different in such a way that small concentrations of weak targets such as mesopelagic fish would not have been included in the integrated echo abundance. The other estimates, 5.5-8.5 million tonnes for the whole area, are fairly similar.

Based on the material available, it is not possible to demonstrate any consistant differences in abundance between seasons or between areas. In general, however, it seems that the area from the 200 m depth contour to 30 n.miles seaward of this line has a higher density of mesopelagic fish than the more offshore areas.

Averaging over the three last cruises (which are supposed to give the most reliable estimates), the following densities were observed:

	0-30 n.miles	30-200 n.miles
N of 18°S	9.1 g/m^2	6.4 g/m^2
S of 18°S	11.0 g/m^2	4.5 g/m^2

These mean densities are much lower than those generally observed in the Northern Arabian Sea (GJØSÆTER, 1978), but they are still high enough to be of commercial interest. An approximate estimate of maximum potential yield of an unexploited stock can be derived from the equation:

$$Y_{max} = 0.5 \cdot M \cdot B_O$$

where M is instantaneous mortality rate and B_O is size of the virgin stock (GULLAND, 1970). The mortality of the mesopelagic fish in the area is not known, but probably the mean instantaneous mortality rate for the most important species is at least 2. Therefore, according to the equation above, the maximum potential yield may be similar to the stock size. This is, however, a first approximation only, and any fishery must be closely followed to discover signs of recruitment failure or other adverse effects on the stock at an early stage.

10. DEEP-WATER CRUSTACEANS

10.1. Characteristics of the main species

By 'deep-water crustaceans' the present authors mean to indicate crustaceans living mainly below 200 m depth. Table 10.1 gives the main species in the crustacean catches from "Aelita", "Kattegat" and "Dr. Fridtjof Nansen" from Delagoa Bay during summer. The data are not comprehensive enough to identify any significant differences in the species composition between areas and seasons. As seen, the spiny lobster (Palinurus delagoa) was dominant at depths down to about 350 m. At 350-400 m the crayfish (Nephrops andamanica) contributed approximately equally to the catches. There was also a minor contribution from the deep-water shrimp (Haliporoides triarthus). This species was dominant in the crustacean catches below 400 m.

Table 10.1. Composition of the crustacean catches below 200 m in Delagoa Bay during summer (% weight).

Depth zones (m)	Palinurus delagoa	Haliporoides triarthrus	Nephrops andamanica
201 - 250	89		
251 - 300	98		
301 - 350	85		15
351 - 400	43	10	46
401 - 500	1	67	32
500		100	

In addition to these dominant species, some other crustaceans such as the shovel-nosed lobster (Scyllaridae) and crabs made a minor contribution to the catches. Table 10.2 lists the deep-water shrimps identified during the investigation.

Spiny lobster

The distribution area of Palinurus delagoa as deduced by the trawl catches from all the research vessels appears in Figs. 10.1 and 10.2. North of 21°S this species was very scattered and occurred rather seldom in deep-water trawl catches. In the Delagoa Bay two distinct distribution areas seemed to occur. There was a western ground off the Limpopo River and an eastern one at the south-eastern slope of the Boa-Paz Bank. The stock off the southernmost coast seemed to have its northern border just north-east of Inhaca Island. There were some gaps in the distribution from the Bazaruto Island to the Boa-Paz Bank. It is uncertain if these gaps in the distribution were real or only reflecting patchiness in abundance. The stock seemed to be most abundant during summer and there was usually a pronounced decrease in the catches during April.

Fig. 10.1. Recordings of deep-water crustaceans during winter.

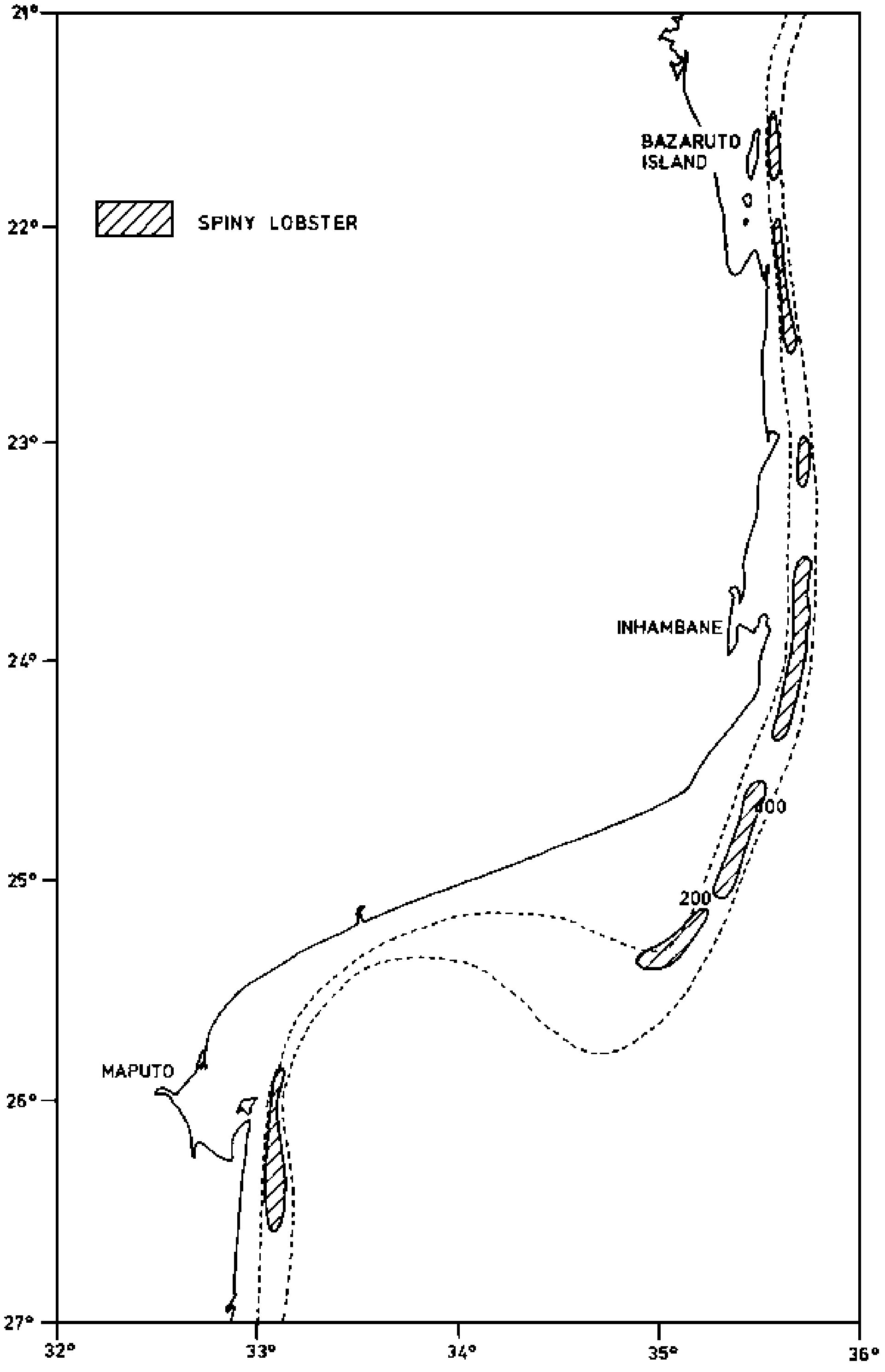
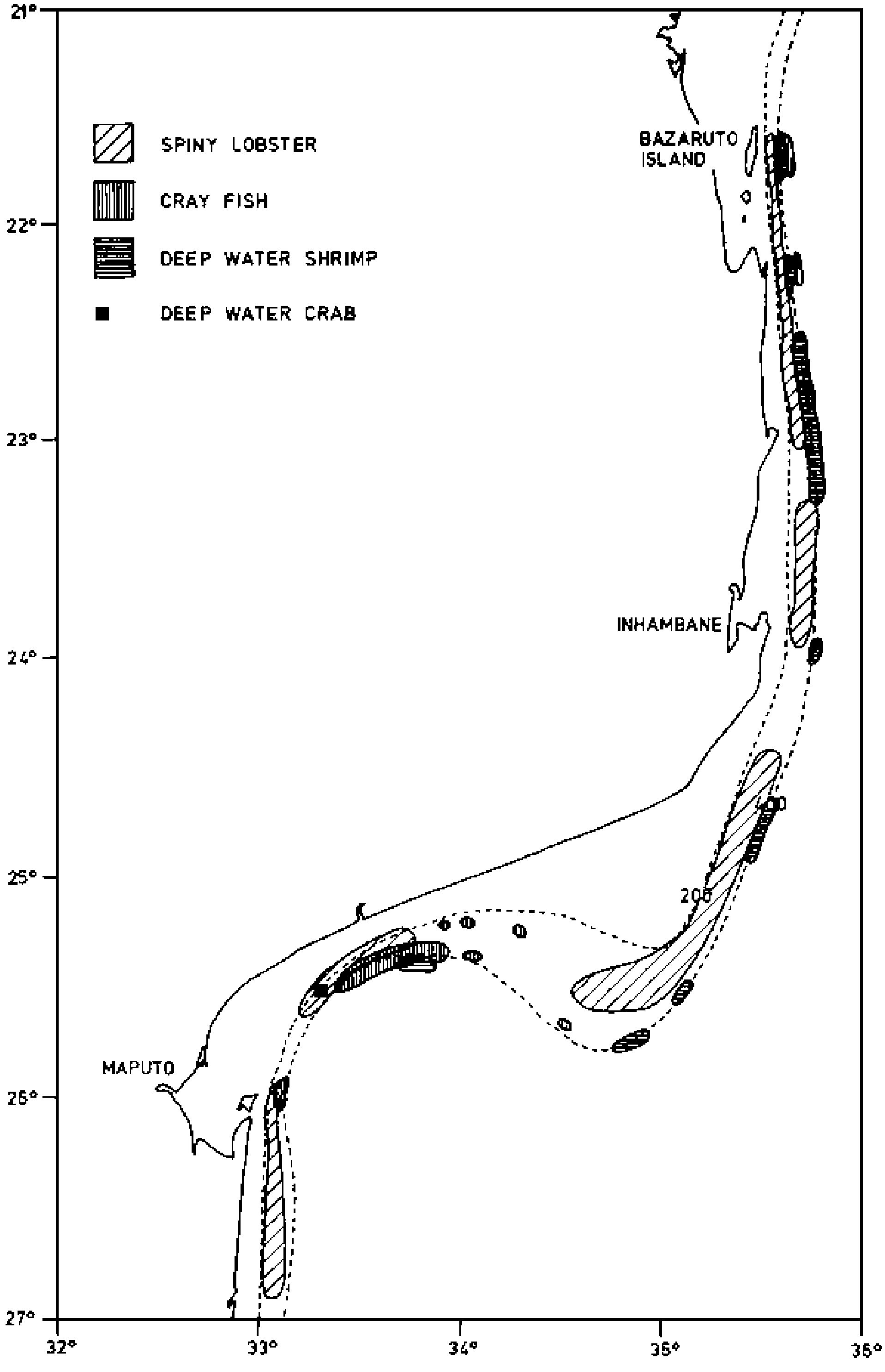
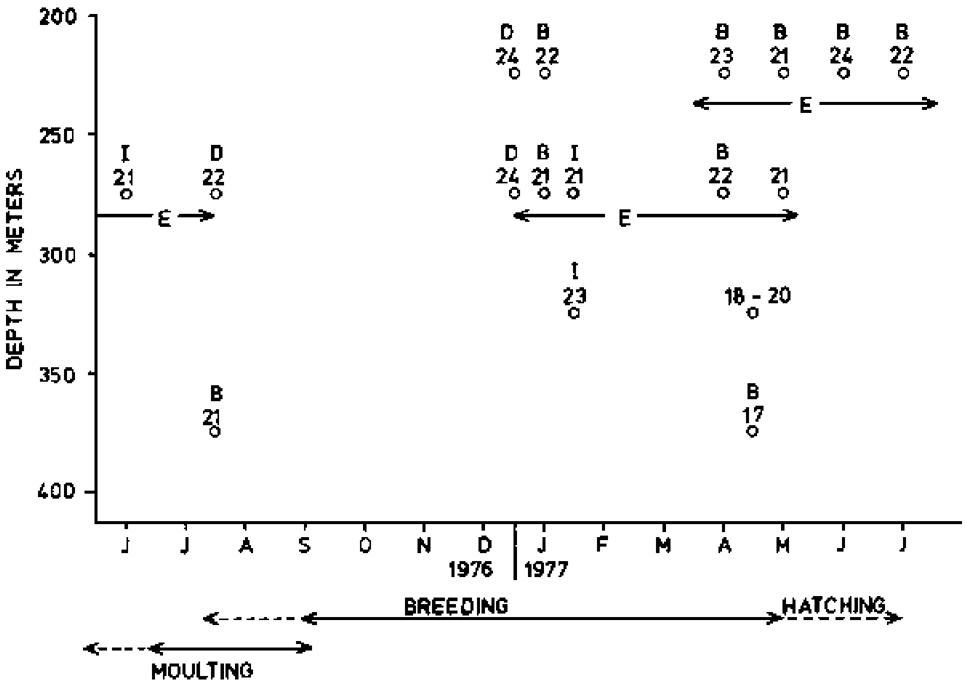


Fig. 10.2. Recordings of deep-water crustaceans during summer.



The spiny lobster was usually caught at depths between 150 and 400 m. Occasionally it was recorded in deeper water. During summer the spiny lobster was most abundant between 200 and 300 m, while in winter 250-350 seemed to be its preferred depth.

Fig. 10.3. Modal length of the spiny lobster.



I) Inhaca, D) Delagoa, B) Bazaruto, E) Egg-bearing females.

Fig. 10.3 is an attempt to put together all the biological information on the spiny lobster catches from "Aelita" (BUDNICHENKO et al. 1977). The modal lengths have been plotted as a function of time and depth. There seems to be some differences in the distribution of modal length between areas, which might indicate differences in the population structure.

The reproductive cycle is also indicated in Fig. 10.3. This is in reasonable accordance with the results of the investigation carried out along the coast of Natal (BERRY, 1973). The main hatching of the larvae probably took place in May, though egg-bearing females were observed until July. The breeding started mainly in September and the main moulting seemed to occur from July to September. A few specimens have also been observed moulting at other times of the year. It is likely, however, that these are a continuation of the sub-adult moulting cycle in which several moultings probably occur per year.

There seemed in general to be a decrease in length with depth. Off Inhaca a decrease in length was observed in the upper part of the distribution area from June to July. This indicates a vertical migration to shallower water during the time of moulting.

Crayfish

The species Nephrops andamanica was recorded in the Bazaruto area and on the western slope of the Boa-Paz Bank, as seen in Figs. 10.1-10.2. Some catches were also obtained over the slope off Sofala Bank. Crayfish were recorded at depths between 300 and 500 m but seem to be most abundant between 350 and 450 m. In the Bazaruto area a few catches were also taken below 500 m.

Crayfish seem mostly to occur at isolated localities. This apparent distribution might be due to the habit of the Nephrops sp, to form burrows in mud and remain there during the night. This habit reduces the possibilities of catching them with the usual bottom trawls. Only on the western slope of the Boa Paz Bank was a larger coherent distribution area recorded. The available data are too sparse to draw any firm conclusion on the distribution area of this species.

The reproductive cycle of the crayfish seems to follow that of the spiny lobster. Although crayfish have a widely extended hatching and spawning period, there are definite peaks of activity (BERRY, 1969). The peak of spawning activity occurs in August, and hatching takes place nine or ten months later with a peak in May. The sexually mature females probably moult annually with a peak of activity during the months of May to July.

Shovel-nose lobster

Species belonging to the Scyllaridae family were occasionally found along most of the coast at depths between 30 and 300 m. They seemed to be most abundant at 150-200 m. Maximum catch in the trawl did not exceed 6 kg per trawling hour. Rather good catches were obtained in pots off the Limpopo River and south of Inhambane in May.

Crabs

The most interesting of the very few catches of crabs were some good pot catches of the deep-water crab Geryon quinquedens. Up to 72 individuals or 30 kg per pot were obtained in Delagoa Bay at depths of about 350 m. A recent publication deals with this potential resource. From this investigation it seems that 350 m is close to the upper limit of Geryon sp. distribution area. This crab was recorded at depths more than 1000 m, and the best catches off the coast of the Congo were obtained at depths between 500 and 700 m. The sex ratio changes with depth, as the number of males increased with increasing depth (CAYRE, LE LOEUFF and INTES, 1979).

In our sample of 72 individuals there was only four males which confirms this observation. The males are the most commercially important as they are bigger. Further investigation should be carried out on this potential resource.

Deep-water shrimps

This group consists of several species listed in Table 10.2, of which Haliporoides triarthrus is the dominant one. The localities where this species were observed appear in Fig. 10.1. It was caught at depths from 350 m down to more than 500 m. Data are too scarce to establish with any certainty the real distribution area. The locality of highest abundance was found off Ponta da Barra Falsa. The deep-water shrimp is most likely also distributed along the slope of Sofala Bank, but no data are available from this area.

Table 10.2 Species of deep-water shrimp identified.

x) The commercially most important.

PENAEIDEA	CARIDES
Haliporoides triarthrus x	Heterocarpus sp. x
Aristeomorpha foliacea x	Plesionika martia
Penaeopsis balsi x	Chlorotocus crassicornis
Penaeus marginatus	Palaemon sp.
P. trissulcatus	Nematopalaemon sp.
P. latissulcatus	
Parapenaeus fissurus	
Plesiopenaeus niticlus	
Trachypenaeus curvirostris	
Metapenaeopsis mogiensis	
Solenocera africana	

10.2 Abundance

Tables 10.3 and 10.4 show the catch rates and percentages of crustaceans in total catches for summer and winter respectively. As the different vessels were using different gear the data for each of them were put into the tables separately. “Dr. Fridtjof Nansen” and “Kattegat” used bottom and shrimp trawls with a horizontal opening of 15-20 m while “Aelita” used a special lobster trawl with a 55 m horizontal opening. As expected, the catches of the first two vessels were in general lower than those of “Aelita”. There seemed to be a minimum both in percentage of crustaceans and in catch rate at 300-350 m.

Table 10.3 Deep-water crustacean catches during winter. N = no. of hauls, C $^{kg}/_{h}$ = catch rate of crustaceans, C % = percentage of crustaceans in total catch.

Vessel	Depth zones	Bazaruto			Delagoa			Inhaca		
		N	$C^{kg}/_{h}$	C %	N	$C^{kg}/_{h}$	C %	N	$C^{kg}/_{h}$	C %
Aelita - Jul.- Aug. 1976	201 - 250	1	1.0	1.0	4	4.5	8.7			
Aelita - Apr.- Jul. 1977		21	9.1	11.0	5	0.4	0.3			
Aelita - Jul.- Aug. 1976	251 - 300	1	0.3	0.8	6	4.3	5.8	13	24.4	21.4
Aelita - Apr.- Jul. 1977		16	14.0	11.9	26	19.1	15.8			
Dr. Fr. Nansen - Cr. IV								2	6.6	7.6
Aelita - Jul.- Aug. 1976	301 - 350	2	13.0	9.2				1	17.8	13.7
Aelita - Apr.- Aug. 1977		9	6.7	5.3	9	10.0	11.6	7	29.0	32.7
Dr. Fr. Nansen - Cr. IV								1	23.9	19.9
Aelita - Jul.- Aug. 1976	351 - 400	4	10.8	17.4						
Aelita - Apr.- Jul. 1977		2	4.7	5.5						
Aelita - Jul.- Aug. 1976	401 - 500	1	8.2	18.8						
Dr. Fr. Nansen - Cr. II		1	27.7	25.5						

Table 10.4 Deep-water crustacean catches during summer. N = no. of hauls, C $^{kg}/_{h}$ = catch rate of crustaceans, C % = percentage of crustaceans in total catch.

Vessel	Depth zones	Bazaruto			Delagoa			Inhaca		
		N	$C^{kg}/_{h}$	C %	N	$C^{kg}/_{h}$	C %	N	$C^{kg}/_{h}$	C %
Aelita - Jan. 1977	201 - 250	10	76.7	46.8	13	17.7	17.2			
Kattegat - shrimp trawl					2	29.4	9.3			
Dr. Fr. Nansen - Cr. II					2	18.1	3.0			
Aelita - Dec.1976 - Jan.1977	251 - 300	9	36.3	37.1	27	23.3	15.7	12	62.4	43.6
Kattegat - shrimp trawl					2	6.4	3.9			
Kattegat - bottom trawl					5	6.0	6.3			
Aelita - Dec.1976 - Jan.1977	301 - 350	4	10.4	18.6	5	1.2	2.2	22	57.3	58.3
Kattegat - bottom trawl					2	2.3	6.7			
Dr. Fr. Nansen - Cr. II					1	24.9	32.9			
Dr. Fr. Nansen - Cr. III					1	1.6	0.4	2	8.7	6.5
Aelita - Dec.1976 - Jan.1977	351 - 400				16	14.6	15.2			
Kattegat - shrimp trawl					4	48.1	13.5			
Aelita - Dec.1976 - Jan.1977	401 - 500				4	15.0	8.6			
Kattegat - shrimp trawl					12	36.0	19.9			
Kattegat - shrimp trawl	500	9	63.6	60.5	2	35.5	73.7			
Kattegat - bottom trawl					2	1.3	21.7			

The abundance of the spiny lobster and deep-water shrimp were calculated using the “swept area” method. For the calculations the distribution areas in the three regions were regarded as continuous. The catch rates used were mostly from “Aelita”. Only for the western ground of Delagoa Bay during summer were the data from “Kattegat” applied. The efficiency coefficient was taken as 1.0 which seems to be reasonable estimate for crustaceans.

Table 10.5. Sampling area and stock size (tonnes) of spiny lobster. A = area km^2 B_S = stock size (summer). B_W = stock size (winter).

	Bazaruto			Delagoa			Inhaca		
Depth (m)	**A**	**B_S**	**B_W**	**A**	**B_S**	**B_W**	**A**	**B_S**	**B_W**
201-250	1030	262	31	1125	81	14			
251-300	1030	125	48	1190	96	47	330	62	29
301-350	1030	63	23	700	1	2	110	19	12
351-400	1030		16						
Total		450	118		178	63		81	41

Table 10.6 Sampling area and stock size (tonnes) of deep-water shrimp during summer. A = area km^2, B_S = stock size.

	Bazaruto		Delagoa	
Depth (m)	**A**	**B_S**	**A**	**B_S**
400 - 500			450	73
500	450	170	150	32
Total		170		105

The results of the calculations are presented in Tables 10.5 and 10.6. The stock of spiny lobster seemed to be much smaller in winter than in summer. The total estimate for summer was 709 tonnes and for winter 225 tonnes. This apparent seasonal variation could be a result of insufficient data. BUDNICHENKO et al. (1977) calculated the stock for summer using the "Aelita" data alone. Even considering a smaller distribution area he reached a total estimate of 1850 tonnes for the stock size of the spiny lobster. The main reason for this discrepancy between the two estimates is that Budnichenko was using an efficiency coefficient for the trawl of 0.3. This figure seems to be rather small for crustaceans and a value between 0.5 and 1.0 seems more likely.

The data available are insufficient to establish either the size of the area or the average density with the desired degree of certainty. The estimates presented should therefore be used with caution. As a first approximation a stock size of 1000 tonnes is suggested for the spiny lobster. This is probably an underestimate.

Longhurst in GULLAND (1970) suggests a stock size of the spiny lobster along the coast of Natal and Mozambique of about 2500 tonnes and a potential annual production of 600-700 tonnes. It we apply the same ratio between the standing stock and the potential annual yield for the coast of Mozambique, an annual production of spiny lobster of about 300 tonnes is to be expected. However, yield estimates calculated from the South African fishery in the area during the late sixties and the early seventies suggest a higher value for the annual production.

The calculations carried out for the deep-water shrimp are even more dubious as these species seem to be more patchily distributed and the number of trawl hauls within the distribution area was very small. The slope of Sofala Bank has not been included in the calculations due to lack of data, but catches confirm that this resource also occurs there. Most likely, this area is the most important for deep-water shrimp and the stock there is at present exploited by a Spanish fleet which is believed to catch some few thousand tonnes annually. As a preliminary estimate of the stock size of deep-water shrimps south of Bazaruto Island we suggest 500 to 1000 tonnes. Due to lack of data from Sofala Bank this stock size is probably seriously underestimated.

For the crayfish the available data give some support to a "guesstimate" of a few hundred tonnes.

11. BY-CATCH IN THE CRUSTACEAN FISHERY

11.1 Shallow-water shrimp

Magnitude of the by-catch

The main fishing areas for shallow-water shrimp are found at the Sofala Bank between Angoche and the delta of the Zambezi River at depths between 10 and 40 m. The total catch of the national fleet in the area is probably 6-7000 tonnes annually. In addition there is a licensed foreign fleet, mainly from Spain, which has an estimated yearly catch of at least 5000 tonnes (ULLTANG et al., 1979). This gives a total of about 12 000 tonnes of shrimps from Sofala Bank.

Table 11.1. Catch rates and percentages of shrimps in catches from the research vessels at Sofala Bank.

			Shrimp catches		
VESSEL - GEAR	**N**	**N_C**	**P**	**P_C**	**$C_C$kg/h**
Summer (Oct-Mar)					
“Aelita” (Oct-Dec 1976)					
Bottom trawl	34	-	6.0	-	6*
“Kattegat” (Oct-Dec 1977)					
Shrimp trawl 22/26-33	13	12	6.9	7.4	14.2
Shrimp trawl 22/26-Mod	9	7	18.6	20.3	43.0
Shrimp trawl 26/32-33	5	4	12.5	12.6	51.6
Bottom trawl RG-140	31	17	0.6	1.8	3.2
“Dr. Fridtjof Nansen”					
Bottom trawl					
Cruise II (Oct-Dec 1977)	6	4	3.2	3.6	9.5
Cruise III (Jan-Mar 1978)	5	4	0.5	0.5	5.8
Winter (Apr-Sep)					
“Aelita” (Jun-Aug 1976)					
Bottom trawl	59	-	13.6	-	8.9*
“Dr. Fridtjof Nansen”					
Bottom trawl					
Cruise I (Aug-Sep 1977)	5	3	3.8	16.8	11.0
Cruise II (Apr-Jun 1978)	14	14	3.8	3.8	9.2

N = total number of hauls, N_C = number of hauls containing shrimps, P = % of shrimps in all hauls, P_C = % of shrimps in positive hauls, C_C = catch rate of shrimps in positive hauls.

* Catch rate calculated for all hauls.

Most of the by-catch in the shrimp fishery is not utilized but discarded at sea. There are no data from the industrial shrimp trawlers on the size and composition of the by-catch. The following is an attempt at elucidating both the magnitude and species composition involved.

Table 11.1 summarizes the percentage of shrimps in the total catch from the research vessel surveys at Sofala Bank at depths shallower than 40 m. As can be seen, the average percentage of shrimps in catches where shrimps occure may vary between 0.5% to 20.3%. Is the percentage of shrimp in the bottom trawl catches representative for that of the commercial shrimp trawlers? The most likely answer to this question is “no”. The ratio shrimp catch/fish catch in a typical bottom trawl is expected to be less than in a typical shrimp trawl for the following reasons:

- the shrimp trawl will catch a large proportion of the shrimps ahead of the trawl due to the lack of bobbins and the use of a tickler chain.

- on a shrimp trawl the trawl doors are usually attached close to the net wings, while on a bottom trawl long bridles are used. The shepherding effect of the bridles will result in a decrease of the shrimp catch/fish catch ratio for the bottom trawl.

Gear most similar to that of commercial shrimp trawlers was applied by “Kattegat”. Shrimp trawls 22/25 with enlarged wings and 28/32-33 had a catch rate of approximately the same size as the commercial trawler. Fig. 11.1 shows the catch rate for these gears for the mean year 1974-1976. In October-November the average catch rate was between 45 and 55 kg/h which corresponded well with those of “Kattegat” for the above mentioned two trawls (Table 11.1).

The small semi-industrial trawlers of size less than 11 GRT in Maputo Bay and less than 16 GRT in Beira Bay usually land the whole catch of both fish and crustaceans. Table 11.2 gives the percentage of shrimps in the landings and the catch rate of shrimps for 1977. As seen, the percentage of shrimps varied between 12 and 33% in Maputo Bay with an annual mean of 20.1%. In Beira Bay the variation was between 8 and 50% with an annual mean of 18.0%. The high values of the percentage in July, August and October in Beira Bay were associated with high catch rates. These percentages are most likely overestimated as the fishermen probably did not land the total catch during days with high catch rate of shrimps.

Fig. 11.1. Average catch rate for the commercial shrimp trawlers.

A reasonable conclusion to this discussion seems to be that the percentage of shrimps for the commercial shrimp fleet will be about 20% of the total catch. This estimate must of course be considered as a first approximation. Only sampling of the commercial catches can improve this figure.

A by-catch of 80% means that the shrimp trawlers are catching about 60 000 tonnes of fish annually at Sofala Bank of which probably only about 1000 tonnes are landed.

Table 11.2. Shrimp percentages in landings and shrimp catch rates (kg/fishing day) made by the smaller trawlers at Maputo and Beira Bays in 1977 (BRINCA, 1979. Pers. comm.).

	Maputo Bay		Beira Bay	
Month	% shrimp	Catch rate	% shrimp	Catch rate
January	12.2	32.2	11.4	88.7
February	21.7	62.2	11.1	89.4
March	33.0	99.4	16.6	135.8
April	24.9	93.9	16.9	121.6
May	27.5	89.3	10.0	60.0
June	25.4	67.5	17.4	134.5
July	18.4	57.0	50.6	382.4

August	19.0	48.0	47.1	194.6
September	14.9	50.3	23.0	89.2
October	17.5	67.1	32.5	185.7
November	12.6	40.8	7.7	48.5
December	12.4	40.2	9.6	68.8
Annual mean	20.1	64.2	18.0	124.9

Species composition of the by-catch

The species composition of the research vessel surveys is shown in Table 11.3. As can be seen, about 50% consisted of pelagic species, while demersal species contributed about 30%. Of the crustaceans, the main part was, of course, shrimps, but swimming crabs may contribute during summer, and also the inshore spiny lobster (Panulirus spp.) can be present.

The main species of ponyfish present were Leiognathus equula, Secutor insidiator and Gazza minuta. In the sardine group Pellona ditchella and Thryssa vitrirostris were dominant. Besides the Trachurus sp. and Decapterus spp. the scad group also included Megalaspis cordyla.

Demersal fish present in the by-catch were mainly small bream, such as Pagellus natalensis and Nemipterus delagoa. The group "Others" consisted mainly of jellyfish in summer, while during winter hairtails Trichurus lepturus and barracudas Sphyraena spp. were frequent. In general, all of the fish present in the by-catch were of some commercial value. It is uncertain to which degree the species composition of the research vessels were representative for the commercial trawlers.

Table 11.3. Composition of the catch from the research vessels at the shrimp ground at Sofala Bank (% weight).

Species	Summer	Winter	Total
CRUSTACEANS	4.0	8.0	5.1
PONYFISH Leiognathidae	20.6	1.7	15.6
SARDINES Clupeidae - Engraulidae	8.7	29.3	14.1
JACKS Carangoides spp	8.0	1.9	7.3
SCADS Decapterus spp	6.8	0.8	6.1
MACKEREL Scomberomorus spp - Rastrelliger spp	2.6	2.5	2.6
SHARKS Carcharhinidae	3.9	8.5	5.1
TOTAL PELAGIC	49.5	46.1	48.6
BREAMS Sparidae - Nemipteridae	9.3	1.7	7.3
GRUNTERS Pomadasyidae	6.6	4.8	6.1
CROAKERS Scianidae	4.8	7.8	5.6
GOATFISH Mullidae	3.5	5.1	3.9
LIZARD FISH Synodontidae	3.5	4.0	3.6
TOTAL DEMERSAL	27.7	23.4	26.5
OTHERS	18.8	22.5	19.8
TOTAL CATCH RATE (kg/h)	247	116	190

Seasonal variations

Table 11.2 indicates that the catch rate of shrimps and the percentage of shrimps in the catch were higher during winter (Apr.-Sep.) than during summer. Fig. 11.1 shows a maximum catch rate at Sofala Bank in April-June. From Table 11.3 sardines seemed to be most abundant in winter while the other pelagic species mainly occurred more frequently in the catches during summer (Oct.-Mar.). For the demersal species it is difficult to see any seasonal variation at all.

11.2 Deep-water crustaceans

The by-catch of fish when fishing for deep-water crustaceans at depths below 200 m comprised usually between 80 and 90% of the total catch. Off Inhaca at depths between 300-350 m and off Bazaruto at 200-250 m the contribution from fish in the catches may decrease to about 50%. During winter there were usually lower total catch rates and percentages of crustaceans than in winter, as can be seen from Table 11.4.

Table 11.4. Percentages of deep-water crustaceans (% weight) and total catch rates from the research vessels surveys.

Area	Summer (Oct.-Mar.)			Winter (Apr.-Sep.)		
Depth	No. of hauls	% Crustaceans	Catch rate kg/h	No. of hauls	% Crustaceans	Catch rate kg/h
BAZARUTO						
201 - 250	10	46.8	164	23	10.5	83
251 - 300	9	37.1	98	18	10.8	117
301 - 350	4	10.4	179	9	5.3	128
351 - 400	-	-	-	4	17.4	63
401 - 500	1	22.5	130	-	-	-
> 500	9	60.5	105	1	42.9	23
DELAGOA						
201 - 250	18	9.6	155	10	1.6	135
251 - 300	32	14.9	138	34	15.3	87
301 - 350	9	4.6	89	9	11.6	86
351 - 400	18	15.5	96	-		
401 - 500	14	22.5	136	-		
> 500	2	66.3	48	-		
INHACA						
251 - 300	12	45.5	143	15	20.0	110
301 - 350	24	52.2	102	9	28.1	97

The by-catch usually consisted of species of little or no commercial value. Quantitatively, the most important groups were the typical mesopelagic fish, such as lanternfish Myctophidae, snake mackerel Gempylidae, man-of-war fish Cubiceps natalansis and Scombropidae.

The rest of the fish catch in the upper 300 m consisted mainly of the spiny dogfish Squalus acanthias, the lizard fish Synodontidae, rat tail Macrouridae, robins Triglidae and crocodile fish Peristediidae, of which the two first species contribute most.

In the Inhaca area squid and cuttlefish (Loligindae and Sepiidae) sometimes contributed significantly, up to 15% of the catch. Molluscs were more abundant during summer and occurred in catches mostly above 350 m. At depths between 200 and 250 m pelagic species, such as horse mackerel, Indian mackerel and barracudas, were sometimes frequent in the by-catches.

The percentage of fish in the catches seemed to be lower in summer when the total catch rates were higher. The available data give no indications of a pronounced seasonal variation in the species composition.

12. SOME REMARKS ON THE FISHING EXPERIMENTS

Bottom trawl

On the research vessel surveys most of the bottom trawl catches were less than 500 kg/hour. For typical demersal species catch rates of up to 1000 kg/h were obtained for croakers and goatfish, these seemed to be the maximum. Every time the catch rate exceeded this figure the main catch consisted of the small pelagic species. The contributors to the highest catch rates were mainly ponyfish, with catches up to 3300 kg/h by "Dr. Fridtjof Nansen" and 4000 kg/h by "Kattegat". Table 12.1 gives the catch rates for the commercial Soviet trawlers at Sofala Bank from December 1977 to June 1978. In October-November the vessels fished at Boa-Paz Bank between 50 and 100 m depths. The catch rates in this area were between 1500 and 2000 kg/h.

Table 12.1. Average catch rates of the largest Soviet trawlers at Sofala Bank - December 1977 - June 1978. (kg/trawling hour.)

	25 - 50 m		50 - 100 m	
	Catch rate	Trawling hours	Catch rate	Trawling hours
December	763	58	1370	500
January	1726	344	1649	280
February	1587	273	2028	140
March	595	34	1436	127
April	1718	474	1795	88
May	1710	903	2672	80
June	2149	865	2224	84

Pelagic trawl

This gear was only applied by "Dr. Fridtjof Nansen" and "Kattegat". The maximum catch rate, 4300 kg/h, was obtained on the buccaneer anchovy. This species did not occur in bottom trawls and is only accessible to pelagic trawls or probably also to purse seines. Good catches, up to 2000 kg/h, were also obtained of Indian pellona, Indian driftfish, hairtail, thryssa and sardinella. The horse mackerel and scad, however, which contribute significantly to the bottom trawl catches, seemed to be difficult to catch with the pelagic trawl.

Bottom longline and floating gill-net

Except at the St. Lazarus Bank the catches from these gears were completely dominated by different sharks. The fishing operations were mainly carried out at depths between 50 and 150 m. It will probably be difficult to use these gears for species other than sharks within this depth interval.

Pots

During the last part of Cruise III and throughout Cruise IV of "Dr. Fridtjof Nansen" pots were used in the research fishery. The different pots are described in Chapter 2. A longline system including 5 to 10 pots was used in the pot fishery operation. A buoy line was connected to one end of the setline and no extra anchoring device was applied. The pots usually fished overnight with soaking time from 15 to 30 hours. They were baited with chopped fish in perforated plastic bait containers. A total of 204 pots were lifted during the investigation.

Table 12.2. Catch in pots by depth.

Depth (m)	No. of pots	Total catch (kg)	Catch per pot (kg)	Dominant species (Total catch - kg)
St. Lazarus Bank				
15 - 23	22	422	19.2	Lutjanus bohar (189)
				Promicrops lanceolatus (94)
Rest of the coast				
15 - 23	35	30	4.4	Epinephelus tauvina (12)

30 - 58	47	83	1.8	Crabs (18)
76 - 122	60	225	3.8	Argyrops spinifer (72), Sharks (41), Sparus major (24)
153 - 200	32	134	4.2	Shovel-nosed lobster (22)
275 - 320	8	4	0.5	Dalatias licha/Shark (4)
Total	204	898	4.4	

The pots were set out at depths from 15 to 320 m. The results may be separated into five different depth intervals, as shown in Table 12.2. Off the Mozambican coast, excluding the St. Lazarus bank, an average catch per pot of 5 kg or more was obtained only at six localities, as seen in Table 12.3.

Table 12.3. Localities where the average catch per pot exceed 5 kg.

St. no.	Area	Depth (m)	Total catch (kg)	Catch per pot (kg)	Dominant species
139	Sofala	85	119	24	Seabreams, Snappers
167	Bazaruto	200	40	8	Groupers, Seabreams
153	Delagoa	195	24	5	Seabreams
154	Delagoa	100	26	5	Seabreams
192	Delagoa	180	24	5	Shovel-nosed lobsters
196	Inhaca	167	45	9	Sharks, Seabreams

During the investigation, 30 pots of the RK type were set and lifted. In shallow water no catch was obtained, except for small incidental catches of swimming crab and Delagoa thread-fin bream, Nemipterus delagoae. In deeper waters a few good catches of crustaceans were taken:

Depth 300 - 320 m; catches of spiny lobster Palinurus delagoae, up to 12 individuals (3 kg) pr. pot.
Depth 200 - 285 m; catches of shovel-nosed lobster Scyllaridae up to 10 individuals (4 kg) pr. pot.
Depth 320 - 352 m; Deep-water crab Geryon quingedens, up to 72 individuals (30 kg) pr. pot.

Some sharks (Squalus acanthias and Mustelus manazo) were also caught in these traps in deep water (200-285 m). Twenty of the RQ-type pots were lifted during the investigation. Except for incidental catches of crabs and fish, no catches were obtained in these pots.

The catches with the RF-traps in coastal waters were generally low. However, the catches in the depth interval from 76 to 200 m, especially at the stations listed in Table 12.3, may indicate exploitable resources by pot fishing. The relatively good catches at the St. Lazarus Bank show that pots might be a suitable fishing gear in this area. As the pots were used only in the last part of the "Dr. Fridtjof Nansen" investigation, pot data from the St. Lazarus Bank are restricted to the four pot stations in this area during Cruise IV in April. Relatively high catches by handline during the other cruises, however, give reason to believe that the abundance of the main species was fairly constant throughout the year.

Catch data from the crayfish pots (RK) are scarce. A few good catches of crab Geryon quingedens, spiny lobster Palinurus delagoae in deep water indicate that these species can be fished by pots in relatively high quantities.

Since pots were used only in the last part of the investigation, the catch data are scarce, but the following statements can be made:

- 1) Pots (type RF) have proved to be successful for catching fish at the St. Lazarus Bank. Because of the rough bottom conditions pots and handlines seem to be the best gear for exploiting the fish resources in this area.

- 2) The fish catches by pots on the coast are too low, but a few relatively good catches indicate that further investigations may show that pots might also be successful in capturing higher quantities of fish in some areas. Such investigations should also include exploratory pot fishing with smaller vessels in the very shallow waters of the coral reefs.

- 3) Based on the few good catches of crab and spiny lobster in crayfish pots (RK), exploratory fishing should be carried out in deep water to investigate the possibility of exploiting these resources by pot fishing.

13. WHALES AND DOLPHINS

13.1 Observations

During the cruises of "Dr. Fridtjof Nansen" sightings of dolphins and whales were recorded. The effective effort used for sightings was not constant during the project period. This is in part due to the fact that only during the first cruise (24 August 1977 - 4 October 1977) did a man with some past experience in whale observations participate.

Table 13.1. Observations of dolphins from "Dr. Fridtjof Nansen" off Mozambique between August 1977 and June 1978.

Date	Position	Depth (m)	Number	Remarks
9.9.77	17°17'S, 38°53'N	100	3	
19.9.77	19°00'S, 36°20'E		4	Probably Tursiops truncatus
21.9.77	20°24'S, 35°02'E	20	3	Probably T. truncatus
27.9.77	26°11'S, 35°04'E	130	20	At the Admiralte Leite Bank. Probably T. truncatus
20.10.77	19°00'S, 36°30'E	30	3 [1)]	Some dolphins
25.11.77	18°33'S, 36°44'E	100	4-5	Seen near the trawl
30.11.77	24°51'S, 35°31'E	200	3 [1)]	Some dolphins
1.12.77	25°14'S, 33°57'E	255	20	
22.1.78	18°41'S, 36°31'E	30	8-10	
13.2.78	17°59'S, 37°34'E	30	5-10	
16.2.78	17°52'S, 37°51'E	30	100+	
18.2.78	18°24'S, 37°26'E	200	10-15	
22.2.78	20°47'S, 35°36'E	200	100+	
3.3.78	20°02'S, 36°00'E	200	100-200	
21.5.78	23°06'S, 35°44'E	230	3 [1)]	Some dolphins
9.6.78	25°30'S, 34°00'E	200	6	

[1)] "Some dolphins" recorded. The number in the brackets is the assumed value drawn in Fig. 13.1.

The ship did not have a mast barrel from which a good outlook could be kept. Furthermore, a continous outlook for whales either from the roof of the steering house, the bridge, or the bow deck was not kept because of other important tasks. It is therefore considered likely that the observations made will only be a small part of what would have been recorded if the ship had been especially equipped and crewed for sightings of whales. The data base is thus not good enough for any reliable estimate of the number of humpbacks in the surveyed area. The handbook by LEATHERWOOD, CALDWELL and WINN (1976) was available for identification.

Table 13.2. Observations of whales from "Dr. Fridtjof Nansen" off Mozambique between August 1977 and June 1978.

Date	Position	Depth (m)	Species	Number	Remarks
25.8.77	24°41'S, 35°12'E	40	Humpback	2	Together. One was "sailing" with its flukes.
25.8.77	24°30'S, 35°24'E	76	Humpback	1	
25.8.77	23°45'S, 35°50'E	320	Unindentified	1 [2)]	
20.9.77	19°50'S, 35°09'E	16	Humpback	2	Together. Approached the whales to 30 m.
21.9.77	20°31'S, 35°13'E	25	Humpback	2	Together
26.9.77	24°34'S, 36°34'E	2500	Balaenoptera sp.	1	Probably scared by the sonar

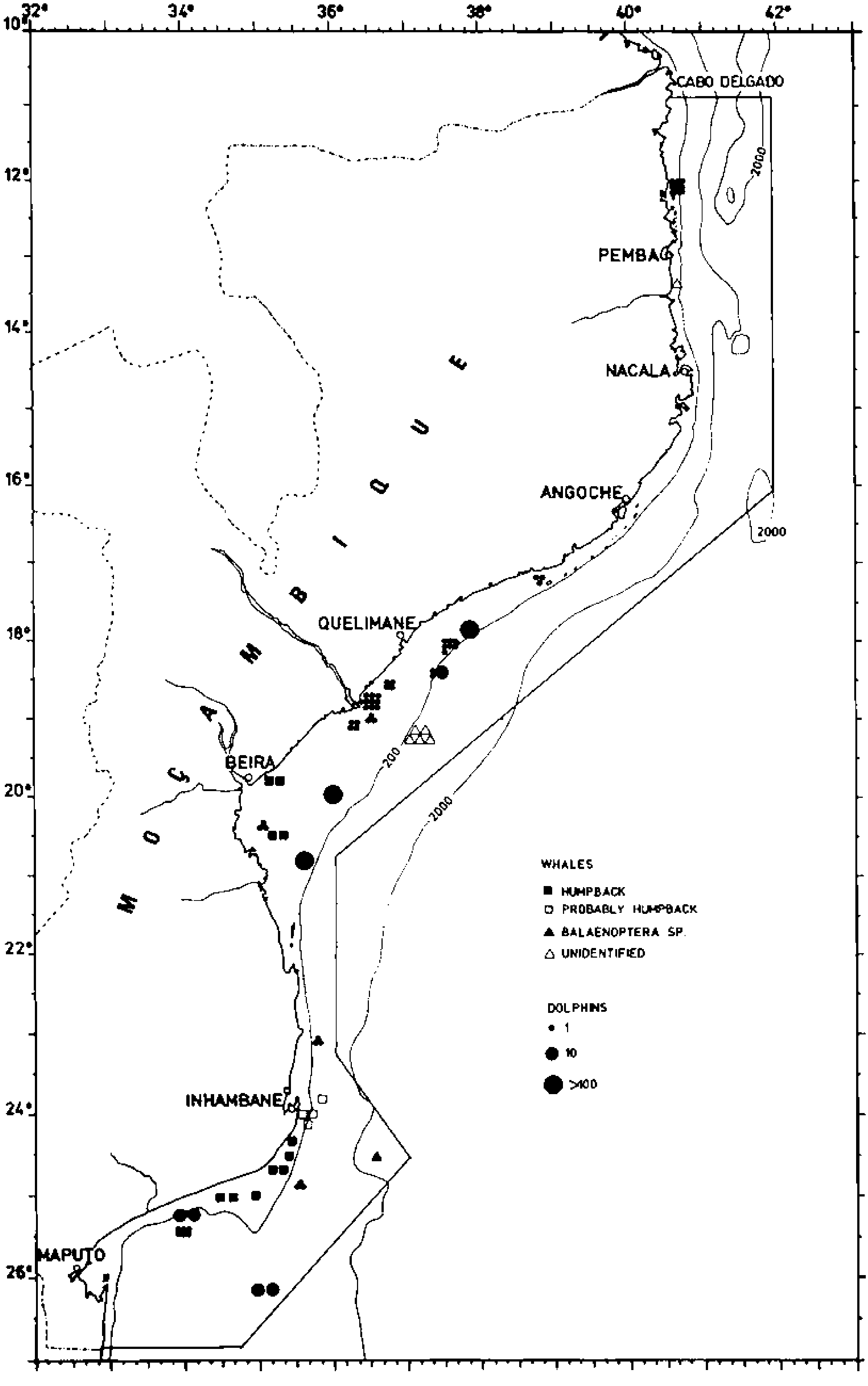
30.9.77	25°04'S, 34°35'E	100	Humpback	2	Together
30.9.77	25°03'S, $34^0$57'E	60	Humpback	1	
16.11.77	19°10'S, 37°10'E		Unindentified	5	
21.5.78	13°21'S, 40°40'E	30	Unindentified	[1] 1)	The blow was seen
6.6.78	24°03'S, 35°34'E	30	Unindentified	[3] 1)	Recorded as: Many and medium sized whales 2)
7.6.77	24°21'S, 35°24'E	30	Humpback	1	Small

1) Number not recorded. The figure in the brackets is the assumed number plotted in Fig. 13.1.

2) Probably humpback because of the depth where the observations were made or because humpbacks are known to occur there at that time of the year.

Table 13.1 and 13.2 give the recordings of dolphins and whales. In Fig. 13.1 these observations are plotted together with the 200 and 2000 m isobath.

Fig. 13.1. Observations of whales and dolphins.



The dolphins were poorly identified due to inexperience with these animals, but some of the smaller groups were probably Tursiops truncatus. The dolphins were commonly seen in the Sofala Bay area (Fig. 13.1). The numbers recorded are subject to considerable uncertainty. Several sightings of dolphins have not been recorded. The dolphins were only observed over the shelf or on the continental slope, although the deeper waters were regularly surveyed.

A total of 22 larger whales were observed on 12 occasions (Table 13.2). Of the 12 larger whales observed during the first cruise, 11 are recorded as humpbacks (Megaptera novacanglia).

One larger whale was observed outside the shelf. This whale seemed to be scared by the vessel, possibly by the sonar. It swam away at approximately the same speed as the ship (10 n.m. pr. h.). The observation distance was 1-1 1/2 n.m. at the minimum. This was a Balaenoptera sp., most likely a fin whale (B. physalus) or a sei whale (B. borealis).

13.2 Modern whaling off Mozambique

Modern whaling off Mozambique was initiated in 1911 by two Norwegian companies (RISTING 1923, TØNNESSEN 1967, 1969). According to these authors a shore station was established at Inhambane, (Table 13.3, Fig. 13.1) and a factory ship was anchored at Angoche. At that time, before satisfactory evaporators had been developed, the whaling stations and the factory ships were dependent on freshwater supplies from land. Thus the whaling companies in Mozambique established themselves near the rivers. In 1912 four companies were engaged in whaling off Mozambique. One of them, The Mozambique Whaling Company, was running two land stations and one factory ship at Inhambane. From 1913 to 1915 only the Mozambique Whaling Company was operating. All the whaling companies were Norwegian.

Table 13.3. The catch of whales off Mozambique, w. = number of whales. b. = number of barrels with whale oil produced. c. = number of catcher boats.

Type of station	Place	1911	1912	1913	1914	1915	1923
Factory ship	Angoche	273 w. 6500 b. 2 c.	3000 b. 3 c.				
Factory ship	Quilimane		5000 b. 3 c.				
Factory ship	Inhambane		5700 b. 3 c.				
Land station	- " -	264 w.[3] 8000 b. 2 c.		900 w. 22300 b.	412 w. 16070 b.	205 w. 8000 b.	81 w.[3] 2385 b.
Land station	- " -		17000 b. 6 c.	5 c.	6 c.	5 c.	5 c.
Factory ship	- " -						
Total number of whales		537[1]	ca.1200	ca.900	412[2]	205[1]	81
Humpback whales			ca.1200	ca. 900			61
Sperm whales							20

From RISTING (1922), TØNNESSEN (1967, 1969) and ANON. (1931).

[1]) Mostly humpbacks. [2]) According to Portuguese statistics. The number is probably too low. Mostly humpbacks. 3) The whaling did not start before September.

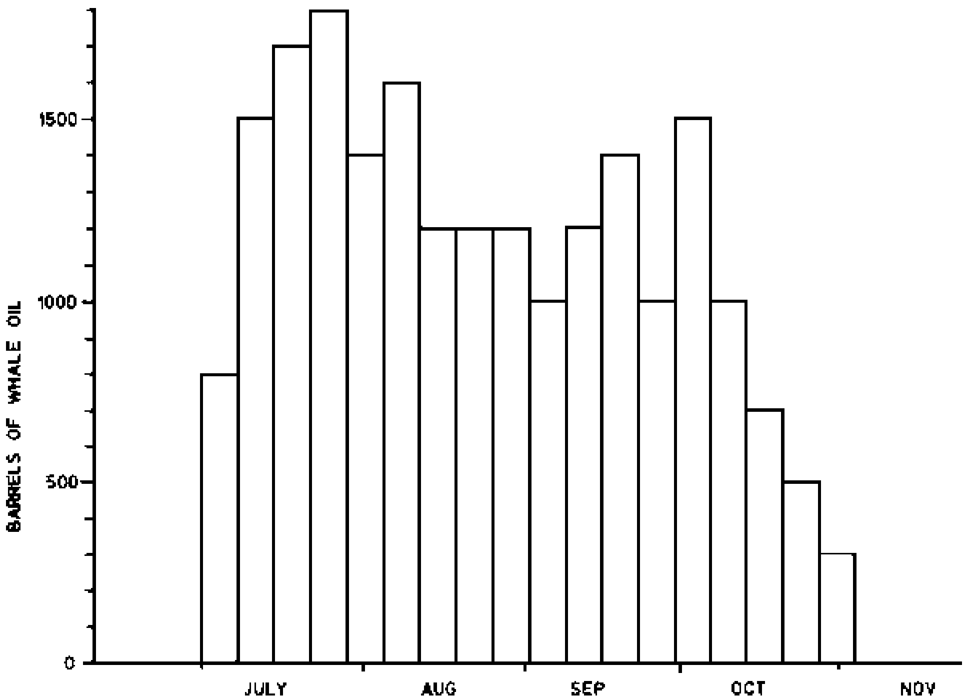
The catches off Mozambique consisted almost exclusively of humpbacks. The experience among the whalers was that the abundance of whales decreased northwards. In May-July the humpbacks arrived from the Antarctic, migrating northwards off South Africa where whaling was being also carried out. The further north. the later they arrived on the grounds. The northernmost whales also started the southward migration earlier.

Fig. 13.2 shows the weekly production of whale oil by the Mozambique Whaling Company in 1913 (RISTING, 1923). This company had two land stations at Inhambane and used five catcher boats. The production in June of that year was only 1000 barrels while weekly production results are available from 1 July.

The whaling off Mozambique lasted for the five consecutive years 1911 to 1915. The stock. or at least that component of the stock which occurs over the shelf off Mozambique. was reduced, and the whaling in this area stopped for economic reasons (RISTING 1923, TØNNESSEN 1967, 1969).

In 1923 the whaling off Mozambique was resumed by one Norwegian company. It was not, however, profitable (TØNNESSEN 1969). Since 1924 whaling has not been conducted off Mozambique, although the same stocks of whales occurring off Mozambique have been exploited elsewhere. The humpbacks of Mozambique belong to the stock of humpbacks which in the southern summer feed in the Antarctic Area III south of Africa (MACKINTOSH 1965). Especially in the 1930’s large catches (1000-4000 animals) were taken from this humpback stock off South Africa and in the Antarctic (MACKINTOSH 1965). The International Whaling Commission banned the catching of humpbacks in the whole southern hemisphere in 1964.

Fig. 13.2. Weekly production of whale oil by the Mozambique Whaling Company in 1913.



13.3 Discussion

All the humpbacks except one were observed in the shelf area, as defined by the 200 m isobath. Whales recorded as humpbacks were observed in the season from June to September. This is in agreement with the time of whaling activity. Although the surveys were not concentrated in the waters south of Inhambane, most of the humpbacks were seen in this area (Fig. 13.1). This is also the area that seemed to be the best whaling grounds in the past (Table 13.3).

14. RECOMMENDATIONS FOR FUTURE RESEARCH

14.1 Current investigations and expected results

In August 1978 a Soviet vessel started a research program with special emphasis on larger pelagic fish species within the economic fisheries zone of Mozambique. These investigations are expected to increase the information about larger offshore pelagic species such as tunas, billfish and sharks. The project will probably not include information on larger pelagic fish in shallower waters. such as the Spanish mackerel.

On a joint basis, a Mozambican and Japanese enterprise is carrying out exploratory fishing for spiny lobsters and crabs. The investigation started in October 1978 and is expected to give information on the distribution and abundance as well as biological characteristics of those species.

About 12 Soviet trawlers are fishing under license for fish mainly on the Sofala Bank. The data from these fisheries are being treated by a joint team of Mozambican and Soviet scientists. Total catch, catch per unit effort, as well as species composition and biological information on the main species, are expected results from this study.

A research vessel from the German Democratic Republic will probably start investigations for 3-4 months in March 1979. For the moment it is not clear what kind of investigation the DDR research vessel will perform. In connection with this survey some DDR trawlers will carry out exploratory fishing, especially for the deep-water shrimp. The data from this fishery will offer possibilities to improve the assessment of the deep-water shrimp stock.

14.2 Recommendations

a) There is nearly complete lack of information on inshore and reef fisheries. The coast between Cabo Delgado and Angoche is edged by coral reefs and unsuitable for trawling. We therefore recommend a survey to be carried out covering the reef areas along the northern part and the inshore areas along the rest of the Mozambican coast. The inshore areas also include the mangrove swamps. The object should be to survey the present fishery in these areas and the possibilities to expand it. The survey could be carried out by a rather small vessel carrying a variety of gears such as traps, lines, nets etc.

b) A sampling program on commercial shrimp trawling should be initiated to investigate closer both the magnitude, the species composition, as well as some biological characteristics of the by-catch of fish. The geographical and seasonal variations of the by-catch should be studied. Changes in the fish stocks of the shallower part of Sofala Bank will be reflected in the by-catch from the shrimp fishery. This information, together with data from the Soviet trawlers, offers a valuable tool in management of the most important fish stocks.

c) Efforts should be made to establish a monitoring program for the fisheries resources of the shelf zone. For the demersal stock, probably one trawl survey each year covering the main fishing areas will be sufficient, as the seasonal fluctuations of this stock seem to be small. The large seasonal variations in the pelagic stock, however, suggest that more frequent investigations are needed. For the latter an acoustic survey appears to be most appropriate. The possibilities of arranging such surveys should be investigated either on a national or regional basis. Regional investigations are to be preferred, as the stocks migrate from one area to another.

d) Exploratory fishing using pots in deeper water should be performed. This investigation could be carried out for fish down to 200 m, for crayfish and spiny lobsters down to 500 m, and for deep-water crabs down to 800-1000 m.

e) We recommend future hydrographic work to be concentrated on the shelf area. One or two fixed hydrographic sections covering the core of the Mozambique Current should be established to follow the seasonal and inter-annual variations. A more detailed study covering the distribution area of the main fish stocks should be carried out on Sofala Bank. The object of this investigation should be better knowledge of the general oceanographic circulation. with special emphasis on the possible influence of the major rivers on the recruitment mechanism of the shallow-water shrimp stock. The study should include ordinary hydrographic parameters as well as current measurement and mapping of the bottom surface sediments.

15. SUMMARY AND CONCLUSIONS

Table 15.1 summarises the results of the present report. All the abundance estimates, as well as the estimates of annual potential yield, should be regarded more as approximates and guidelines rather than the results of accurate calculations. Both the available data as well as the methods used introduce sources of error. In order to be able to do the abundance and yield calculations, some important assumptions had to be presupposed. It is uncertain to which degree these assumptions are fulfilled. We therefore recommend that any increase in fishing should aim at less than the maximum potential yield presented here, until better assessment data are available. It should also be noted that the stock size presented is the maximum observed.

Table 15.1. Summary of the marine fishery resources of Mozambique. (thousand tonnes).

	Maximum stock size	Present catch	Maximum potential yield
DEMERSAL FISH			
St. Lazarus Bank	10	0	1
Rest of the coast	200	30	50
PELAGIC FISH			
Anchovies	300	0	300
Other small pelagics	300	30	150
Larger pelagics	?	<0.5	?
Sharks	?	2-3	?
MESOPELAGIC FISH	1000	0	1000
CRUSTACEANS			
Shallow-water shrimps	16	12	15
Deep-water shrimps *)	0.5-1	<0.5	?
Spiny lobsters	1	<0.1	0.3
Crayfish	0.1-0.5	?	?
REEF FISHERIES	?	?	5-10
INSHORE FISHERIES	?	7	5-10

*) Includes only the stock south of Bazaruto Island.

Demersal fish

The stock of St. Lazarus Bank consists of larger demersal species with slow growth rates. and is dominated by the red snapper. The stock is at present not exploited and the annual potential yield is probably of the order 1000 tonnes. The bank area is unsuitable for trawling and traps and handlines appear to be the most appropriate gears. Fishing could be carried out by rather small boats.

The potential along the rest of the coast is about 50 000 tonnes. The most important species are breams, croakers, grunters and lizard fish and the main fishing area is the Sofala Bank. The catch presented in Table 15.1 consists of the estimated by-catch in the shrimp fishery and the catch from the Soviet trawlers from September 1977 to June 1978. These catches are expected to increase during 1979 due to increased effort and skill of the fishermen. If an increase in the shrimp fishery is also to be expected, the catch will probably reach close to the maximum potential yield. Caution should therefore be shown, and the rate of exploitation of the demersal stock closely followed.

Pelagic fish

The main pelagic species is the buccaneer anchovy at Sofala Bank. This fish, 7-8 cm long, has a very short life cycle and the potential yield will therefore most likely equal the stock size. The abundance is subject to very large seasonal variations, between 30 000 and 300 000 tonnes, and the potential yield suggested therefore presupposes, a theoretical maximum exploitation of the stock which may not be fully achievable in practice. At present it is not exploited, as its behaviour differs somewhat from the other pelagic species in such a way that it does not settle at the bottom during daytime. It is therefore not accessible to bottom trawls. It is easily caught by pelagic trawls and probably also purse seines.

For the other pelagic fish we have suggested a maximum potential annual yield of about 150 000 tonnes. The most important of these species are the scad. the Indian pellona, the larger anchovy and the ponyfish. As for the demersal species the present catch consists of the by-catch from the shrimp fishery as well as catches from the Soviet trawlers from September 1977 to June 1978. This stock is rather lightly exploited and there are possibilities for increased catches.

The group 'larger pelagic species' consists mainly of tunas. Spanish mackerel and sharks. The available data offer us no possibilities even to guess at the abundance of these species. The current Soviet long-line investigation will increase the knowledge on the more offshore species. The Spanish mackerel is distributed at depths shallower than 50 m at Sofala Bank and Boa-Paz Bank. It is frequently taken as by-catch when trawling is done on the smaller pelagic species on which it feeds. Spanish mackerel might be an important by-catch in a fishery for the small anchovy. There is also probably a significant resource of sharks, especially off the mouth of the Zambezi River.

Mesopelagic fish

This group consists mainly of lantern fish which inhabit the deeper part of the ocean during daytime and migrate to the surface during night. They are widely distributed in most of the oceans of the world and especially abundant in the northern Indian Ocean. The abundance calculations have been carried out for an area from the continental slope to 30 nautical miles seawards. Though the estimate of about 1 million tonnes seems impressive, this group is not believed to represent any immediate significant resource. The main reason for this is the lack of concentrations and techniques for commercial catches. Some contribution from this group, however, will occur as by-catch in bottom trawl hauls from depths greater than 200 m.

Crustaceans

The estimate of shallow-water shrimps is taken from the assessment carried out by ULLTANG, BRINCA and SILVA, 1979. For further comments on the shallow-water shrimp stock we refer to that report.

The estimate of the deep-water shrimp stock is probably seriously underestimated as the population on the slope of Sofala Bank has not been included. The estimate in Table 15.1 includes only the stock south of Bazaruto Island. The deep-water shrimp off Sofala Bank is exploited by Spanish trawlers and the catch is believed to be some few thousand tonnes annually. Some fishing vessels from the German Democratic Republic started fishing on this stock in October 1978. An improved assessment of the deep-water shrimp will probably be possible at the end of 1979. Caution should be shown in not increasing the effort in the deep-water shrimp fishery before a proper assessment can be made.

The stock of spiny lobsters is probably about 1000 tonnes which is most likely an underestimate. At present no regular all-season fishery is carried out on this stock. Fishing from September to November 1977 and in April-May 1978 gave a total catch of about 30 tonnes. Exploratory fishing by a joint Mozambican and Japanese enterprise is now in progress and will significantly improve the necessary data basis for assessment.

The crayfish stock is believed to be of the order of a few hundred tonnes. No specific fishing is carried out on this stock. The catches are mainly a by-catch of the deep water shrimp fishery, as the area of distribution of these two groups overlaps. The chances of over-exploitation of this stock are considered to be small, due to the habit of crayfish of forming burrows in the bottom and staying there at night. This habit make them less assessible for bottom trawls.

Reef and inshore fishery

The coast between Cabo Delgado and Angoche is edged by coral reefs and thus is unsuitable for trawling. Investigations from other reef areas in the region suggest that an annual potential production of about 5 tonnes/km^2 should be expected. This will probably give a potential yield in the range of 5-10 000 tonnes. There is lack of information on the current fishery in the area and thus also the possibilities of increasing the fishery.

By an inshore fishery we mean fishing at depths less than 10 m. If an annual production of about 2 tonnes/km^2 is reasonable. the expected potential yield will probably be of the same order as that of the reef fishery. A fishery for shad, a small pelagic fish, is carried out in the bays of Maputo and Beira. The annual catch in Maputo Bay was about 900 tonnes in 1977. For Beira Bay no information is available. As for the reef fishery, there is lack of information on the current fishery carried out in the inshore area.

16. REFERENCES

ANON 1931. Int. Whal. Statist., II.

ANON 1976 a. A synopsis of the informations on the pelagic resources off the south-west coast of India. Progress Report No. 18. UNDP/FAO Pelagic Fishery Project (IND 69/593).

ANON 1976 b. Estatístac basicas de pescas de Mocambique 1961-1975. Estudo 1, Direccão Nacional de Pescas, Setembro 1976, Maputo.

ANON 1977 a. Final report. Survey results of R/V "Dr. Fridtjof Nansen". Indian Ocean Fishery and Development Programme. Pelagic Fish Assessment Survey North Arabian Sea. FAO: 1-26. [Mimeo.]

ANON 1977 b. Cruise report no 1 of R/V "Dr. Fridtjof Nansen". Joint NORAD/MOZAMBIQUE/FAO project to investigate the fish resources off the coast of Mocambique.

ANON 1978 a. Cruise report no 2 of R/V "Dr. Fridtjof Nansen", October-December 1977. Joint NORAD/MOZAMBIQUE/FAO Project to investigate the fish resources off the coast of Mozambique.

ANON 1978 b. Cruise report no 3 of R/V "Dr. Fridtjof Nansen", January-March 1978. Joint NORAD/MOZAMBIQUE/FAO Project to investigate the fish resources off the coast of Mozambique.

ANON 1978 c. Cruise report no 4 of R/V "Dr. Fridtjof Nansen", April-June 1978. Joint NORAD/MOZAMBIQUE/FAO Project to investigate the fish resources off the coast of Mozambique.

ANON 1978 d. Survey results of R/V "Dr. Fridtjof Nansen" in July 1978. The joint NORAD/SEYCHELLES Project to investigate the fish resources in Seychelles waters.

ANON 1978 e. Report on the test fishing trip of the freezer trawler "Kattegat" in the waters of the People's Republic of Mozambique from October 2 to December 12, 1977. Institute of Deep-Sea Fishery and Fishprocessing, Rostock. German Democratic Republic, February 1977.

ANON 1979. Report of the FAO/IOP workshop on the fishery resources of the western Indian Ocean south of equator. IOFC/DEV/79/45 FAO, Rome.

ALLEN, J.S. 1973. Upwelling and coastal jets in a continuous stratified ocean. J. Phys. Oceanogr., 3: 245-257.

BASS, A.J., AUBREY, J.D.D. and KISTNASAMY, N. 1973. Sharks of the east coast of southern Africa. I. The genus Carcharhinus (Carcharhinidae). Invest. Rep. oceanogr. Res. Inst., (33): 1-168.

BASS, A.J., AUBREY, J.D.D. and KISTNASAMY, N. 1975. Sharks of the east coast of southern Africa. III. The families Carcharhinidae (Excluding Mustelus and Carcharhinus) and Sphyrnidae. Invest. Rep. oceanogr. Res. Inst., (38): 1-100.

BERRY, P.F. 1969. The biology of Nephops andamanica Wood-Mason (Decapoda, Reptantia). Inv. Rep. oceanogr. Res. Inst. (22): 1-55.

BERRY, P.F. 1973. The biology of the spiny lobster Palinurus delagoa Barnard, off the coast of Natal, South Africa. Invest. Rep. oceanogr. Res. Inst., (31): 1-27.

BIRKETT, L. 1978. Western Indian Ocean Fishery Resources Survey. Report on the cruises of R/V PROFESSOR MESYATSEV December 1975-June 1976/July 1977-December 1977. Indian Ocean Program, Technical report No 21, FAO, Rome - August 1978.

BUDNICHENKO et al. 1977. Results obtained from the "Aelita" exploratory surveys undertaken in the shelf and open waters continuous to the coast of the People's Republic of Mozambique (May 1976 through August 1977). Azcher-NIRO, Kerch 1977.

BURCZYNSKI, J. 1976. Echo survey along the East African coast from Mombasa to Laurence Marques by R/V PROFESSOR MESYATSEV in January-February 1976. FAO Fisheries Travel Report and Aide Memoire no 12, Rome 1976.

CAYRE, P., LE LOEUFF, P. et INTES, A. 1979. Geryon quinquedens, le crab rouge pro fond. Biologi, peche, conditionnement, potentialités d'exploitation. La Peche Maritime, Janvier 1979.

CLARKE, T.A. 1973. Some aspects of the ecology of lantern fishes (Myctophidae) in the Pacific Ocean near Hawaii. Fishery Bull. Fish Wildl. Serv. U.S. 71: 401-434.

CLOWES, A.J. 1950. An introduction to the hydrology of South African waters. S. Afr. Fish. Mar. Biol. Survey, Investl., Rep., 12: 1-42.

CREPON, M. 1964. Présentation d'observations faites á GEK en 1962. Cahiers Oceanographique, 16: 869-874.

DARBYSHIRE, J. 1964. A hydrological investigation of the Agulhas Current area. Deep-Sea Res., 11; 781-815.

FISHER, W. and WHITEHEAD, P.J.P. (eds), 1974. FAO species identification sheets for fishery purposes. Eastern Indian Ocean (Fishing area 57) and Western Central Pacific (Fishing area 719. I-IV. FAO, Roma. pag. var.

FORBES, S. and NAKKEN, 0. 1972. Manual of methods for fisheries resource survey and appraisal. Part 2. The use of acoustic instruments for fish detection and abundance estimation. FAO Man. Fish. Sci., (5): 138 p.

FREY, H.W. 1971 (Ed.). California's living marine resources and their utilization. State of Calif. The Resources Agency, Dept. of Fish and Game.

GJØSÆTER, J. 1978. Aspects of the distribution and ecology of the myctophidae from the western and northern Arabian Sea. Dev. Rep. Indian Ocean Programme (43) Vol. 2: 62-108.

GREY, M. 1964. Family Gonostomatidae. Pp 78-272 in Olsen, Y.H. [ed.] Fishes of the Western North Atlantic No 1. Part 4. Mem. Sears Found. Mar. Res. Yale Univ.

GRINDLEY, J.R. and PENSITH, M.J. 1965. Notes on the bathypelagic fauna of the seas around South Africa. Zoologica Afr. 1: 275-295.

GRÜNDLINGH, M.L. 1977. Drift observations from NIMBUS VI Satellite-tracked buoys in the south-western Indian Ocean. Deep-Sea Res., 24: 903-913.

GULLAND, J.A. 1970. The fish resources of the ocean. Fishing News (Books) Ltd. Surrey, England.

HARRIS, T.F.W. 1972. Sources of the Agulhas Current in the spring of 1964. Deep-Sea Res., 19: 633-650.

HIPKINS, F.W. 1974. Fishery fact-7. A trapping system for harvesting sablefish Anoplopoma fimbria. U.S. Dept. of Comm., Natl. Oceanic. Atmos. Adm., Natl. Mar. Fish. Serv., Fishery Facts 7: 1-22.

HURLBURT, H.E. and THOMPSON, J.D. 1973. Coastal upwelling on a B-plane. J. Phys. Oceanogr., 3: 16-32.

JOHNSON, D.R., BARTON, E.D., HUGHES, P. and MOOERS, C.N.K. 1975. Circulation in the Canary Current upwelling region off Cabo Bojador in August 1972. Deep-Sea Res., 22: 547-558.

KOTTHAUS, A. 1972. Fische des Indischen Ozeans. Ergebnisse der ichthyologischen Untersuchungen während der Expedition des Forschungsschiffes "Meteor" in den Indischen Ozean, Oktober 1964 bis Mai 1965 A. Septematischer Teil IX Iniomi (Nachtrag: Fam. Myctophidae) "Meteor" Forsch.-Ergebnisse Reihe D 12: 12-35.

LEATHERWOOD, S., CALDWELL, D.K. and WINN, H.E. 1976. Whales, Dolphins, and Purpoises of the Western North Atlantic. A guide to their identification. NOAA Technical Report NMFS Circ - 396. SEATTLE. 176 p.

LUTJEHARMS, J.R.E. 1976. The Agulhas Current system during the northeast Monsoon season. J. Phys. Oceanogr., 6: 665-670.

LUTJEHARMS, J.R.E. 1977. The need for oceanological research in the South-west Indian Ocean. S. Afr. J. of Science, 73: 40-43.

MACKINTOSH, N.A. 1965. The Stocks of Whales. Fishing News (Books) Ltd. London. 232 p.

MCNIDER, R.T. and O'BRIEN, J.J. 1973. A multi-layer transient model of coastal upwelling. J. Phys. Oceanogr., 3: 258-273.

MENACHE, M. 1963. Première campagne oceanographique du Commandant Robert Giraud dans le canal de Mozambique, 11 octobre au 28 novembre 1957. Cahiers Oceanographique, 15: 224-235.

MOISEEV, P.A. 1969. Living resources of the word ocean. Moskva, 1969 Pischevaia piomyshlennost'. 338 p. [In russian].

MOOERS, C.N.K., COLLINS, C.A. and SMITH, R.L. 1976. The dynamic structure of the frontal zone in the coastal upwelling region off Oregon. J. Phys. Oceanogr., 6: 3-20.

MUNRO, J.L. 1969-1973. The biology, ecology, exploitation and management of the Carribbean reef fishes. Scientific Report of the O.D.A.U.W.I. Fisheries Ecology Research Project (1969-1973) Vols. 1-6.

NAFPAKTITIS, B.G. and NAFPAKTITIS, M. 1969. Lanternfishes (Family Myctophidae) collected during cruises 3 and 6 of the R/V "Anton Bruun" in the Indian Ocean. Bull. Los Angeles Country Mus. Nat. Hist. Science 5: 1-79.

NAFPAKTITIS, B.G. 1978. Systematics and distribution of lantern-fishes of the genera Lobianchia and Diaphus (Myctophidae) in the Indian Ocean. Bull. Los Angeles Country Mus. Nat. Hist. Science 30: 1-92.

NAKKEN, O. 1975. On the problem of determining the relationship between integrated echo intensity and fish density. Coun. Meet. int. Coun. Explor. Sea., 1975 (B:26): 1-8. [Mimeo.]

NAKKEN, O. and OLSEN, K. 1977. Target strength measurements of fish. Rapp. P.-v. Reun. Cons. int. Explor. Mer, 170: 52-69.

NEKRASOV, V.V. 1968. Revision of the species of Decapterus (family Carangidae, Order Perciformes) found in the Indian Ocean. J. Ichthyology, 9(2): 159-167.

O'BRIEN, J.J. and HURLBURT, H.E. 1972. A numerical model of coastal upwelling. J. Phys. Oceanogr., 2: 14-20.

ORLOWSKI, A. 1975. Scientific report of the cruise of R/V PROFESSOR SIEDLECKI in the Indian Ocean. [In Polish]. Gdynia, Morski Instytut Rybacki; 46-54.

ORREN, M.J. 1963. Hydrological observations in the south west Indian Ocean. Investl. Rep., Div. Sea Fish. Un. S. Afr., 45: 1-61.

PAULY, D. 1978. A discussion of the potential use in population dynamics of the interrelationships between natural mortality, growth parameters and mean environmental temperature in 122 fish stocks. Coun. Meet. int. Coun. Explor. Sea., 1978 (G:21). [Mimeo.]

PEARCE, A.F. 1977. Some features of the upper 500 m of the Agulhas Current. J. Mar. Res., 35: 731-751.

RISTING, S. 1922. Av Hvalfangstens Historie, J. Petlitz Boktrykker, Kristiania. 625 p.

SMITH, J.L.B. 1972. Smith's fishes. Valiant Publishers, Sandton, 580 p.

SMITH, R.L. 1974. A description of current, wind and sea level variations during coastal upwelling off Oregon Coast, July-August 1972. J. Geophys. Res., 79: 435-443.

STAVROPOULOS, C.C. and DUNCAN, C.P. 1974. A satellite tracked buoy in the Agulhas Current. J. Geophys. Res., 79: 2744-2746.

TIEWS, K., MINES, A. and RONQUILLO, I.A. 1968. On the biology of Saurida tumbil (Bloch, 1801), family Synodontidae in Phillippine waters. I-p.F.C., 13th session, Brissbane, Doc. I-P.F.C/C 68/SYMP 10.

TINLEY, K.L. 1971. Determinants of coastal conservation dynamic and diversity of the environment as excamplified by the Mocambique coast. Proceeding of the Symposium on Nature Conservation as a Form of Land use Gorongosa National Park, Mozambique. Sarccus, Pretoria: 125-153.

TØNNESSEN, J.N. 1967 and 1969. Den Moderne Hvalfangst/Historie, II. Kommandør Chr. Christensens Hvalfangstmuseum, Sandefjord. Vol. I. 1967. 619 pp., Vol. III 1969. 647 pp.

ULLTANG, Ø., BRINCA, L. and SILVA, C. 1979. A preliminary assessment of the shallow water prawn stocks off Mozambique, North of Beira (In press).

WHITEHEAD, P.J.P. 1972. Synopsis of the clupeoid fishes of India. J. mar. biol. Ass. India., 14(1); 160-256.

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

WYRTKI, K. 1973. Physical oceanography of the Indian Ocean, in Biology of the Indian Ocean, B. Zeitzshel (Ed.). Springer-Verlag Berlin, Heidelberg, New York 1973.

Figure

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. The first four years of operation from 1975 to 1978 include a survey of the pelagic fish resources in the NW Arabian Sea organized with FAO's Fisheries Department (1975-76), a survey off Pakistan under a bilateral agreement with this country, a survey of Mozambique waters organized bilaterally with the government of Mozambique (1977/78); a brief assignment off the Seychelles in July 1978 and a survey off Sri Lanka in Aug.-Sept. 1978. All of these programmes formed part of and were sponsored by FAO's Indian Ocean Fisheries Development Programme. The Institute of Marine Research, Bergen is under a sub-contract with NORAD responsible for the operation of the vessel, and the various research programmes were planned and conducted jointly with the relevant fisheries research organizations in the countries concerned.

Results of the previous surveys have been reported on in a number of cruise-and progress reports under each programme.