A Survey of the Fish Resources in the Coastal Waters of the Republic of Cape Verde, November 1981

Reports on Surveys with the R/V Dr Fridtjof Nansen

Institute of Marine Research, Bergen

September 1982

“Dr. Fridtjof Nansen”

The fishery research vessel “Dr. Fridtjof Nansen” belongs to the Norwegian Agency for International Development (NORAD). It was designed and built for scientific and exploratory investigations of fishery resources of developing countries under a joint plan with the Fisheries Department of FAO, based on a funding of operation to be shared by UNDP/FAO and Norway. The Institute of Marine Research, Bergen, is under a sub-contract with NORAD and FAO responsible for the scientific programme and the operation of the vessel.

This report has been prepared at the Institute of Marine Research, Bergen, by T. Strømme, S. Sundby (hydrography) and G. Sætersdal.

TABLE OF CONTENTS

1. INTRODUCTION

1.1 Objectives

In the period May 1981 - April 1982 a programme of acoustic fish resource surveys was conducted in West African waters with the R/V “Dr. Fridtjof Nansen”. The programme included ten surveys covering areas between Agadir and Point Noir planned and carried out in close cooperation with the FAO/UNDP/Project: Development of Fisheries in the Eastern Central Atlantic through its headquarters in Dakar.

The work reported here was planned during a meeting in Praia in October 1981. The main objectives were:

a) An acoustic survey of the distribution and abundance of the pelagic and demersal resources.

b) Sampling of the distribution and size composition of the main species with pelagic and bottom trawl and with long lines where bottom conditions do not permit trawling.

c) A pilot acoustic study of the distribution and abundance of mesopelagic fish within the Cape Verde Archipelago.

d) Mapping of bottom conditions suitable for trawling, based on bottom traces from the acoustic system.

e) Investigations of main hydrographical conditions.

The participating scientific and technical staff is listed in Annex I. All staff took part in sampling and gathering of data and carried out analysis and processing to the extent possible on board the vessel. The preliminary results were presented in a short cruise report.

1.2 Itinerary and survey coverage

The survey started from Dakar on 3 November and the vessel called on Praia on 5 November to pick up personnel from Cape Verde. After a calibration of the acoustic instruments in the bay of Praia, the vessel's propeller was seriously damaged, and the vessel had to return to Dakar for docking. After a ten days' delay the local participants were again embarked in Praia on 16 November.

The survey track together with fishing and hydrographical stations are shown in Figures 1 and 2. The islands were surveyed in a clockwise direction, beginning with Fogo in the west. The shelves of all the islands were covered, including also fishing banks within the archipelago. On the tracks between the islands and also on some broader sweeping tracks pelagic resources over deep water were investigated.

The vessel called on Praia on 27 November to exchange some of the Norwegian crew and the biologist from Cape Verde. The next day the vessel set out for a short trip of three days to resurvey the area around the islands Sal, Boavista and Maio, and this time also an attempt to evaluate the demersal resources by bottom trawling was made. The vessel made a last call on Praia on 1 December.

The Portugese navigational charts provided for the survey proved to be lacking in details for some of the islands with many shoals and breakers unmarked. For safety reasons this made parts of the shelves inaccessible to the vessel. As this mostly concerns the islands Santiago, Fogo, Brava and St. Nicolau where the shelf is extremely small, the lack of important acoustic and catch data seems negligible.

The traditional method of identifying and sampling the echo targets by midwater and bottom trawling could not be fully used as underwater peaks and heavily serrated shoals occurred frequently both on the shelf and close by. In such locations fishing with long lines was tried.

Fig. 1. Cruise track and stations 16 - 27 November 1981.

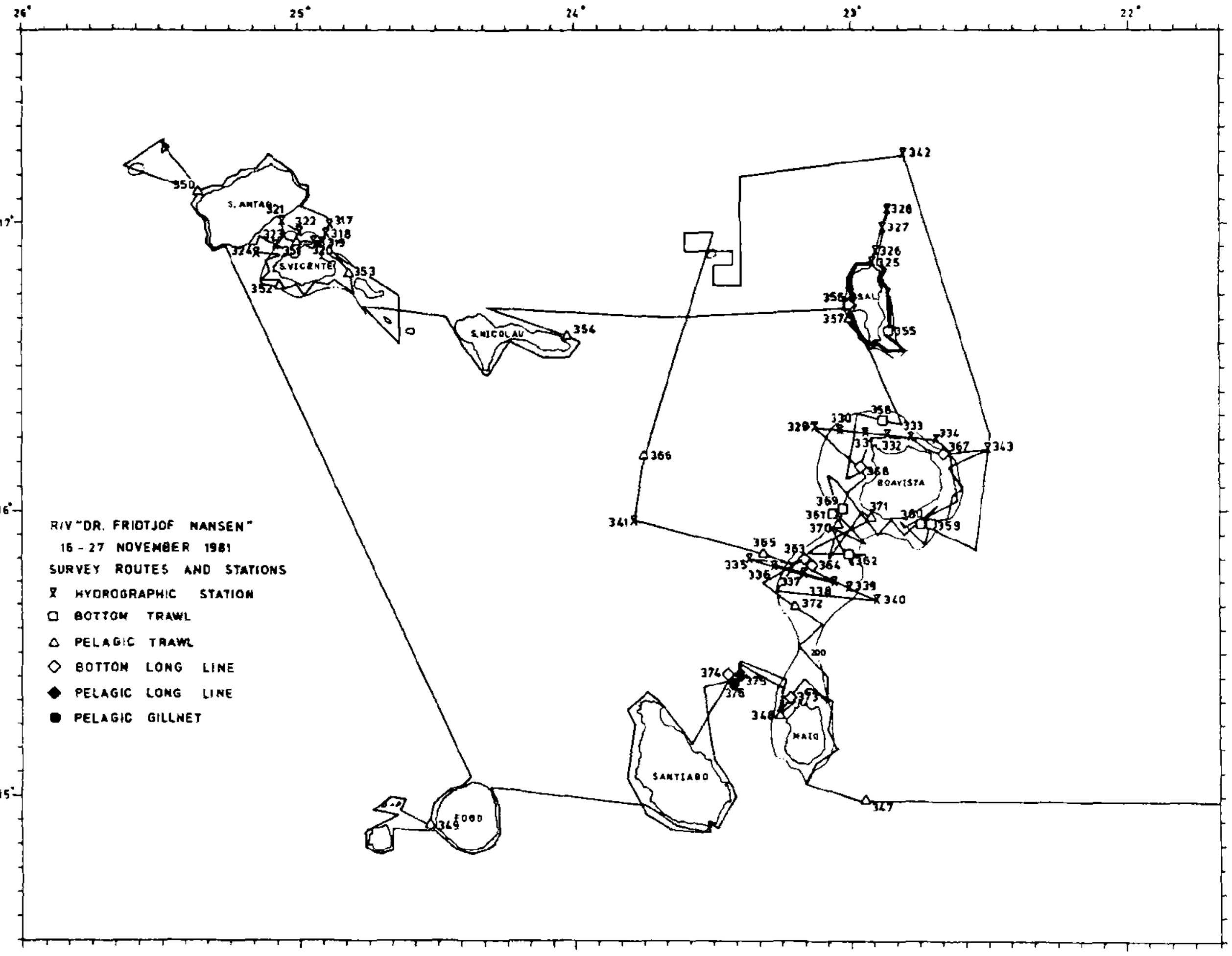
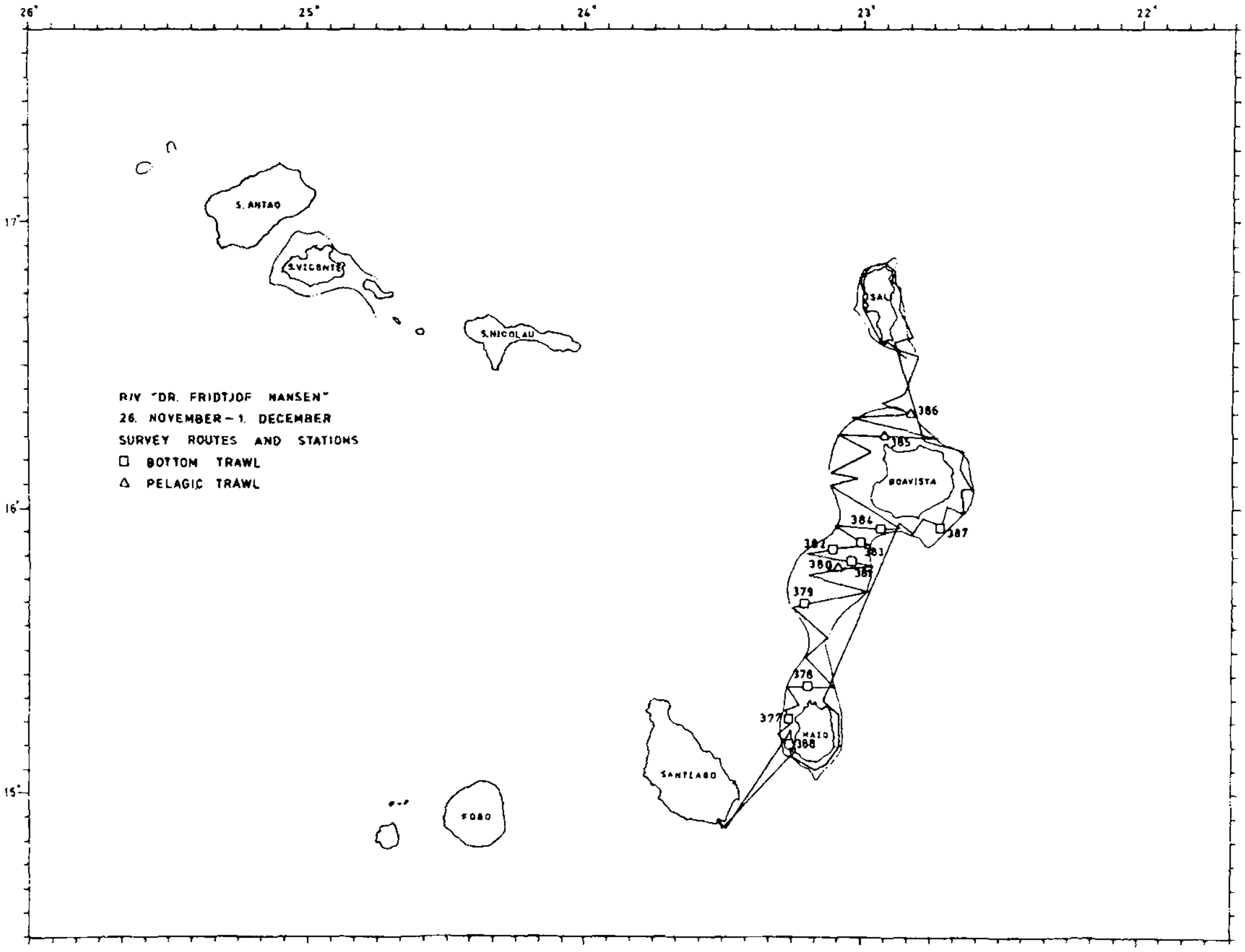


Fig. 2. Cruise track and stations 28 November - 1 December 1981.



During the daily study of the echogrammes the bottom which seemed suitable for bottom trawling was marked off.

The survey comprised:

17 bottom trawl stations
17 pelagic trawl stations
8 long line stations
27 hydrographical stations

The total cruise track within the Cape Verde archipelago was 2500 nm.

2. RESULTS

2.1 Hydrography

General features of wind- and current conditions around the Cape Verde Islands

The Cape Verde Islands lie in the southern part of the Canary Current which runs south-westerly along the Northwest African Coast. The current direction is still south-westerly through the Cape Verde archipelago, but beyond this area it turns west and nortwest and then becomes the Northern Equatorial Current. The speed of the residual current is less than 0.5 knots (DIETRICH and ULRICH, 1968). The atmospheric circulation is dominated by the trade-wind of north-easterly direction.

Wind conditions and hydrographic conditions 18-25 november 1981

Standard meteorological observations were taken at the hydrographical stations. The wind velocity during this period was gentle to moderate breeze (4-7 $m \cdot sec^{-1}$), and the direction was constantly of NNE and NE. The wind measurements from the hydrographic stations around the eastern archipelago (Fogo-Sal) is somewhat more northerly than from the stations in the sound between S. Antao and S. Vicente. Wind speed was also higher in the sound. This may be due to the time lag of 2-4 days between the measurements taken of the two areas. However, it may also be due to the local topography of the two islands S. Antao and S. Vicente, which may give a change of wind direction and an increase of wind speed through the sound.

During the cruise 27 Nansen casts were made. Temperature, salinity, and dissolved oxygen were observed at standard depths to the bottom or maximum 500 m.

In the upper wind-mixed layer the temperature is about 0.7°C lower at the west side of the archipelago Fogo-Sal, while salinity is somewhat higher. At most stations both temperature and salinity decrease towards the bottom. However, in the basin to the west of Fogo-Sal a layer of high saline water exists, about 50 m thick, with the core at about 75 m depth (Fig. 4). T-S analysis of the data shows that this water mass is also present on the east side, but here it is less pronounced.

Fig. 3, 4 and 5 show temperature, salinity and density of the João Valente Bank section. The bank seems to have influence on the vertical circulation. Upwelling occurs at the western edge. It seems to be most vigorous down to 150 m depth, but the salinity distribution indicates that it occurs to a less extent down to 300 m depth.

At the eastern edge of the bank the opposite process, down-welling, seems to occur below 125 m depth.

The upper mixed layer extends down to about 30 m depth around the Cape Verde islands. Above the João Valente Bank, it is considerably deeper, extending here to about 50 m depth. The deepening of the mixed layer above the bank is most probably due to higher vertical turbulence generated by waves and current. In the same way the upwelling at the western edge and downwelling at the eastern edge may be explained by an obstacle effect on the eastwest component of the upper layer current.

Fig. 3. Temperature, t °C, at the João Valente Bank section 23 November 1981.

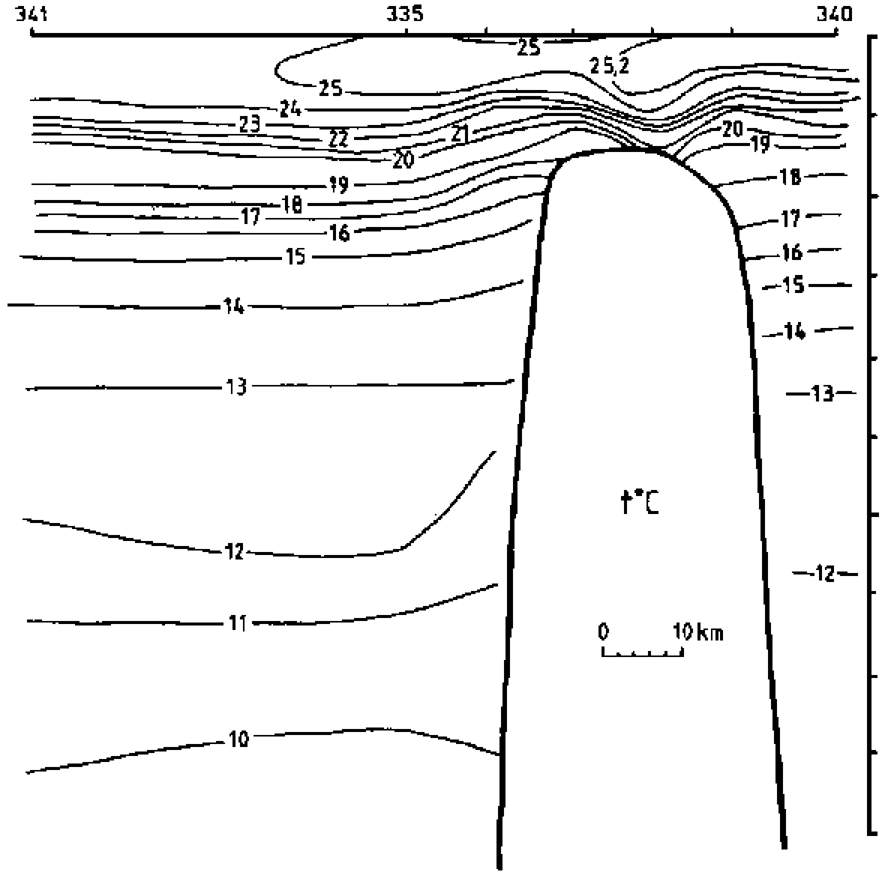


Fig. 4. Salinity, S ‰, at the João Valente Bank section 23 November 1981.

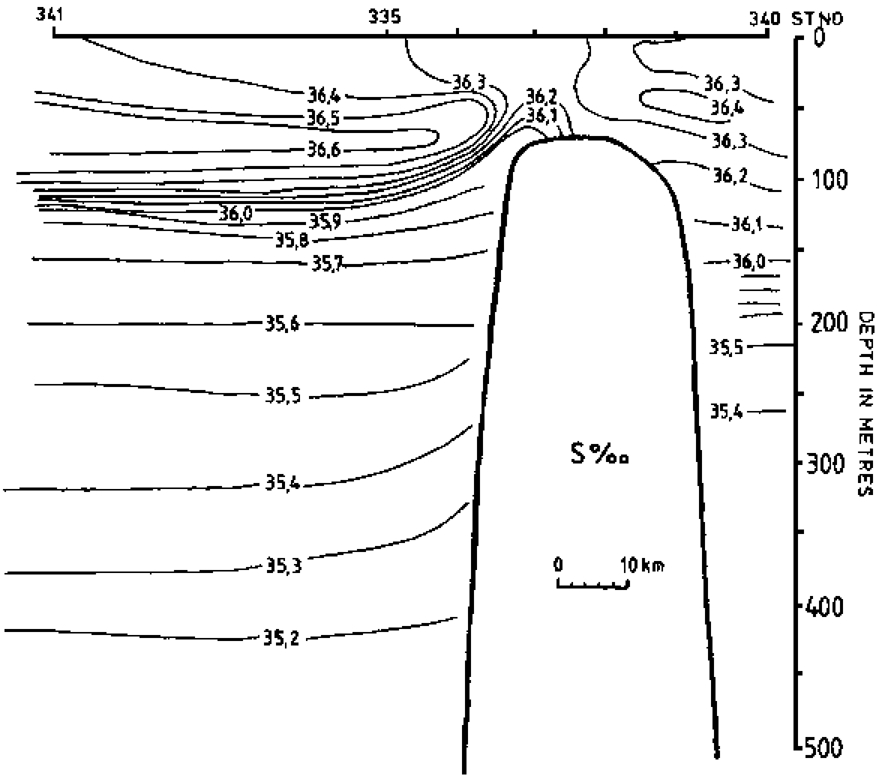


Fig. 5. Density, G_t, at the João Valente Bank section 23 November 1981.

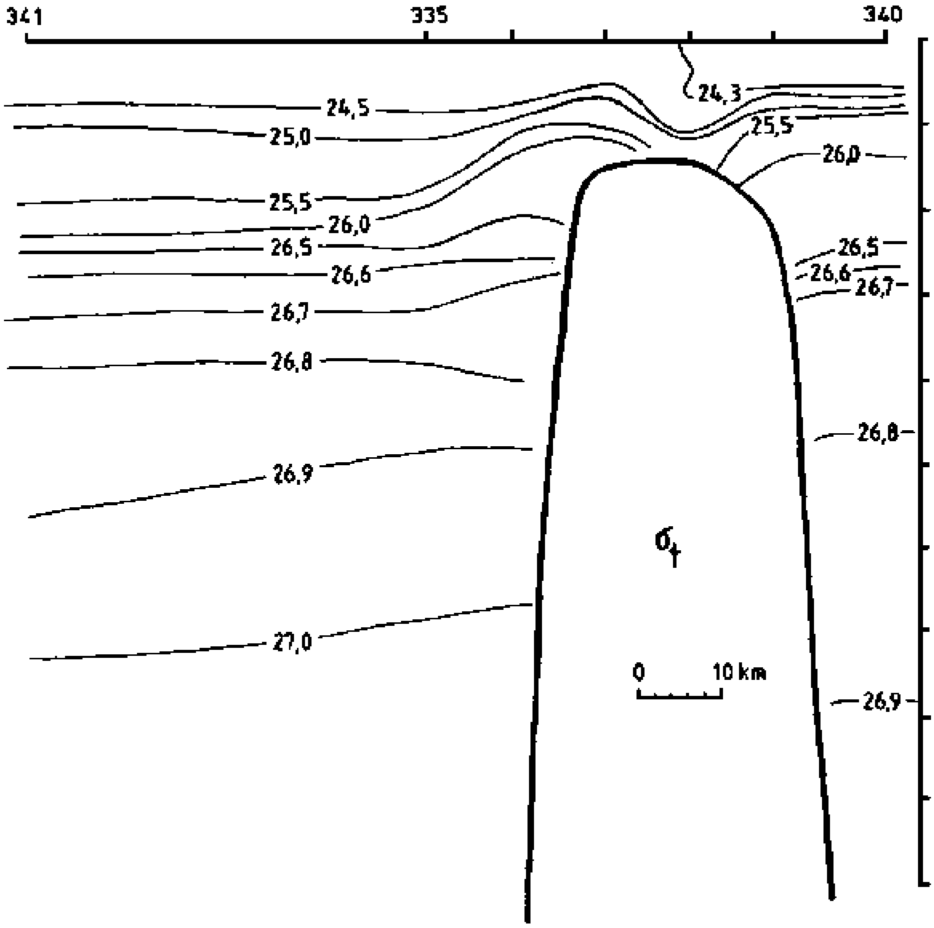
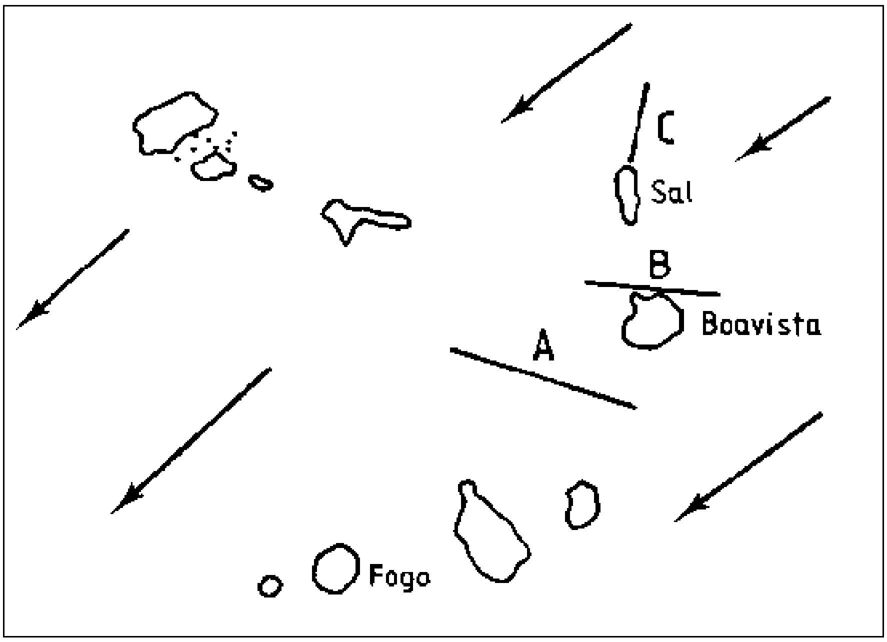


Fig. 6. General features of the current of the upper layer.



A. The João Valente Bank hydro-graphic section.
B. The Boavista hydrographic section.
C. The Sal hydrographic section.

Fig. 7. Tentative vertical circulation across the João Valente Bank November 1981.

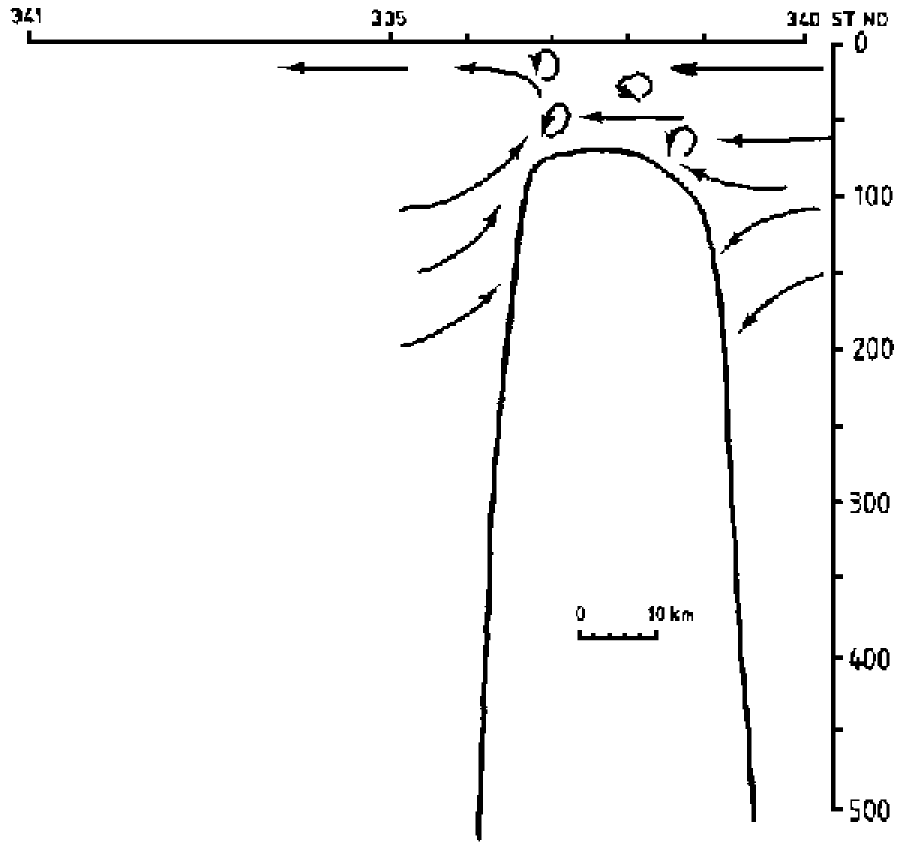


Fig. 8. Oxygen, ml/l, at the João Valente Bank section.

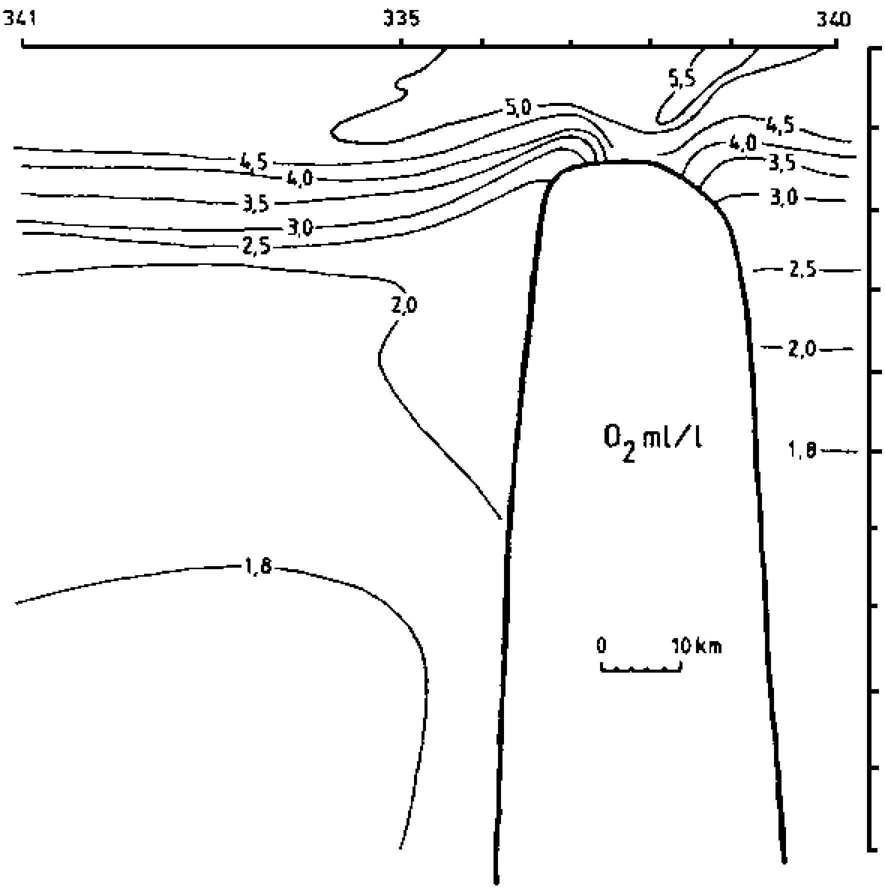
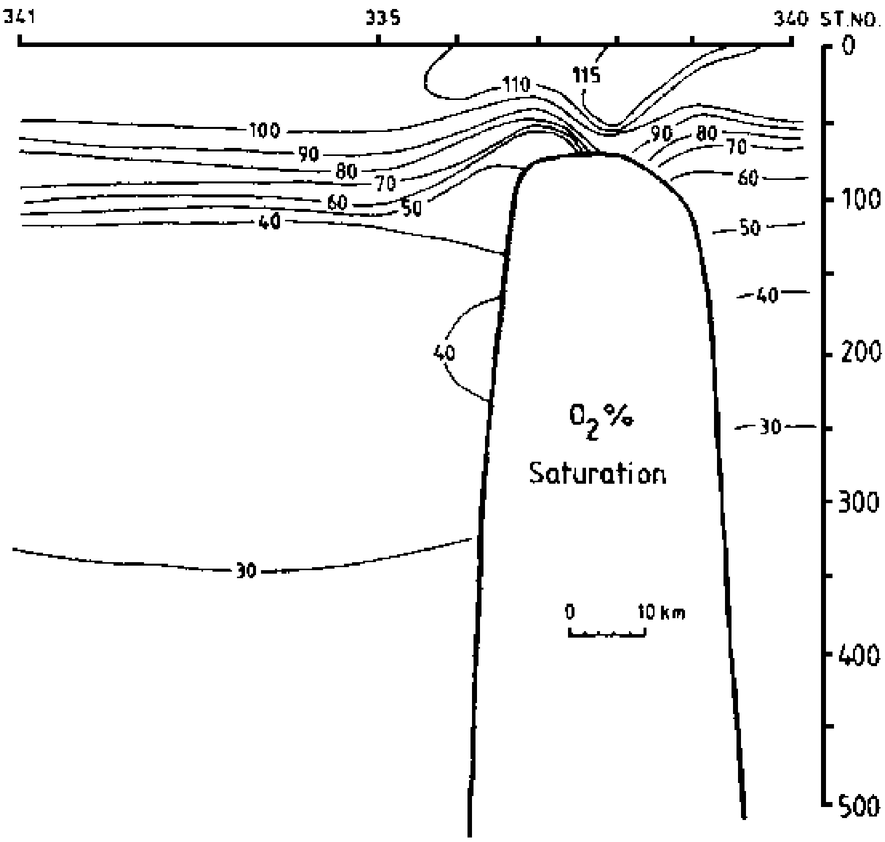


Fig. 9. Oxygen, % saturation, at the João Valente Bank section.



In Fig. 6 the residual current direction is drawn after DIETRICH and ULRICH (1968). Fig. 7 shows the vertical circulation around the João Valente Bank as described above.

The oxygen distribution at the João Valente Bank section shows similar features as the density distribution, indicating upwelling of oxygen poor water on the western edge. Fig. 8 and 9 show oxygen distribution in ml/l and percent saturation, respectively. The upper well mixed layer above the bank has very high concentrations of oxygen (120 percent saturation) indicating high primary production. This must be caused by the combined effect of upwelling and mixing bringing nutrient rich water into the euphotic zone.

The Boavista section shows similar features as the João Valente Bank section, but both upwelling and mixing of the upper layer above the shallow area are less pronounced here. This may, however, be an effect of the position of this section at the north part of the bank.

The surface temperature is shown in Fig. 10.

2.2 Bottom conditions

Fig. 11 shows the distribution of trawlable and non-trawlable bottom inside the 200 m depth contour. The evaluation is based on the degree of smoothness of the recordings from the echo sounder observations and on hauls with the bottom trawl gear. Only the Maio-Boavista shelf has appreciable areas suitable for trawling. A small patch southeast of Sal is also trawlable.

Fig. 10. Temperature °C in surface layer.

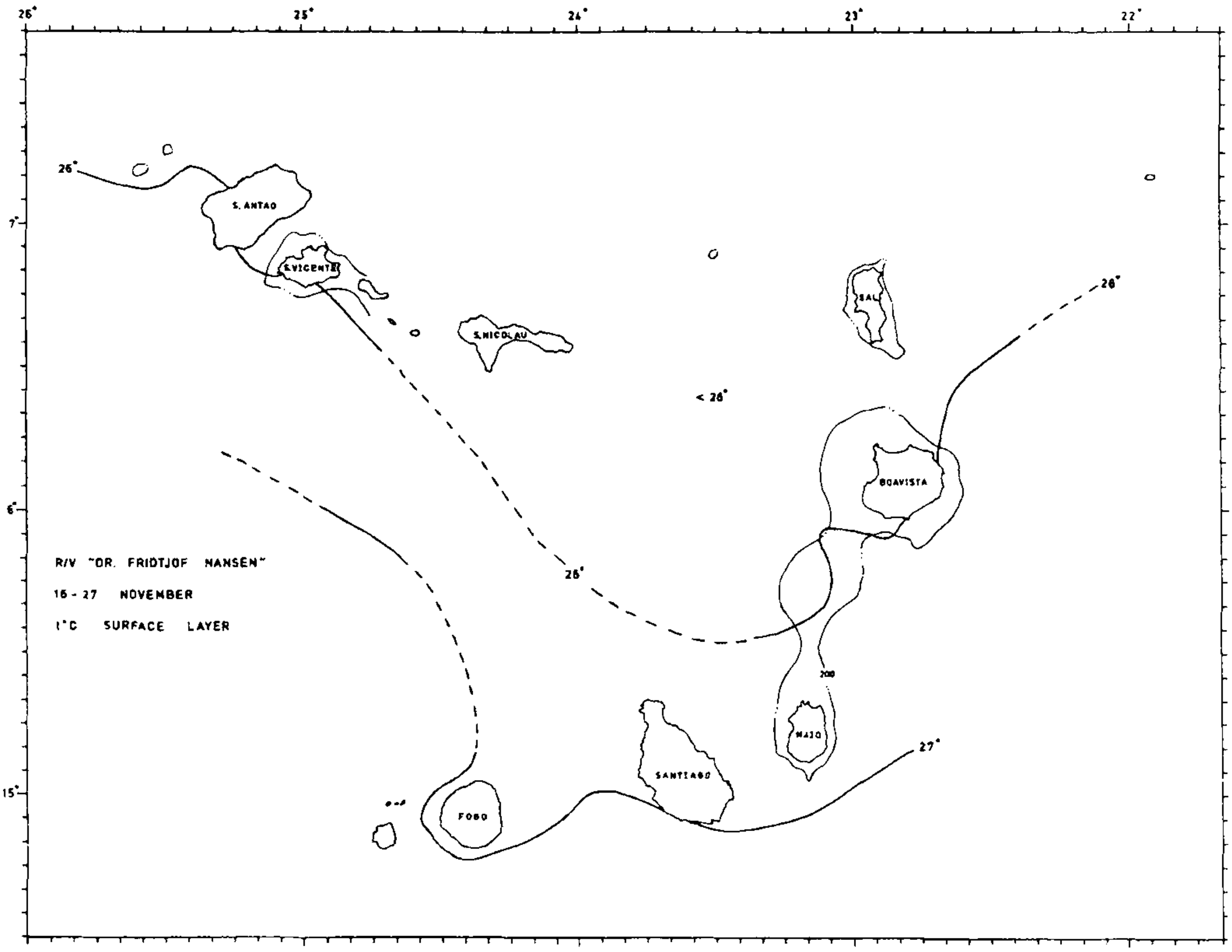
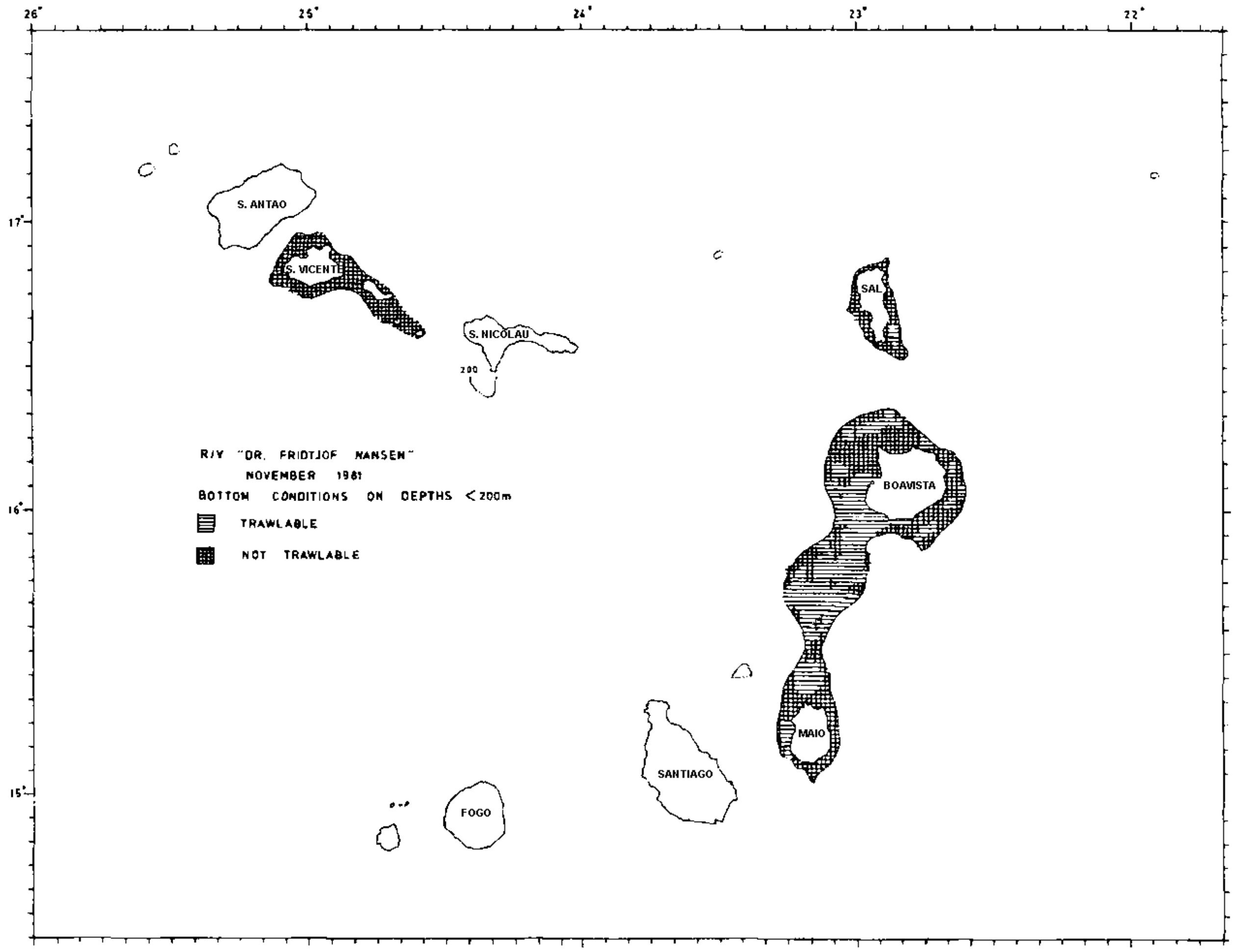


Fig. 11. Bottom conditions at depths less than 200 m.



2.3 Fish distribution and abundance

Figures 12 and 13 show the distributions of fish found during the first and second coverage respectively. The main species in the area when identified by fishing is marked off with a species code in Fig. 12.

Based on the characteristics of the echotraces and partly on the composition of the catches the indices of abundance were split into pelagic and demersal fish. This is a customary classification based on the distributional- and feeding behaviour of the various fish species. The criteria on which the separation is made are, however, uncertain and too much confidence should not be placed in these sub-estimates.

One result of the survey is the demonstration that the distribution of small pelagic and demersal fish is closely restricted to the shelf regions of the islands. No significant recordings of commercial fish were made over the deep-water areas between the islands. One should note, however, that this type of survey is not suitable for large pelagic fish such as tunas, and a possible occurrence of these would not be shown.

The observations of echo-intensity have been converted to measures of fish density in accordance with the conventional method described in Annex V. By area integration estimates of fish biomass are obtained and these are shown in Table 1 split on four sub-areas within the archipelago. The table includes approximate estimates of shelf areas and a calculation of the mean fish density inside the shelf, although this measure of productivity per unit shelf area may be of limited relevance in archipelagos with narrow shelves.

The estimate of total fish biomass for the Cape Verde Islands is 100 thousand tonnes of fish. Of this about half is allocated to pelagic species, mainly the scads Decapterus macarellus, D. punctatus and D. rhonchus.

Fig. 12. Fish distribution 16 - 27 November 1981. Echo-intensity by levels of integrator deflection.

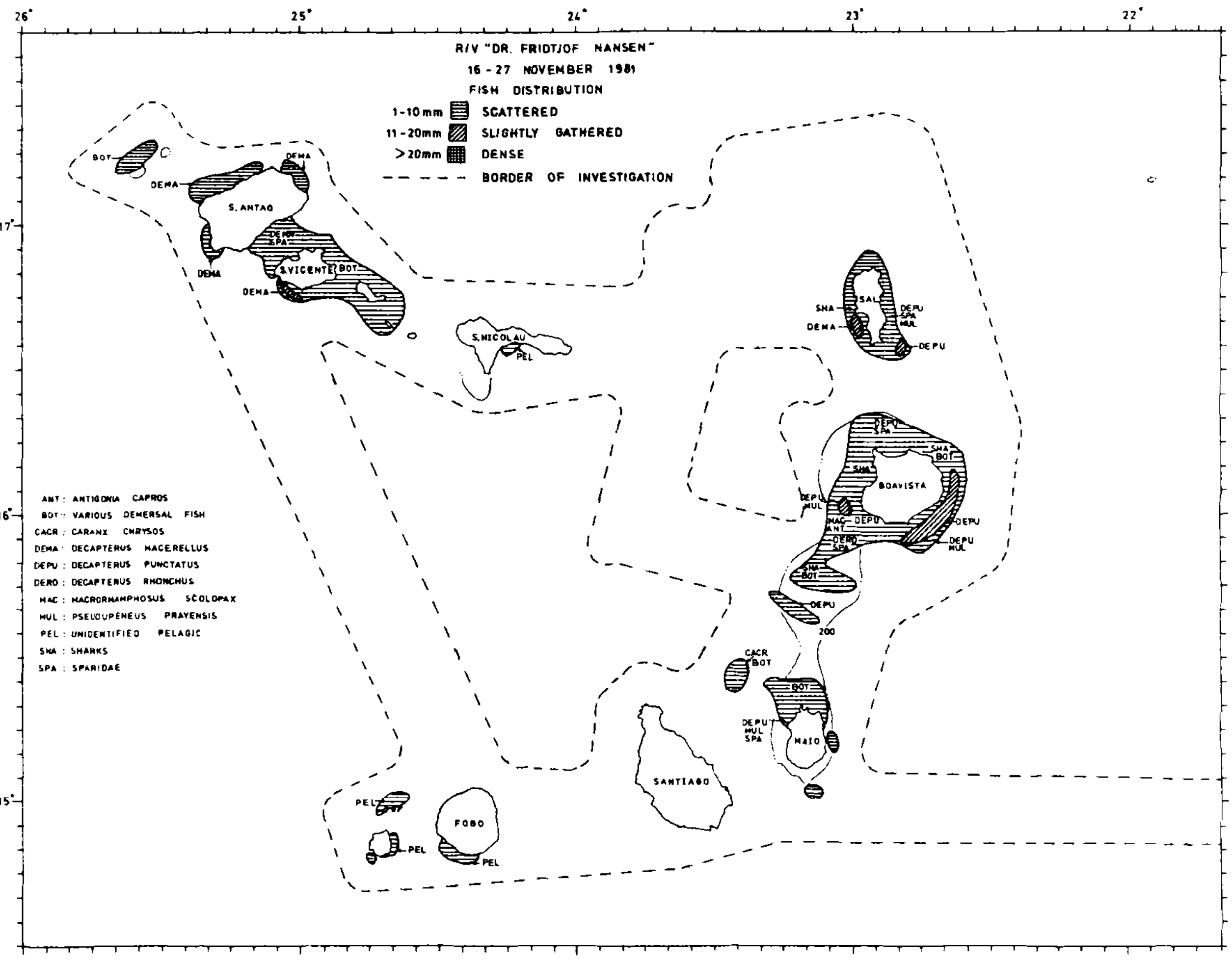
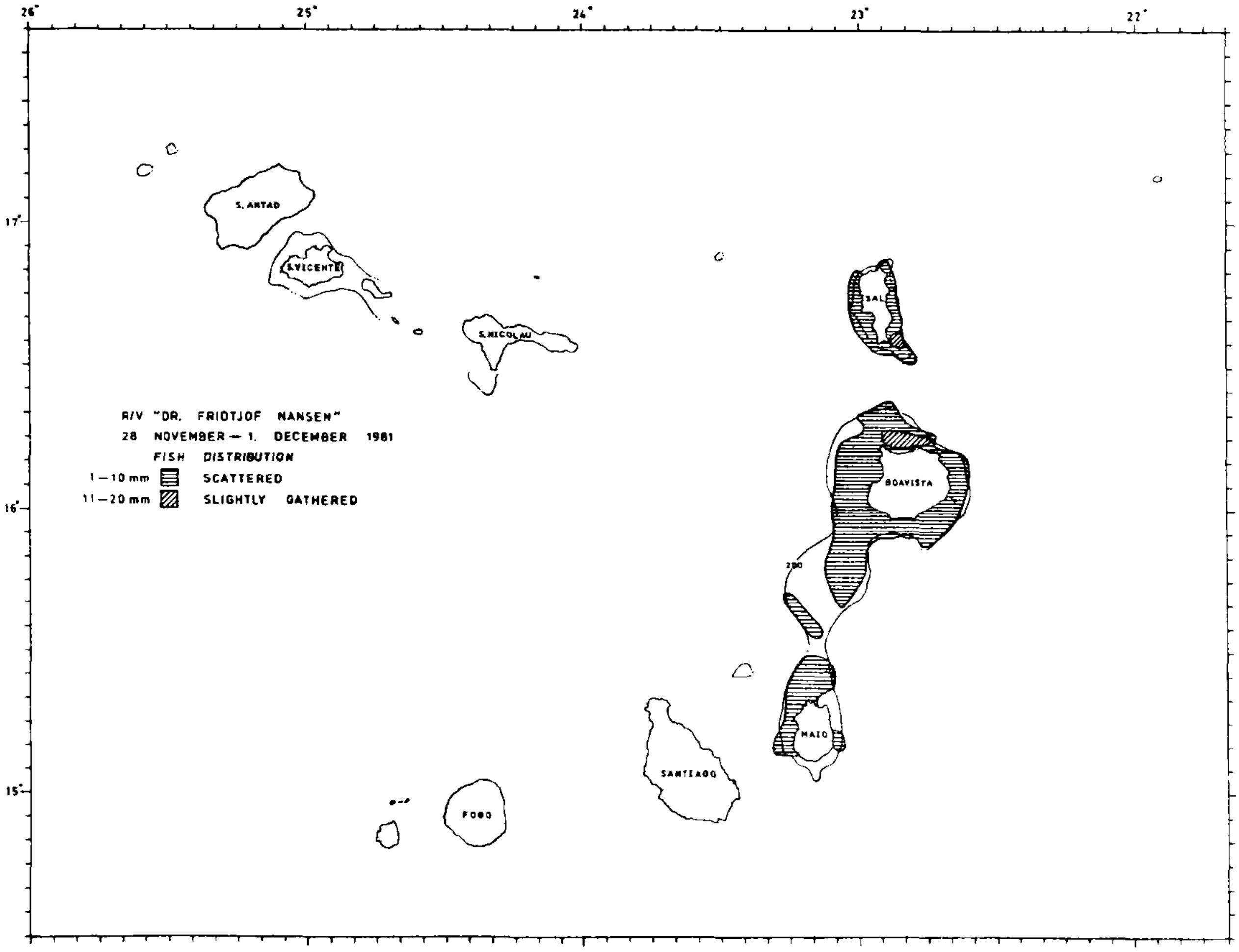


Fig. 13. Fish distribution 28 November - 1 December 1981. Echo-intensity by levels of integrator deflection.



The islands Fogo and Santiago had only some faint recordings of fish, and the total estimate of 1 500 tonnes is considered to be of very low precision.

The shelf around Sto. Antao, S. Vicente and S. Nicolau contained about 20 thousand tonnes of fish. The pelagic contribution to this is about 15 thousand tonnes, which is mainly Decapterus macarellus around S. Vicente. The amount of demersal fish in the catches in this area is too low to provide any basis for assessment of species composition and distribution.

The shelf around Sal is approximate 150 nm². The estimate from the first covering is 9 thousand tonnes of fish. The dominating species were Decapterus macarellus, D. punctatus and Sardinella maderensis.

The shelf around Boavista and Maio and between the two islands is 850 nm² and comprises about 60% of the total shelf area belonging to Cape Verde Islands. This makes the area the most interesting in terms of fishery resources. The two repeated surveys of this area resulted in very similar assessments of total fish biomass: 69 thousand tonnes and 64 thousand tonnes respectively.

15 bottom trawl hauls were carried out around the islands Sal, Boavista and Maio. Though some of the hauls were aimed at fish concentrations identified by echo-sounders and thus not statistically random, a biomass estimate based on the catches and area swept by the trawl could give some tentative measure.

With a total shelf area around these islands of about 1000 nm² a "swept area-estimate" of about 20 thousand tonnes of demersal fish is obtained. This is based on an assumed catchability coefficient q equal to one for the area between the wing ends of the trawl.

Catches of pelagic schooling species such as scads in the bottom trawl hauls have been excluded in these assessments. As shown in Table 1 the acoustic estimate of demersal fish on the Sal, Boavista, Maio-shelf is about 43 thousand tonnes. In contrast to the trawl estimates the acoustic assessment will include demersal type of fish traces which occur above the near-bottom layer of about 6 m covered by the trawl. It may on the other hand also include some pelagic fish with distributional characteristics similar to those of demersal fish. The best estimates of demersal fish on this shelf part is probably 20-30 thousand tonnes which leaves 50-60 thousand tonnes of pelagic fish.

The pelagic resources around Boavista and Maio are mainly made up of the species Decapterus punctatus, D. macarellus, D. rhonchus and Sardinella maderensis, mentioned in order of importance.

The demersal fish were mainly representatives of the families Sparidae, Mullidae, Acanthuridae, and Caproidae.

2.4 Results of fishing operations

The records of the fishing operations are shown in Annex II. The catch rates in the 15 successful bottom trawl catches are shown in Table 2. The high catches consisted mainly of scads. Also generally the carangids dominated the catches, being present in 65% of the trawl hauls as shown in Table 3. Other common families were Sparidae and Mullidae.

The pelagic trawl hauls are of less interest from a fishing operations point of view as they were made mainly for the purpose of identifying acoustic scatterers.

A total of 8 bottom line trials of 300-400 hooks each yielded catches from 0 to abt 80 kgs mostly small sized sharks.

Table 1. Estimated biomass and approximate shelf areas in the waters off Cape Verde Islands.

	Pelagic (10^3 tonnes)	Demersal (10^3 tonnes)	Total (10^3 tonnes)	Shelf area 0-200 m (nm^2)	Mean density ($tonnes/nm^2$)
Fogo, Santiago	1	0.5	1.5	-	-
Sto Antao, S. Vicente, S. Nicolau	15	5	20	440	45.8
Sal, Boavista, Maio, first covering	34	43	77	1008	76.8
Sal, Boavista, Maio, second covering	-	-	79	1008	78.6
Total Cape Verde Islands	50	50	100	1447	69.1

Table 2. Catch rates in bottom trawl. Catch per hour in kgs.

Catch (kgs)	0-100	100-200	400-500	500-1000	Abt 2000	Abt 4000	Abt 6000
No hauls	3	1	1	7	1	1	1

Table 3. Distribution of trawl catches by main families.

Catch grouping: kg/hr	1-9	10-49	50-199	200-499	>500	% incidence in total no of hauls	Mean catch	% of total catch
TRAWL: BOTTOM	NO OF HAULS : 17							
FAMILY:								
CARANGIDAE	0	4	1	2	4	65	1050.3	59
SPARIDAE	0	1	3	4	1	53	301.5	14
MULLIDAE	2	0	4	1	1	47	212.6	9
CAPROIDAE	2	1	1	2	1	41	233.3	8
POMADASYIDAE	0	1	2	0	0	18	100.0	2
SHARKS	0	5	1	0	0	35	50.3	2
ACANTHURIDAE	0	0	0	1	0	6	248.0	1
DACTYLOPTERIDAE	4	3	1	0	0	47	16.4	1
FISTULARIDAE	5	1	1	0	0	41	13.1	1
MACROURIDAE	1	0	0	1	0	12	131.6	1
PRIACANTHIDAE	2	1	1	0	0	24	44.5	1
Other fish	-	-	-	-	-	-	30.7	2
TOTAL	0	0	3	1	11	88	1155.2	
GEAR: PELAGIC	NO OF HAULS : 17							
FAMILY:								
CARANGIDAE	2	3	4	1	0	59	71.2	49
MYCTOPHIDAE	0	1	1	0	1	18	228.2	47
CLUPEIDAE	1	1	0	0	0	12	8.7	1
Other fish	-	-	-	-	-	-	2.0	2
TOTAL	1	6	6	1	1	88	85.2	

2.5 Mesopelagic fish

This category of fish consists of small-sized species of less than 10 cm total length which occur in layers at water depths of 200-600 m, but often rise to the surface layers at night. On all the off-shelf tracks in the archipelago observation of mesopelagic fish formed part of the programme. They were found to occur over wide areas, but nowhere in rates of abundance which might indicate a resource of commercial interest. Catches up to 600 kg/hr were obtained in pelagic trawl hauls, consisting mostly of Myctophids.

2.6 Findings regarding the main species

Decapterus macarellus

This scad was the dominating species in the northern part of Cape Verde Islands. It was caught west of Sto. Antao, around S. Vicente, west of Sal and around Boavista. The highest concentrations were found south of S. Vicente and east of Sal (st. 357). All catches were made with pelagic trawl. The best catch was 136 kg/hr, but this do in no way indicate the best possible catches, as fishing were carried out only to identify the echo targets. Decapterus macarellus was found on five stations around Boavista, but in low quantities only. The species was here mixed with Decapterus punctatus of which the last was clearly the dominating one. In the region Sal - Boavista the mean length in the samples were within the range 17.4 - 20.1 cm, while in the Sto. Antao - S. Vicente region the mean ranged from 25.2 to 28.1 cm.

Decapterus punctatus

was found around Sal, Boavista and Maio. The best concentrations were on the south-eastern part of Boavista, where good schools formed during the day, and a dense scattering layer during the night. The biomass estimate for these dense concentrations is 6500 tonnes. The best catches of Decapterus punctatus were also obtained from these concentrations with 4.8 and 3.9 tonnes/hour. Mean lengths were in the range

11.5 - 21.3 cm. No clear size-dependent distribution could be seen from the samples, but samples from the dense concentrations southeast of Boavista gave mean lengths of 11.2 and 11.5 cm. It is interesting to note that Decapterus punctatus had its center in terms of density southeast of Boavista while D. macarellus was concentrated south of S. Vicente. Only on some part of the shelf off Boavista did the two species mix somewhat, but then only with very disperse concentrations of Decapterus macarellus. The separate habitats of the closely related species seems to be a way to avoid a competitive exclusion, though no hydrological or biological differences is found to explain the phenomenon.

Decapterus rhonchus

The false scad was caught on five stations north and southeast of Boavista. Except two catches of 842 and 81 kg/hr respectively, only scattered specimens were caught. The mean length in samples were from 15.6 to 26.8 cm. The species do not seem to form an important part of the total biomass of pelagic fish.

Sardinella maderensis

was caught on four locations around Sal and Boavista, but only in small quantities (max. 32 kg/hr). Mean lengths in samples were from 14.5 to 22.4 cm.

Caranx crysos

The blue runner was caught and identified on one location only, on the bank 15 nm northwest of Maio. The species is too fast-swimming to be trapped in the trawl gear used, but was caught on two settings with bottom long line. The fish formed dense schools during the day, easily detected by the echosounders. 26 specimens of 37 kg were caught on 400 hooks. The size range was from 41 to 64 cm.

Sharks

The sharks caught in the area were mainly Mustelus mustelus and Rhizoprionodon acutus. They were caught both in bottom trawl and on bottom long line. The species were caught on nine fishing stations around Sal, Boavista and Maio. The best catch was on a 300 hook, long line station just west of the João Valente Bank (st. 363). The catch was 35 sharks of 79 kg.

Other fish

Pseudupeneus prayensis was caught on 8 locations. The best catches were 1070 and 212 kg/hr. The mean lengths from five samples were within the range 16-20 cm. The commercial valuable groupers Epinephelus guaza and E. alexandrinus were caught only on two locations, st. 364 and st. 370.

3. SUMMARY OF FINDINGS AND DISCUSSION

The survey covered mainly the shelf areas of the islands, but with some course lines extending off the shelves and in-between the islands. The larger shelf Maio - Boavista was covered two times. Observations of bottom conditions showed that only the Maio - Boavista shelf had appreciable areas suitable for trawling. An interesting feature of the findings of the oceanographical observation is the indication of upwelling on the western side of the João Valente Bank. This is judged to be an effect of the prevailing current- and wind systems and since these are active over large parts of the year, it seems likely that the upwelling is a process of significant importance for the biological production in this area. About 3/4 of the total fish biomass estimated for the whole archipelago of about 100 thousand tonnes was found over the shelf areas of Maio - Boavista - Sal. The findings of small pelagic and the demersal fish was almost exclusively located to the island shelf areas. Over the deeper waters off the shelf only very limited resources of mesopelagic fish was observed. It should be noted, however, that resources of larger pelagic fish such as tunas are not covered by this type of survey.

The acoustic survey indicates that the total biomass of 100 thousand tonnes consists of demersal and small pelagic fish in a 50/50 proportion. An estimate of the stock of demersal fish based on the trawl swept area method suggests that this category may have been somewhat overestimated by the acoustic survey, and that true proportion may be approximately represented by about 65 thousand tonnes og small pelagic fish and 35 thousand tonnes of demersal species. The bulk of the pelagic fish consists of scads. These were also the only species caught in considerable quantities by bottom trawl, up to about 5 tonnes per hour's tow.

A report of previous exploratory resource surveys carried out with the trawler “Ernst Haeckel” of the German Democratic Republic was made available by the Department of Fisheries, Praia (Anon 1976). In about two weeks surveys in each of April and October 1976 good fishing grounds for bottom trawl were located on the shelf around Boa Vista and on the João Valente Bank. Good catches were obtained with the bottom trawl with an average of 5-6 tonnes per hour and ranging up to 30 tonnes per hour. About 50% of the catches was reported to consist of the horse mackerel species Trachurus picturatus. Not a single specimen of this fish was identified in the survey reported here. Boops boops was the next common species in the 1976 surveys with about 19% of the total catch in the October coverage. The high catch rates of Trachurus picturatus by the “Ernst Haeckel” suggests a considerable abundance of this species in the archipelago at that time. Its absence in the autumn of 1981 indicate that the occurrence of this horse mackerel which otherwise is known from the Azores, Madeira and Canary Islands systems and from Morocco is periodical in the Cape Verde archipelago.

4. LITERATURE

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Annexes

Annex I. Participating scientific staff

From the Institute of Marine Research, Bergen:

Mr. T. Strømme (cruise leader)
Mr. H. Gjøsæter (biologist)
Mr. K. Strømsnes (research technichian)
Mr. H.P. Knutsen (instrument chief)
Mr. B. Kvinge (instrument technichian)

From CECAF, Dakar:

Mr. G. Everett (CECAF project leader), Nov 3-8

From the Republic of Cape Verde:

Miss V. Marques da Silva (biologist) Nov 5-6, Nov 16-27
Mrs. M.H. Vieira (biologist) Nov 28-Dec 1

From FAO/UNDP Cape Verde:

Mr. G. Beven (fishing master) Nov 5-6, Nov 16-Dec 1

Annex II. Records of fishing operations

DATE	TIME START	STN No.	GEAR TYPE	DEPTH (M) BOTTOM	GEAR	POSITION NORTH	EAST	CATCH (KG) TOTAL	PR HR	DOMINANT SPECIES	WEIGTH (KG) PR HR	%
14.11	1948	346	PT	>500	25	14°43'	018°38'	1000,0	2000,0	SALPS	2000,00	100,0
15.11	1951	347	PT	>500	15	15°00'	022°57'	300,3	600,6	MYCTOPHIDAE	600,00	99,9
16.11	0134	348	PT	44	1	15°18'	023°15'	2,3	4,6	Sardinella maderensis	,40	8,6
										Ablennes hians	,40	8,6
										Decapterus punctatus	,20	4,3
										Selar crumenophthalmus	2,60	56,5
										C E P H A L O P O D A	1,00	21,7
17.11	0736	349	PT	>500	60	14°65'	024°32'	5,0	12,0	Vinciguerria sp	12,00	100,0
18.11	0450	350	PT	250	60	17°06'	025°21'	68,0	136,0	Decapterus macarellus	136,00	100,0
18.11	1457	351	PT	70	60	16°56'	025°00'	10,0	10,7	Spondyliosoma cantharus	3,85	35,9
										Decapterus macarellus	6,95	64,9
18.11	2354	352	PT	85	25	16°47'	025°03'	34,0	56,4	Decapterus macarellus	56,44	100,0
19.11	0350	353	PT	25	1	16°49'	024°49'	,0	,0	NO CATCH	,00	,0
19.11	2324	354	PT	>500	30	16°38'	024°03'	19,0	38,0	Cubiceps sp	2,24	5,8
										Neolatus tripes	,38	1,0
										SALPS	35,14	92,4
20.11	1715	355	BT	23	23	16°37'	022°52'	298,0	810,5	Decapterus punctatus	224,40	27,6
										Pseudupeneus prayensis	122,67	15,1
										Diplodus bellottii	149,60	18,4
										Trachinotus ovatus	59,84	7,3
										Lithognathus mormyrus	92,75	11,4
20.11	2135	356	BL	49	49	16°43'	023°01'	6,0	6,0	Mustelus mustelus	6,00	100,0
20.11	2220	357	PT	60	20	16°41'	023°01'	78,1	141,3	Decapterus macarellus	118,55	83,8
										Sardinella maderensis	2,26	1,5
										Selar crumenophthalmus	4,34	3,0
										Uraspis secunda	4,76	3,3
21.11	0949	358	BT	78	78	16°19'	022°53'	878,1	1317,1	Decapterus punctatus	1236,00	93,8
										Pagellus acarne	22,50	1,7
										Diplodus sp	28,50	2,1
										Mustelus mustelus	13,50	1,0
22.11	0930	359	BT	62	62	15°57'	022°43'	10,0	20,0	SALPS	,00	,0
22.11	1100	360	BT	60	60	15°57'	022°44'	3000,0	6000,0	Lithognathus mormyrus	93,80	1,5
										Decapterus punctatus	4837,60	80,6
										Pseudupeneus prayensis	1068,80	17,8
22.11	1630	361	BT	80	80	15°59'	023°03'	,0	,0	NO CATCH	,00	,0
22.11	2125	362	BT	73	73	15°51'	021°55'	1131,0	2262,0	Decapterus rhonchus	842,00	37,2
										Boops boops	966,00	42,7
										Antigonia capros	234,60	10,3
										Chelidonichthys lastoviza	30,00	1,3
22.11	2320	363	BL	54	54	15°50'	023°10'	79,0	79,0	Mustelus mustelus	79,00	100,0
23.11	1009	364	BL	32	32	15°48'	023°11'	35,0	35,0	Cephalopholis taenopsis	11,30	32,2
										Paraphristipoma sp	4,20	12,0
										Epinephelus guaza	14,00	40,0
										Epinephelus alexandrinus	2,80	8,0
23.11	1900	365	PT	>500	40	15°50'	023°18'	23,3	30,9	MYCTOPHIDAE	23,67	76,6
										Cubiceps gracilis	1,96	6,3
										SALPS	4,92	15,9
24.11	0215	366	PT	500	40	16°21'	023°45'	33,0	66,0	MYCTOPHIDAE	61,00	92,4
										SALPS	1,00	1,5
										S H R I M P S	2,00	3,0
										C E P H A L O P O D A	1,00	1,5
25.11	0704	367	BL	24	24	16°12'	022°39'	75,0	75,0	Mustelus mustelus	38,00	50,6
										Rhizoprionodon acutus	21,00	28,0
										Lethrinus atlanticus	8,30	11,0
										Lagocephalus laevigatus	4,40	5,8
25.11	1210	368	BL	20	20	16°09'	022°58'	27,1	27,1	Mustelus mustelus	2,10	7,7
										Rhizoprionodon acutus	16,50	60,8
										Lethrinus atlanticus	1,70	6,2
										Lagocephalus laevigatus	1,70	6,2
										Lycodontis sp	5,10	18,8

DATE	TIME START	STN No.	GEAR TYPE	DEPTH (M) BOTTOM	GEAR	POSITION NORTH	EAST	CATCH (KG) TOTAL	PR HR	DOMINANT SPECIES	WEIGTH (KG) PR HR	%
25.11	1515	369	BT	73	73	16°05'	023°02'	255,0	510,0	Boops boops	16,00	3,1
										Pagellus acarne	25,60	5,0
										Pseudupeneus prayensis	212,80	41,7
										Decapterus punctatus	232,00	45,4
25.11	1655	370	BT	90	90	15°57'	023°03'	229,0	458,0	Macrorhamphosus scolopax	261,00	56,9
										Antigonia capros	122,40	26,7
										Dactylopterus volitans	65,70	14,3
										Epinephelus alexandrinus	7,30	1,5
25.11	2000	371	PT	59	25	15°59'	022°56'	28,8	28,8	Sardinella maderensis	,90	3,1
										Boops boops	,90	3,1
										Decapterus punctatus	21,80	75,6
										Decapterus macarellus	4,70	16,3
26.11	0150	372	PT	72	35	15°40'	023°12'	22,0	44,0	Decapterus punctatus	29,80	67,7
										SALPS	14,20	32,2
26.11	0805	373	BL	24	24	15°21'	021°13'	,0	,0	NO CATCH	,00	,0
26.11	1300	374	BL	40	40	15°26'	023°26'	30,0	12,0	Seriola carpenteri	1,40	11,6
										Caranx crysos	10,32	86,0
										Lycodontis sp	,20	1,6
26.11	1440	375	BL	45	45	15°26'	023°25'	13,0	4,8	Caranx crysos	4,25	88,5
										Diplodus fasciatus	,37	7,7
26.11	1810	376	PN	47	47	15°27'	023°25'	,0	,0	NO CATCH	,00	,0
26.11	1650	377	BT	32	32	15°16'	023°15'	330,0	660,0	Pseudupeneus prayensis	152,40	23,0
										Decapterus punctatus	76,80	11,6
										Decapterus macarellus	18,00	2,7
										Pagellus acarne	312,00	47,2
28.11	1935	378	BT	46	46	15°23'	023°12'	440,0	880,0	Acanthurus monroviae	248,00	28,1
										Priacanthus arenatus	150,40	17,0
										POMADASYIDAE	144,00	16,3
										Boops boops	51,20	5,8
										Mustelus mustelus	144,00	16,3
28.11	2355	379	BT	72	72	15°40'	023°12'	447,0	894,0	MYCTOPHIDAE	15,20	1,7
										Pagellus acarne	22,80	2,5
										Boops boops	463,60	51,8
										Antigonia capros	330,60	36,9
29.11	0435	380	PT	70	20	15°48'	023°05'	30,0	60,0	Decapterus macarellus	25,20	42,0
										Decapterus punctatus	2,40	4,0
										SALPS	32,60	54,3
29.11	0635	381	BT	72	72	15°49'	023°01'	80,0	160,0	Mustelus mustelus	44,00	27,5
										Fistularia petimba	63,00	39,3
										Zeus faber	8,60	5,3
										Decapterus punctatus	23,40	14,6
29.11	0935	382	BT	112	112	15°52'	023°06'	463,0	926,0	Antigonia capros	924,00	99,7
29.11	1130	383	BT	74	74	15°53'	023°00'	45,0	90,0	Mustelus mustelus	49,60	55,1
										Decapterus punctatus	9,60	10,6
										Antigonia capros	16,40	18,2
										Dactylopterus volitans	6,80	7,5
29.11	1400	384	BT	42	42	13°56'	022°56'	45,0	90,0	Mustelus mustelus	23,00	25,5
										Fistularia petimba	6,80	7,5
										Aluterus punctatus	61,20	68,0
29.11	2151	385	PT	42	15	16°16'	022°55'	124,0	224,4	Decapterus punctatus	123,08	54,8
										Decapterus rhonchus	81,08	36,1
										Sardinella maderensis	15,20	6,7
										Boops boops	3,25	1,4
30.11	0355	386	PT	83	35	16°20'	022°49'	46,0	92,0	Decapterus punctatus	91,60	99,5
30.11	1720	387	BT	68	68	15°56'	022°43'	2000,0	4000,0	Decapterus punctatus	3938,00	98,4
										Pseudupeneus prayensis	62,00	1,5
01.12	0225	388	BT	27	27	15°05'	015°08' 23°15	280,0	560,0	Lithognathus mormyrus	282,00	50,3
										Diplodus prayensis	12,60	2,2
										Pomadasys incisus	125,60	22,4
										Pseudupeneus prayensis	75,20	13,4

Annex III. Results from length measurements

FAMILY/SPECIES	STATION	LENGTHS IN SAMPLE				
		LOWEST	HIGHEST	MEAN ST.	DEV.	N
CAPROIDAE						
Antigonia capros						
	379	11.0	16.0	14.2	.8	89
	383	6.5	15.5	13.3	1.9	48
CARANGIDAE						
Caranx crysos						
	374	41.0	64.0	51.9	6.4	18
	375	43.0	63.0	52.7	6.8	8
Decapterus punctatus						
	355	11.5	21.5	18.2	1.8	147
	358	12.5	19.0	14.0	1.0	117
	360	9.0	17.0	11.5	1.3	119
	369	12.5	19.0	14.3	1.1	115
	371	12.0	19.5	15.6	1.5	126
	372	17.5	23.5	21.3	1.1	107
	377	15.0	22.0	17.4	1.1	134
	380	18.0	21.0	19.4	.9	14
	381	19.0	24.0	21.1	1.1	98
	383	18.5	22.0	20.0	1.9	32
	385	8.5	18.0	11.7	2.1	96
	386	13.5	21.5	16.2	1.6	159
	387	10.0	13.5	11.2	.9	100
Decapterus rhonchus						
	362	24.0	30.0	26.8	1.2	111
	371	12.0	18.0	15.5	1.8	39
	385	13.0	24.0	15.6	1.4	99
Decapterus macarellus						
	350	19.0	32.0	25.2	3.9	100
	351	28.5	32.0	29.9	1.0	23
	352	21.0	33.5	28.0	2.4	53
	357	11.0	22.0	17.4	2.1	97
	371	16.5	27.0	18.7	2.0	82
	377	17.5	21.5	19.5	1.1	20
	380	17.0	28.5	20.1	1.7	150
Selar crumenophthalmus						
	348	13.5	17.0	15.3	1.0	32
	357	13.5	17.5	14.7	.9	32
CLUPEIDAE						
Sardinella maderensis						
	357	12.0	17.0	14.5	1.2	23
	371	16.0	25.0	20.2	3.0	11
	385	17.5	26.0	22.4	1.7	35
LETRINIDAE						
Lethrinus atlanticus						
	367	35.0	41.0	37.8	2.0	10
LUTJANIDAE						
Lutjanidae indet.						
	378	41.0	48.0	45.3	2.3	8
MULLIDAE						
Pseudupeneus prayensis						
	355	13.5	19.5	16.2	1.3	80
	360	12.5	21.5	16.3	1.8	115
	369	14.0	22.0	18.0	1.6	104
	377	10.0	24.0	17.4	2.4	166
	388	16.0	24.5	20.0	2.2	34

POMADASYIDAE						
Paraphristipoma sp.						
	364	31.0	36.0	33.7	2.0	8
Pomadasys incisus						
	388	20.0	24.5	22.3	1.0	41
SERRANIDAE						
Cephalopholis taenopsis						
	364	39.0	48.0	44.7	3.5	8
SHARKS						
Rhizoprionodon acutus						
	367	81.0	92.0	87.4	3.7	8
	368	66.0	85.0	80.0	6.7	7
Mustelus mustelus						
	363	66.0	97.0	84.7	5.8	35
	367	80.0	96.0	86.4	5.6	16
SPARIDAE						
Boops boops						
	369	14.0	16.5	15.3	.7	26
	371	13.5	16.0	15.1	.6	26
	379	22.5	27.5	25.1	1.2	70
Lithognathus mormyrus						
	355	21.0	30.0	25.8	2.9	14
	388	23.5	29.5	26.5	1.4	55
Pagellus acarne						
	369	19.0	22.5	21.1	1.4	12
	377	19.0	31.0	25.2	1.8	122
Spondyliosoma cantharus						
	351	36.0	46.0	40.3	5.1	3

Annex IV. List of species

List of species caught with R/V Dr. Fridtjof Nansen off Cape Verde Islands November 1981.

ACANTHURIDAE	
	Acanthurus monroviae
ANGUILLIFORMES	
BALISTIDAE	
	Balistes capriscus
BELONIDAE	
	Ablennes hians
BRAMIDAE	
	Brama brama
CAPROIDAE	
	Antigonia capros
	Capros aper
CARANGIDAE	
	Caranx crysos
	Decapterus punctatus
	Decapterus rhonchus
	Decapterus macarellus
	Selar crumenophthalmus
	Seriola carpenteri
	Seriola fasciata
	Trachinotus ovatus
	Trachurus trachurus
	Uraspis secunda
CENTRACHANTIDAE	
	Spicara sp.
CLUPEIDAE	
	Sardinella maderensis
CONGRIDAE	

	Rhechias sp.
DACTYLOPTERIDAE	
	Dactylopterus volitans
FISTULARIIDAE	
	Fistularia petimba
GEMPYLIDAE	
	Gempylus serpens
	Neolatus tripes
	Promenthichthys prometheus
GERREIDAE	
	Eucinostomus melanopterus
GONOSTOMATIDAE	
	Vinciguerria sp.
HOLOCENTRIDAE	
	Adioryx hastatus
LABRIDAE	
	Bodianus speciosus
	Xyrichtys novacula
LETRINIDAE	
	Lethrinus atlanticus
LUTJANIDAE	
MACRORHAMPHOSIDAE	
	Macrohamphosus scolopax
MONACANTHIDAE	
	Aluterus sp.
	Aluterus punctatus
	Stefanolepis hispidus
MULLIDAE	
	Pseudupeneus prayensis
	Lycodontis sp.
MYCTOPHIDAE	
NOMEIDAE	
	Cubiceps sp.
	Cubiceps gracilis
	Psenes sp.
PARALEPIDIDAE	
	Lestidium sp.
POLYNEMIDAE	
	Galeoides decadactylus
POMADASYIDAE	
	Paraphristipoma sp.
	Paraphristipoma octolineatum
	Pomadasys incisus
	Pomadasys peroteti
PRIACANTHIDAE	
	Priacanthus arenatus
SALPS	
SCARIDAE	
	Sparisoma rubripinne
SCORPAENIDAE	
SERRANIDAE	
	Cephalopholis taenopsis
	Epinephelus guaza
	Epinephelus alexandrinus
SHARKS	
	Rhizoprionodon acutus
	Mustelus mustelus
SHRIMPS	
SPARIDAE	
	Boops boops
	Dentex sp.
	Dentex macrophthalmus

	Diplodus sp.
	Diplodus bellottii
	Diplodus fasciatus
	Diplodus prayensis
	Lithognathus mormyrus
	Pagellus acarne
	Pagellus bellottii
	Spondyliosoma cantharus
	Viridentex acromegalus
CEPHALOPODA	
LOLIGINIDAE	
	Todaropsis sp.
SYNODONTIDAE	
	Synodus sp.
	Synodus saurus
	Synodus synodus
TETRAODONTIDAE	
	Lagocephalus laevigatus
TRACHINIDAE	
	Trachinus sp.
	Trachinus draco
TRIGLIDAE	
	Chelodonichthys sp.
	Chelodonichthys lastoviza
TRICHIURIDAE	
	Aphanophus sp.
ZEIDAE	
	Zeus faber

Annex V. Equipment and methods

The R/V DR. FRIDTJOF NANSEN is a 150 foot stern trawler with a main engine of 1500 horsepower. The vessel is equipped for acoustic surveying, bottom and midwater trawling, hydrography and plankton observations.

The bottom trawl was a 134 foot headline shrimp trawl adapted for demersal fish trawling. The foot rope was equipped with 0.5 m rubber bobbins. Bridles of 40 m gave it a horizontal distance between the wings of about 25 m. The effective vertical opening of the net was about 6 m. The pelagic trawl was of about 120 m circumference, and the vertical opening was normally 13 m. The pelagic trawl had an inner-net of mesh size 1 cm in the cod end. Pelagic trawl operations were usually monitored by aid of a 50 kHz acoustic net sonde.

Hydrographic observations were carried out with Nansen bottles with which temperature readings and samples for salinity and oxygen determinations were collected at standard depths. The salinity was determined with an inductive salinometer and dissolved oxygen by the Winkler method.

Two Simrad EK Sounders, 120 kHz and 38 kHz, connected to QM integrators, were run continuously. Settings and performance of the two acoustic systems were:

	120 kHz	**38 kHz**
Basic range	0 - 100 m	0 - 100 m or 0 - 250 m
Transmitter	1/1 (330 W)	Ext. (2500 W)
Transducer (ceramic)	10° (circular)	7.5° × 8°
SL + VR	116.7 dB	139 dB (13.9.81)
Bandwith and pulse length	3 kHz, 0.6 ms	3 kHz, 0.6 ms
TVG and gain	20 logR, -0 dB	20 logR, -20 dB
Recorder gain	4	7
Integrator threshold		0.5
Ingegrator gain		20 dB (×10)
Depth intervals		According to recordings

The 38 kHz system coupled to the integrator was used for abundance estimation of fish, while the 120 kHz system was used as an additional aid during the daily analysis of the echo recordings.

Sampling and processing of catch data

For each trawl catch the weight and number of each species were estimated by sampling. Species determination was mainly based on ANON (1981) and partly on BLANCHE et al. (1970). Length measurements were frequently taken, mainly on the commercially important species. The catches and their main composition are listed in Annex II and main results from the length measurements are given in Annex III.

The echo recordings and their interpretation

Assessment of the abundance of fish resources based on acoustic observations combined with experimental fishing is a method which especially lends itself to fish found in schools or other aggregations in midwater. But there are also notable exceptions, e.g. surface schooling tunas and tuna-like species and strictly bottom dwelling fish such as rays and flounders. Any fish found very close to the bottom (½-1 m) or in the very surface layer will escape echo sounder detection. For navigational reasons the work with the R/V DR. FRIDTJOF NANSEN is limited to waters deeper than 10 m. The extreme inshore waters could thus not be covered.

Because of differences in behaviour and size, different species or groups of fish species may give rise to various types of echo-recordings. Small-sized pelagic fish are, for instance, often found in well-defined schools, the recordings of which can be distinguished from those of the often looser aggregation in which semi-demersal larger fish are often found. Such classification of the echo recordings is of considerable assistance in interpreting the acoustic observations, but a positive identification by fishing operations is still indispensable and also provides the only means of sampling fish in this type of combined survey.

Based on previous experience and on identification by fishing, the echo recordings in the surveyed waters were classified as follows:

(i) Recordings of true larger schools or dense layer mostly in upper water. These will most often derive from pelagic schooling fish usually of smaller size, e.g. clupeids, scads.

(ii) All other fish recordings which especially comprised looser aggregations of smaller and larger fish near bottom. These are ascribed to demersal or semi-demersal fish such as grunts, seabreams, groupers, croakers, bigeyes etc.

(iii) Recordings of mesopelagic fish distributed in scattering layers.

Acoustic abundance estimation

Average integrator deflection per nautical mile was calculated each five nautical mile steamed. All echo traces were evaluated daily and together with the information from the trawl catches the readings from the integrator were split in categories small pelagic fish, demersal fish, mesopelagic fish and plankton. The integrator deflection was classified in two levels scattered (1-9 mm), and slightly gathered (11-20 mm), and contour lines were drawn to distinguish between areas of different density of fish. This forms the basis for the preparation of the charts of distributions of fish. For each of the areas the mean integrator value and the area of extention were calculated and their product gives an indice of abundance for that area. The conversion factor C from index of abundance to absolute abundance is linearity dependent upon the length of the fish, and we can correct for this by multiplying the index of abundance with a length-correcting factor f, where f = l/17 (l = fish length). After summing up all indices of abundance within a region the length corrected indices are converted into fish biomass by multiplying with the C value for the fish of standard length 17 cm. For the 38 kHz system with standard settings C_{17} = 13.6 tonnes/nm²/mm/nm.

Calculation of C-value

The relationship between target strength of 1 kg of small pelagic fish with swim bladder and the length of the fish can be written:

$TS_{kg} = -10 \log 1 - 22$ dB

Analytical relation between C value, the acoustic system performance constants and the target strength of 1 kg of fish can be written:

$$C = 3430 \text{ antilog } 0.1\,(C_1 - A + \overline{V}_0 - TS_{kg}) \text{ tonnes/n.mile}^2\text{mm}$$

It can be seen from those two formulas that the C value expressed in tonnes/n.mile² mm is straightly related to the fish length in cm

$C = a \times l$

where

$$a = 3430 \times \text{antilog } 0.1(C_1 - A + \overline{V}_0 + 22)$$

$$C_1 = -(SL + VR) + 20 \log R + 2R - 10 \log \frac{C}{2} - 10 \log \psi$$

A = integrator gain

$\overline{V}_0$ = integrator performance constant

For the actual performance data of the acoustic system of R/V DR. FRIDTJOF NANSEN:

C_1 = -26.5 dB
A = 30 dB
$\overline{V}_0 = -1.8$ dB
C = 0.8 × L T/n.mile²/mm/nm (L in cm)