CHAPTER 3 THE ENVIRONMENT

3.1 BATHYMETRY

A brief description of the bathymetry of the Namibian continental shelf is given in the "DR. FRIDTJOF NANSEN" Cruise Report No.1.

3.2 HYDROGRAPHY

Figures 2a, 2b and 2c show the temperature, salinity and oxygen profiles of the nine hydrographic transects worked. The positions of the transects are shown in Figures 1a, 1b and 1c.

The period of hydrographic observations cover almost three weeks and the data are therefore not synoptic.

The hydrography of the Namibian near-shore region of the continental shelf during this cruise was characterised by its uniformity along the entire coastline, with slight differences in the region north of 20°00'.

The sections between Dolphin Head (26°00') and Ambrose Bay (21°00') showed fairly strong upwelling from a depth of over 400 m. Temperatures were low close to the shoreline, about 12 to 14°C, while further offshore they rose to 16 or 17°C and even as high as 19°C at 26°00'. The water column was moderately layered, with signs of a thermocline at about 50 m. Dissolved oxygen levels were low inshore and near the ocean bed, but rose to 6 ml/l and more offshore in the south, and 4 to 5 ml/l north of 23°00'. Low oxygen waters were apparently being transported up from below 400 m, thus the entire shelf bottom was exposed to water with a dissolved oxygen content of below 2 ml/l. The waters north of 23°00' were more oxygen depleted than the area further south.

The sections from 20°00' to 18°00' showed slight upwelling. Oxygen values were similar to those from the southern sections, except from the 18°00' section where the entire water column was oxygen deficient, especially below 100 m. The water temperatures of these sections were slightly higher than those from the south.

Salinity levels were, in general, higher in the north, rising from surface values of 35.0‰ on the sections south of 23°00' to 35.6‰ at 18°00'. Within each section the salinity level was virtually homogeneous throughout the water column, with slightly lower concentrations in deeper waters.

The inshore part of the 20°00' section was sampled in sequence with the other sections, and then the entire section out to 125 nm was sampled one week later. Active upwelling was occurring at this latitude, similar to all other sections, during the first sampling period. When the section was sampled later, upwelling had ceased, while salinity levels and temperature had increased. The second sampling period occurred following several days of low wind

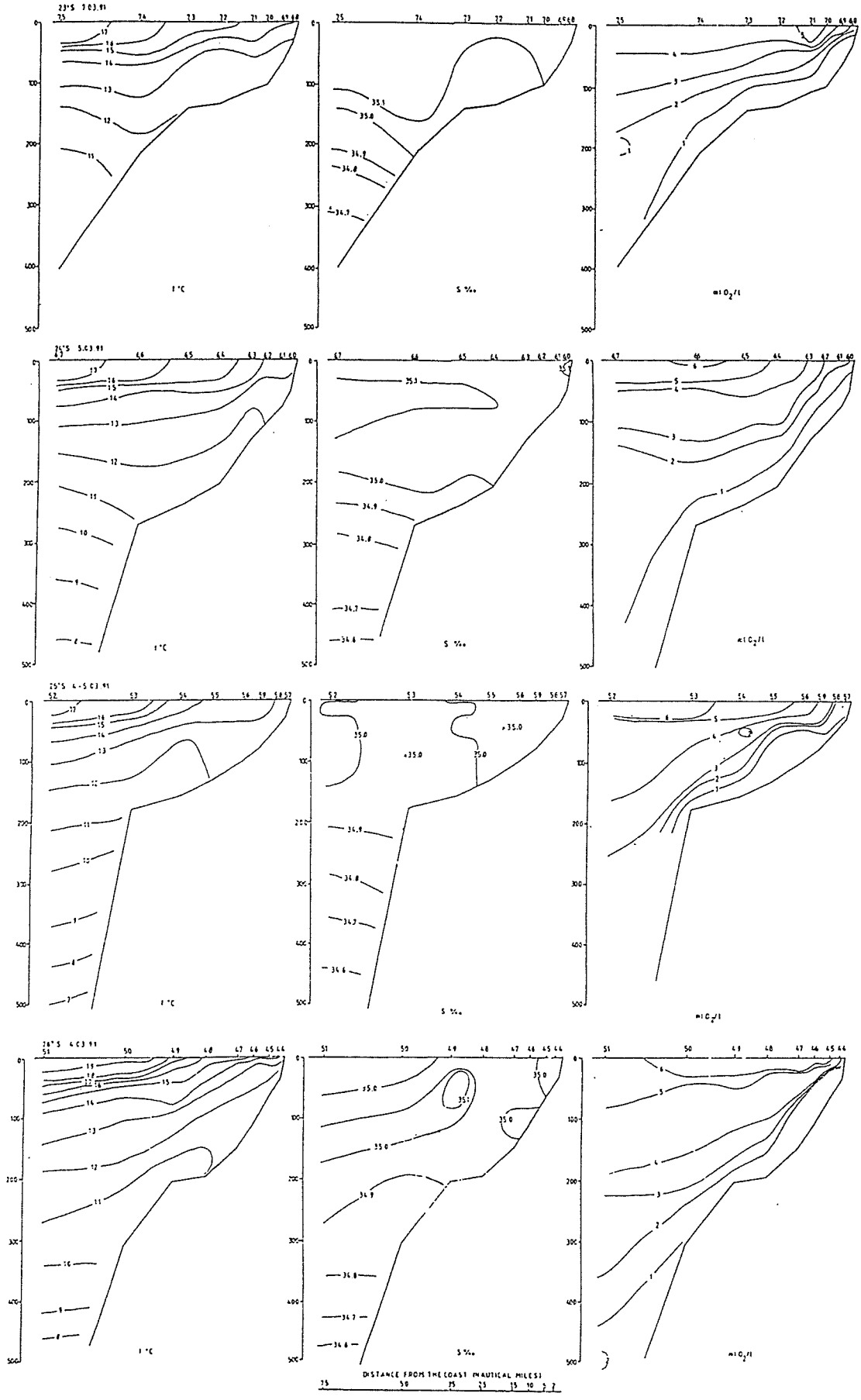

Figure 2a. Hydrographic profiles. Dolphin Head to Conception Bay.

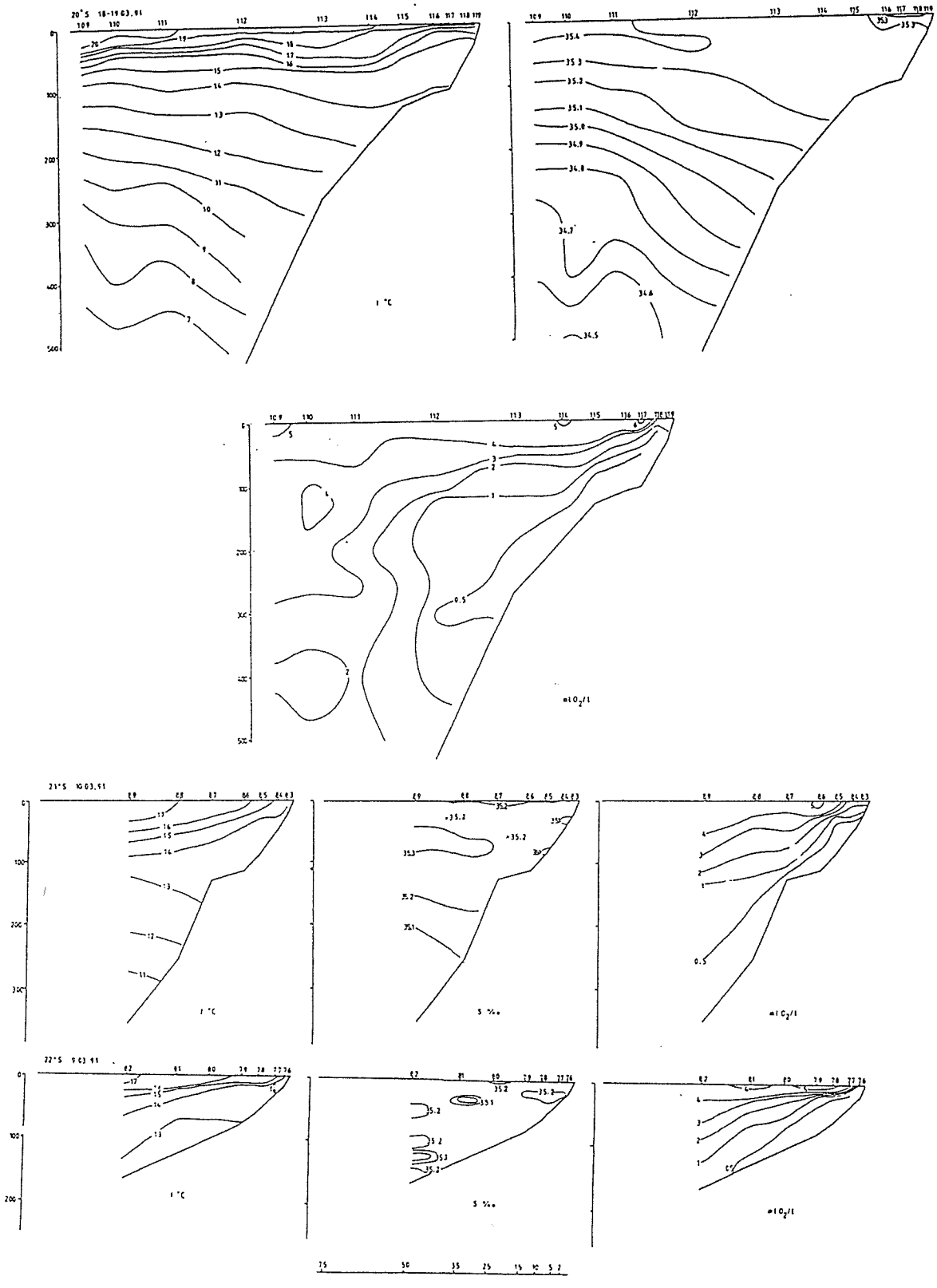

Figure 2b. Hydrographic profiles. Walvis Bay to Ambrose Bay.

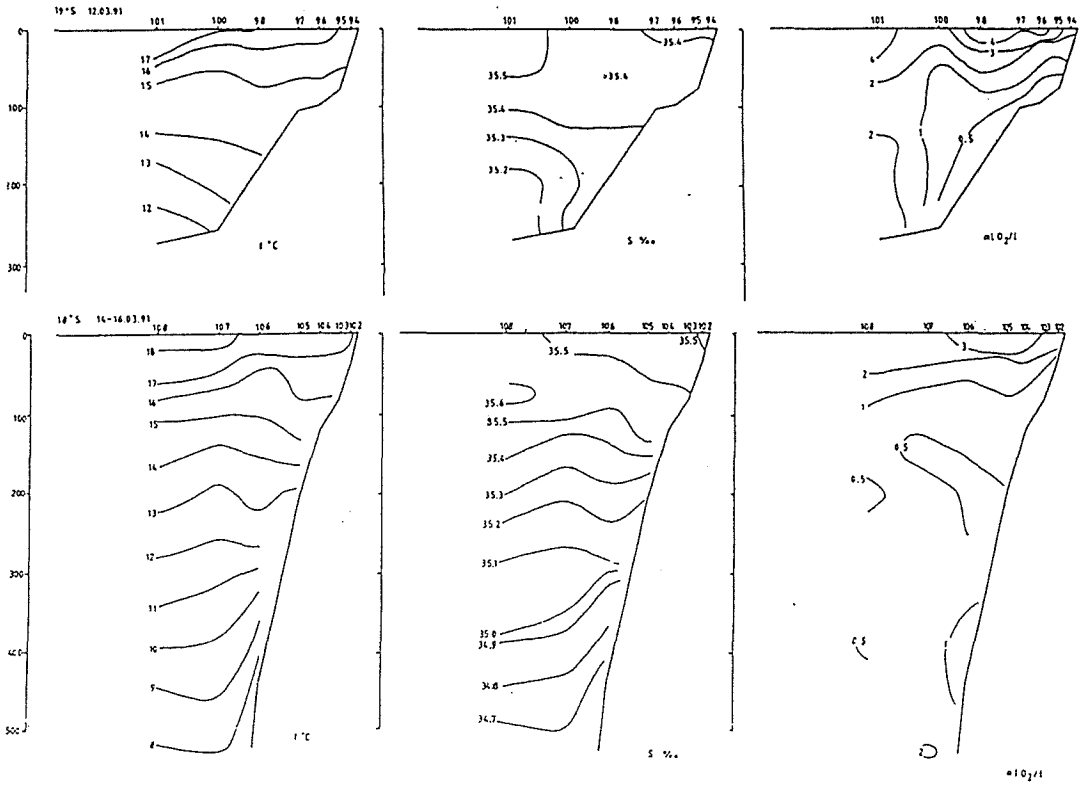

Figure 2c. Hydrographic profiles. Ambrose Bay to Cunene River.

strengths. A weak thermocline was found between the oceanic waters and the near-shore Benguela current on the 20°00' line at about 90 nm from the coast. The thermocline was more marked on the 19°30' transect, occurring at 75 nm offshore.

The sea surface temperature (measured at -4 m) isolines, shown in Figures 3a and 3b, confirm the occurrence of extensive longshore upwelling throughout the region. Upwelling is more active in the south, with an upwelling cell centred around Easter Point (24°40'). A second upwelling centre occurred between Möwe Point and Rocky Point (19°10').

A comparison with the hydrography of the same area taken during the previous cruise, in the winter period, shows that the strength of upwelling was similar, and that, in general, hydrography of the region was likewise similar. Surface temperatures were slightly higher, while surface oxygen concentrations were also slightly greater. When compared to the hydrography of the previous summer, the strength of upwelling was again similar, except that surface temperatures were much higher in the north during the 1990 survey. For example sea surface temperatures are approximately 1°C lower in the south, and up to 3°C in the north. This indicates that the tropical Angolan current may have had a lesser impact on the hydrography of the Namibian coast during 1991, than in 1990.

CHAPTER 4 DISTRIBUTION AND ABUNDANCE OF PELAGIC FISH

The acoustic integration system provided observations of fish densities averaged, usually, over 5 nm distances, but in areas of high fish concentrations over 1 nm. The unit of acoustic reflection used was 0.1 x mm^2/nm^2 reflecting surface. The integrator values from fish targets were allocated to the following groups on the basis of trawl sampling and characteristic behaviour recognised from the echo recordings:

Pelagic fish type 1: Clupeidae (pilchard and round herring) and Engraulidae (anchovy).

Pelagic fish type 2: Carangidae (horse mackerel).

Non-commercial pelagic fish and plankton: myctophids, gobies and, primarily, jellyfish.

4.1 DISTRIBUTION

The weather was favourable to hydroacoustical surveying during this cruise. In summary, only one area of pelagic fish was found south of Ambrose Bay (21°00'), while further north several regions with extremely dense shoals of pilchard, in association with other pelagic species, were surveyed. No type-1 pelagic fish were reported in shallow waters during the period of this survey. Layers of plankton, consisting largely of jellyfish, with pelagic gobies in the south, made the allocation of acoustic signals difficult in many areas. Sampling of fish was generally successful, except for some hauls which were disrupted by high concentrations of jellyfish.

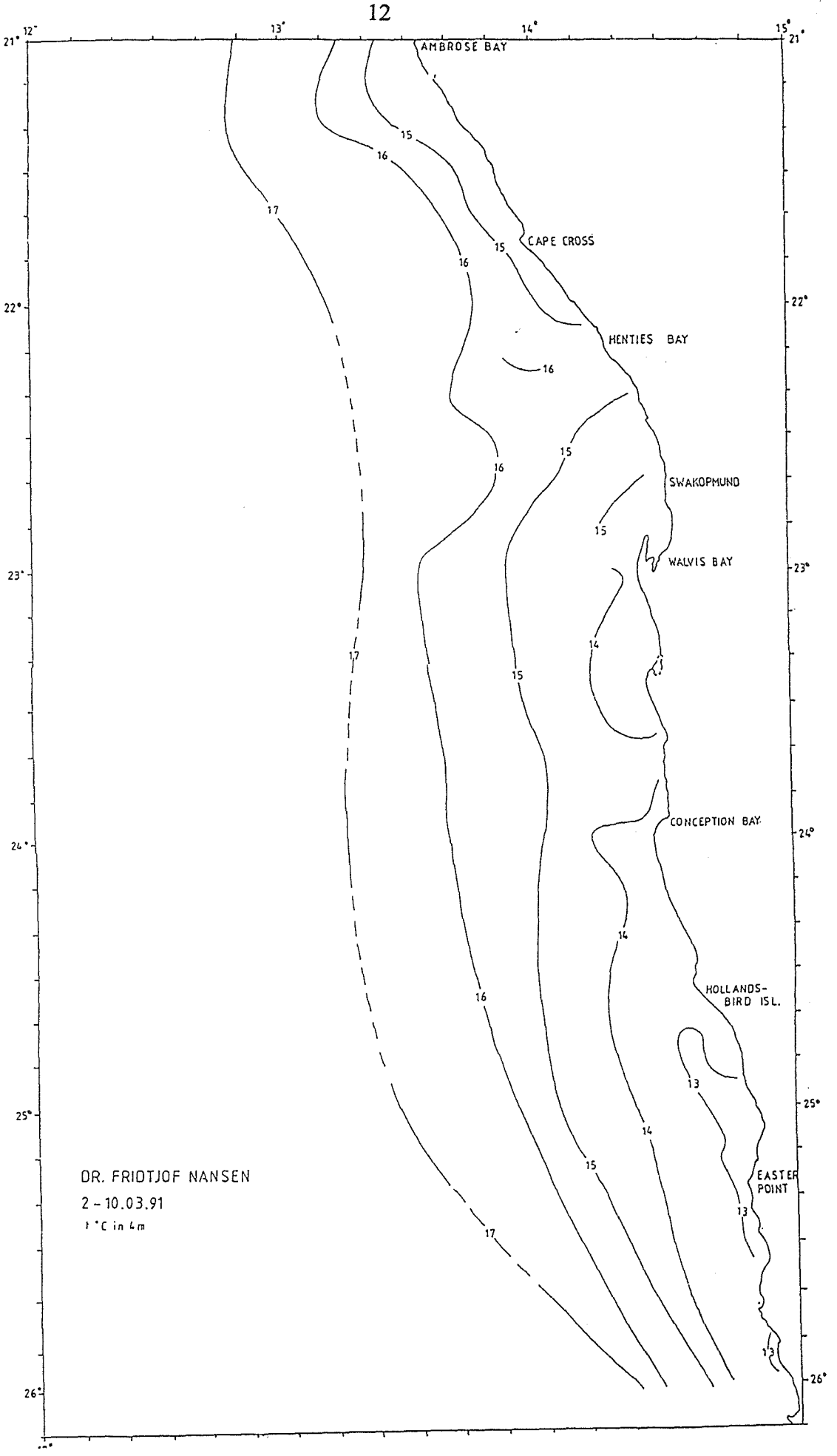

Figure 3a. Sea surface temperatures. Dolphin Head to Ambrose Bay.

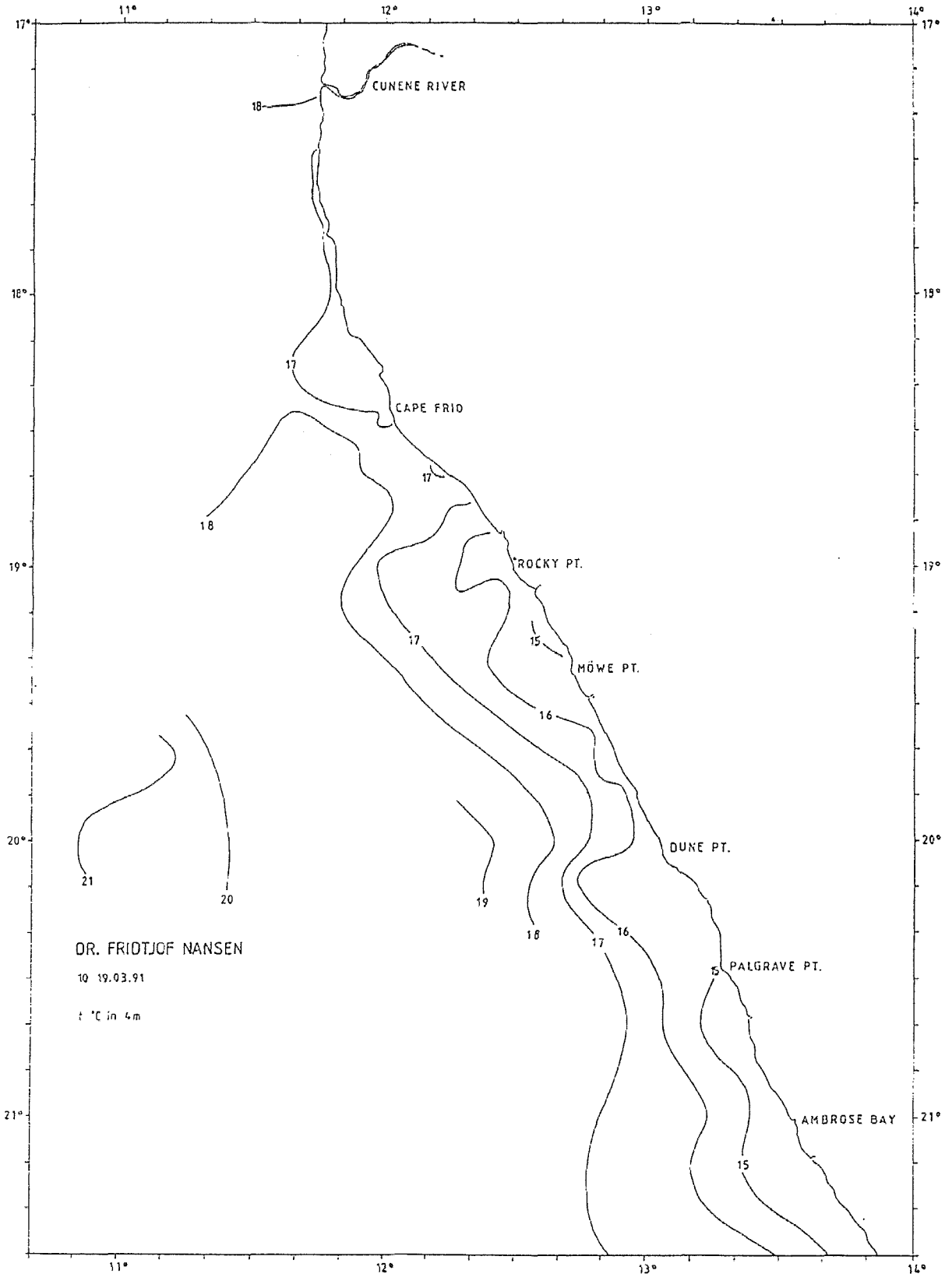

Figure 3b. Sea surface temperatures. Ambrose Bay to Cunene River.

The distributions of clupeids and engraulids are shown in Figures 4a and 4b, and the distribution of carangids in Figure 5. Additional maps of areas of high density of pilchard are given in Figures 6a, 6b and 6c. The distribution of the very dense layer of organisms occurring in the south, consisting mainly of plankton, gobies and jellyfish, is shown in Figure 7. An arbitrary scale was used in the distribution charts to illustrate different levels of concentration.

4.1.1 Dolphin Head to Ambrose Bay

Scattered, but dense, shoals of pilchard and anchovy occurred in a large region in waters of 80 m to 120 m deep offshore of Swakopmund (22°44') and northwards to Cape Cross (21°45'). The fish of both species were large, with modal peaks of 13.5 to 14.5 cm and 22.5 to 24.5 cm respectively, although some few smaller pilchard (14.5 cm) were trawled with the anchovy.

The area between Cape Cross and south of Walvis Bay (23°10') was re-surveyed during the southwards part of the cruise, in order to improve the precision of the biomass estimates, but the fish was not found. Fishing boats reported a strong southwards movement of shoals and it is assumed that the greater part of the fish had moved beyond the area searched, at least as far as 23°10'. This represents a shift in distribution of more than 50 nm in the intervening 10 days.

Very few pelagic fish of commercial value were found in the area south of Walvis Bay (23°00'). Near Easter Point, between 25°25' and 25°35', a few scattered shoals with an acoustical appearance of type-1 pelagic fish occurred. Trawling was disrupted by jellyfish concentrations and the determination of species composition was not possible. A small concentration of fish, mainly represented by one dense shoal of anchovy, occurred off Hollandsbird Island (24°30'). These fish had a modal length of 11.5 to 12.0 cm.

Large amounts of small pelagic goby (modal length of 3.5 to 4.5 cm) were found throughout the entire area as far north as Cape Cross (21°45'), mainly in water depths of 40 m to 150 m, while a few trawls also contained larger gobies. Lantern fish were found in waters deeper than 150 m (Figure 6). Large snoek *Thyrsites atun* were also caught in many of the trawls throughout this region, and cape gurnard *Chelidonichthys capensis* were caught south of Walvis Bay. Jellyfish was found in large concentrations throughout this region, but to what extent the jellyfish contributed to the reflected echo intensity is unknown.

4.1.2 Ambrose Bay to Cunene River

The approximate distribution of areas with high fish concentrations was determined during the northwards part of the cruise and these areas were re-surveyed intensively on the return trip southwards.

In general, the distribution of pilchard in this region was similar to that found during the May/June 1990 survey.

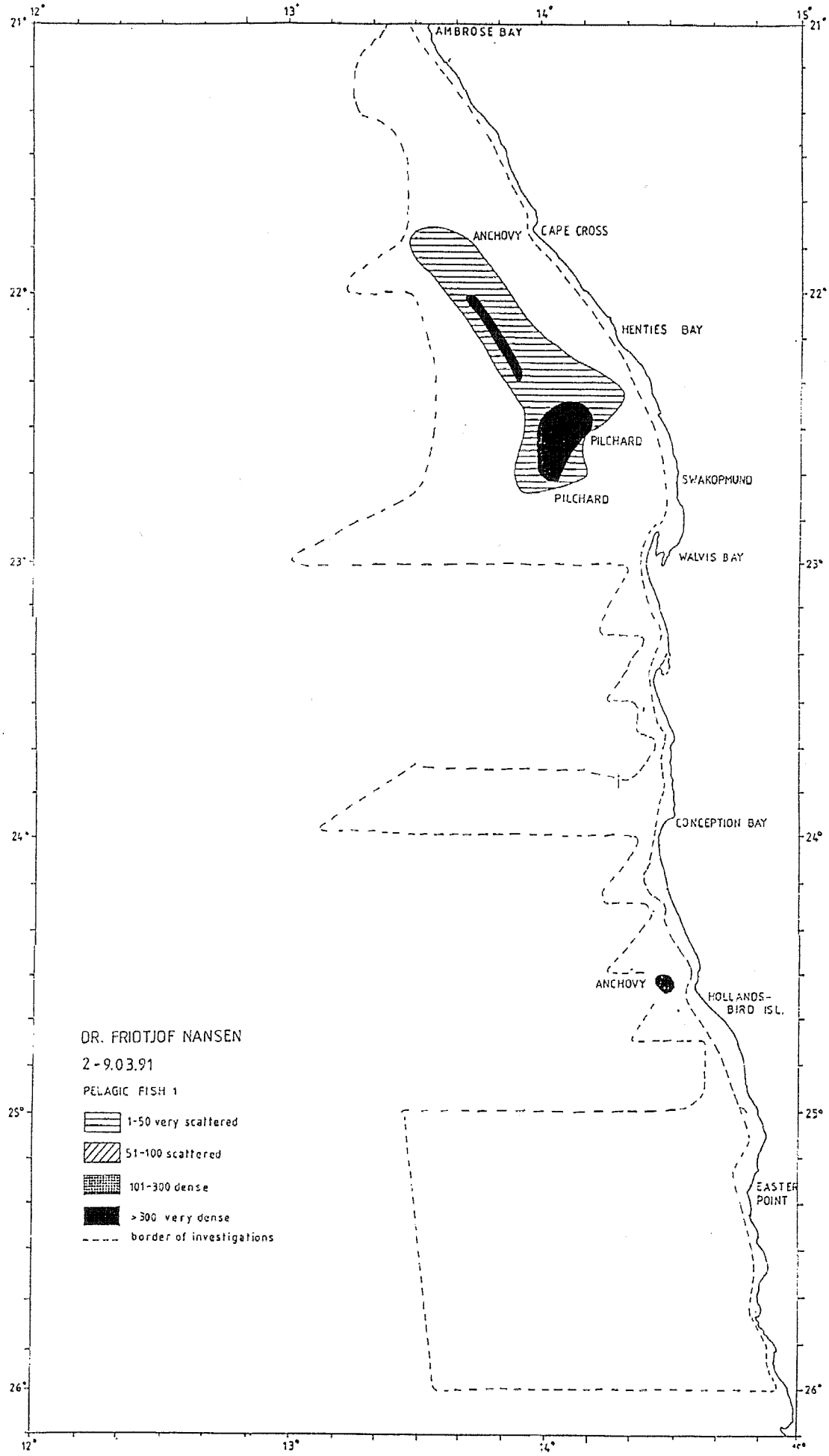

Figure 4a. Distribution of pelagic fish type 1, clupeids and anchovy. Dolphin Head to Ambrose Bay.

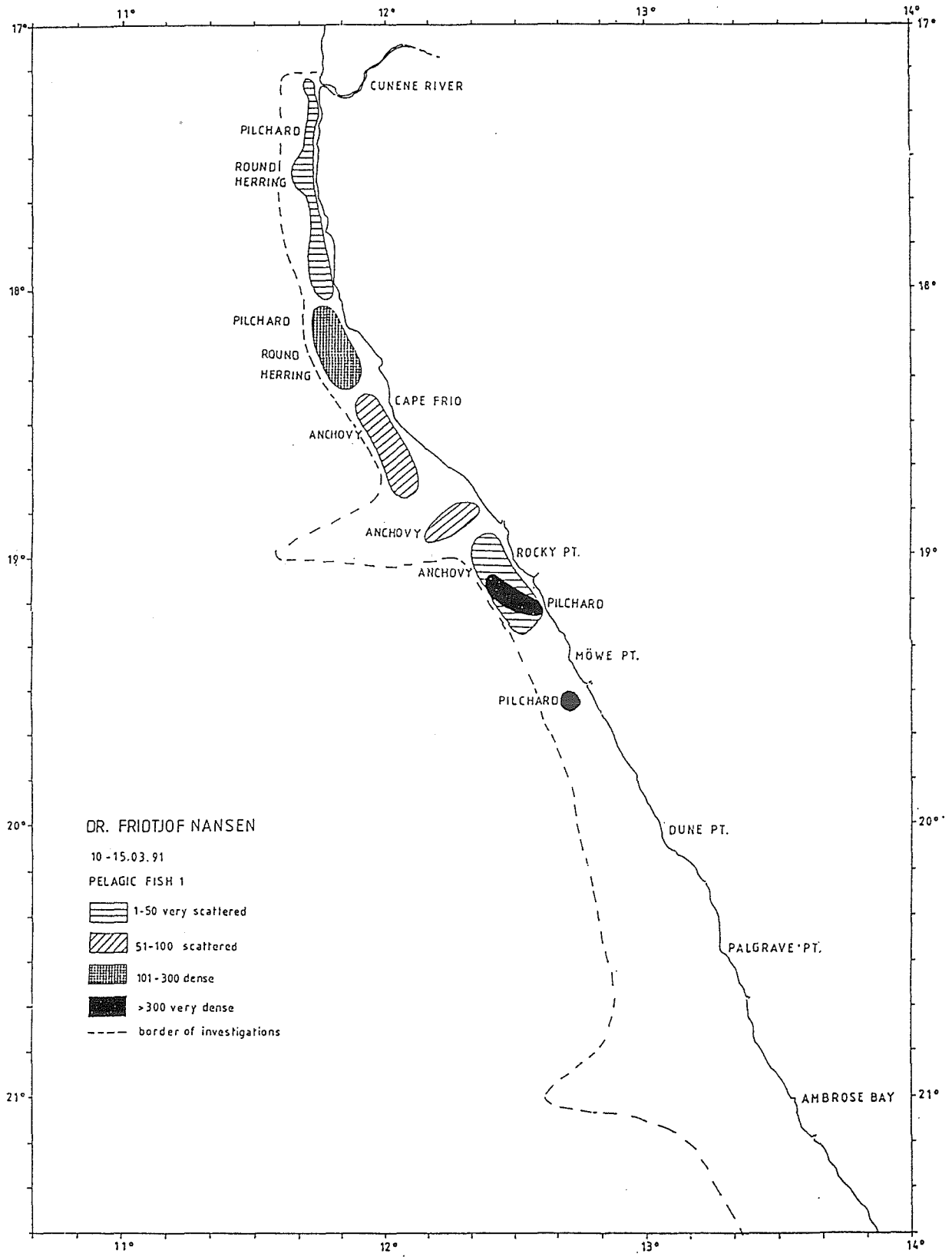

Figure 4b. Distribution of pelagic fish type 1, clupeids and anchovy. Ambrose Bay to Cunene River.

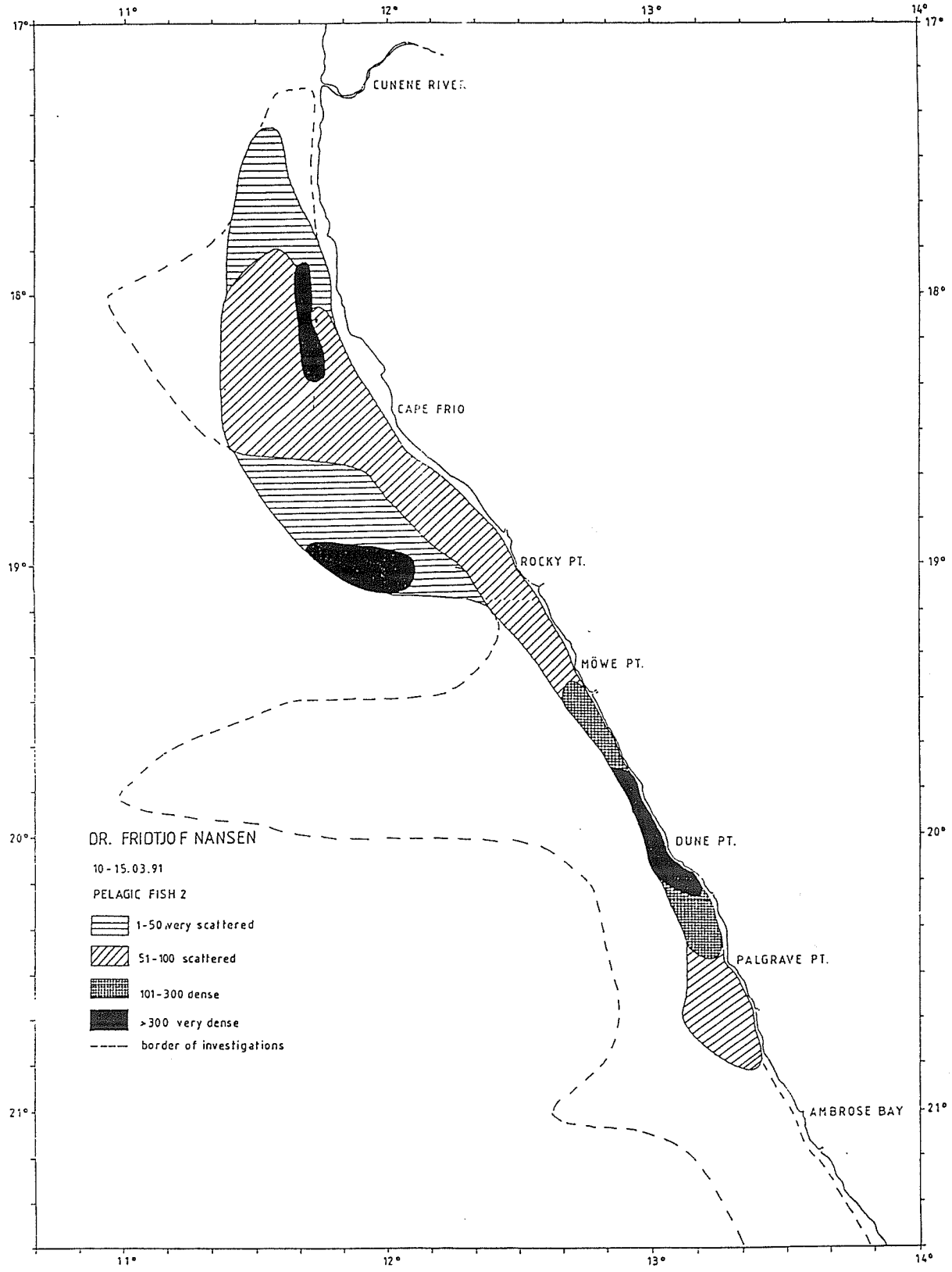

Figure 5. Distribution of pelagic fish type 2, horse mackerel. Ambrose Bay to Cunene River.

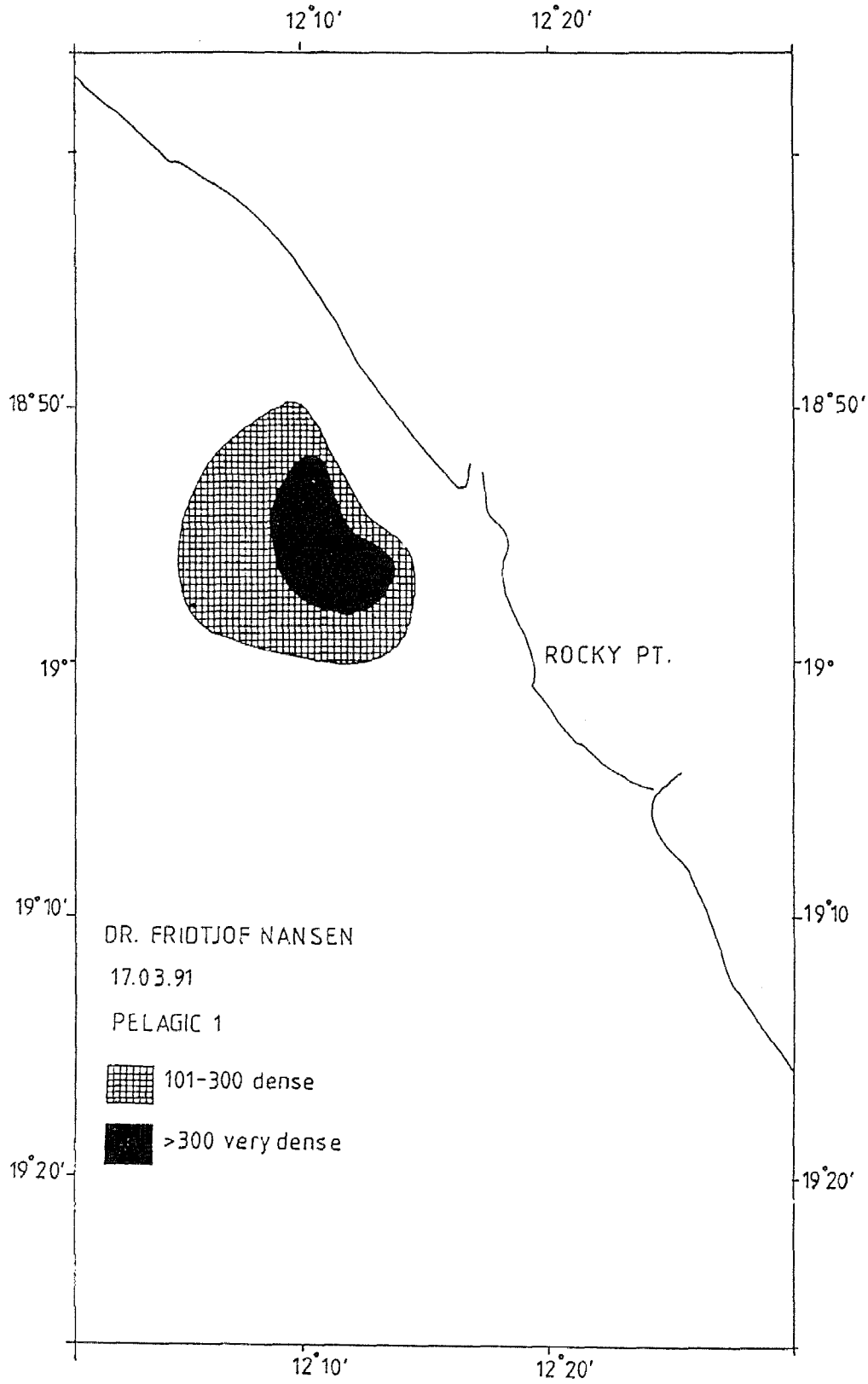

Figure 6a. Distribution of pilchard. Rocky Point.

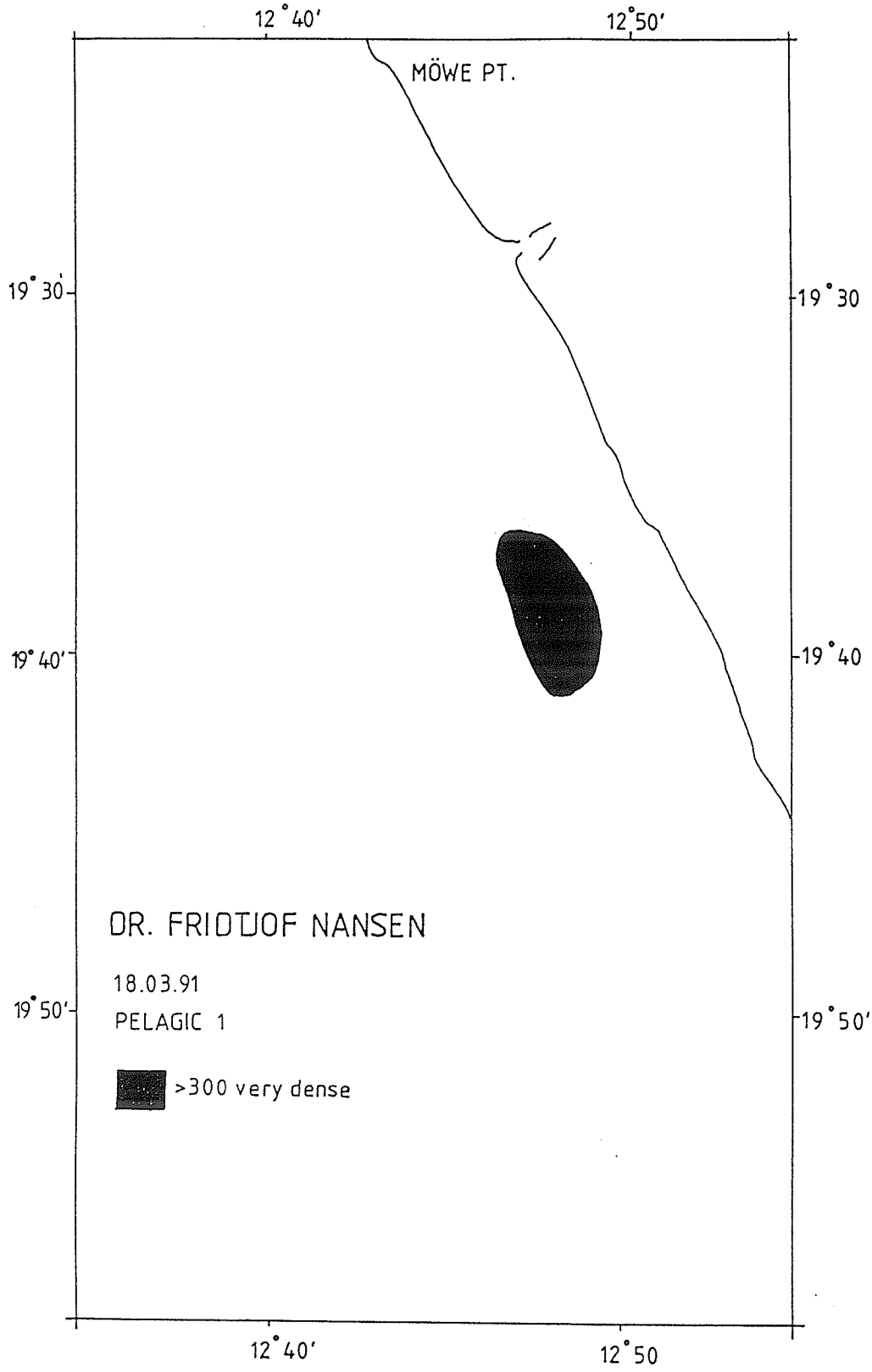

Figure 6b. Distribution of pilchard. Möwe Point.

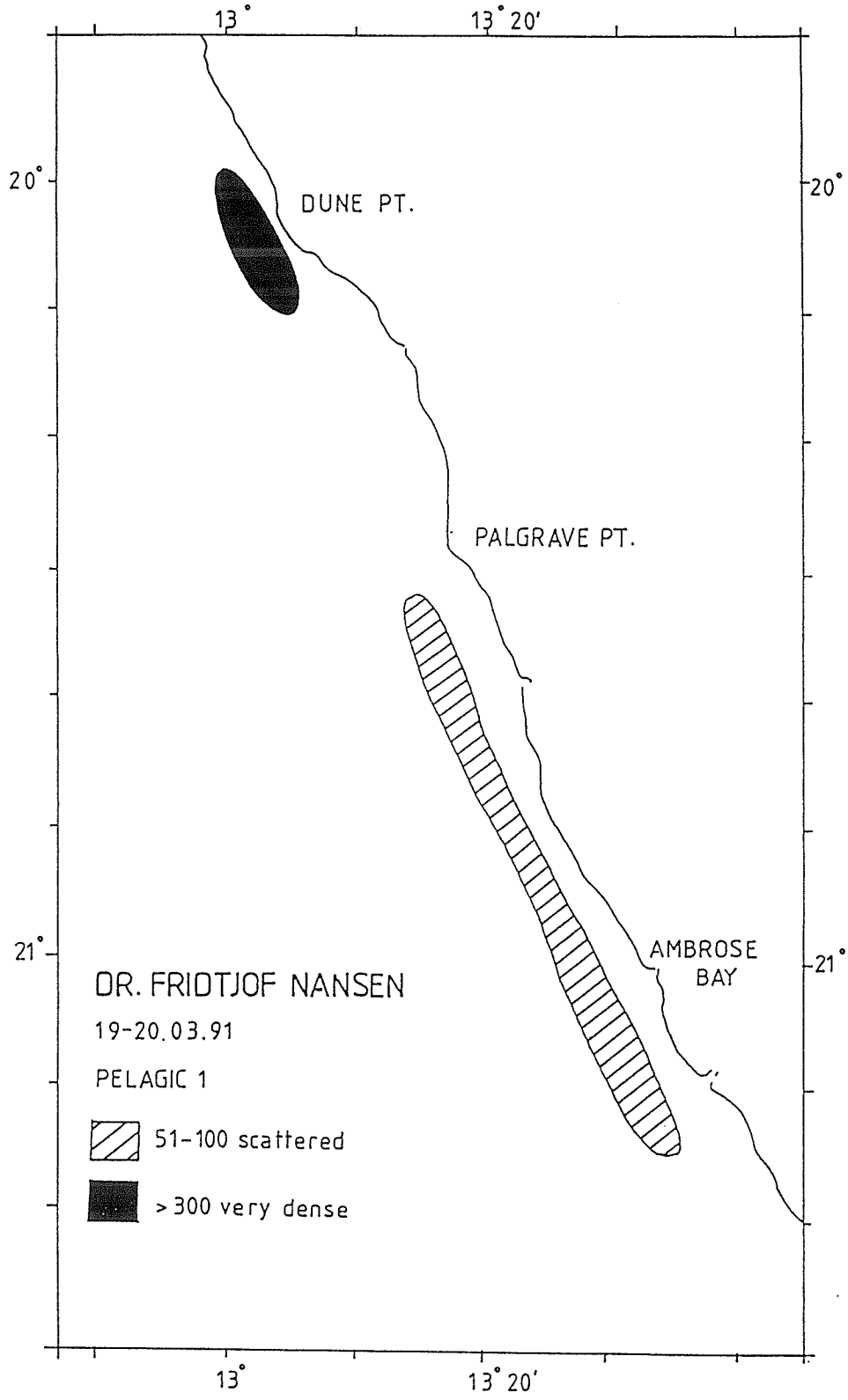

Figure 6c. Distribution of pilchard. Dune Point to Ambrose Bay.

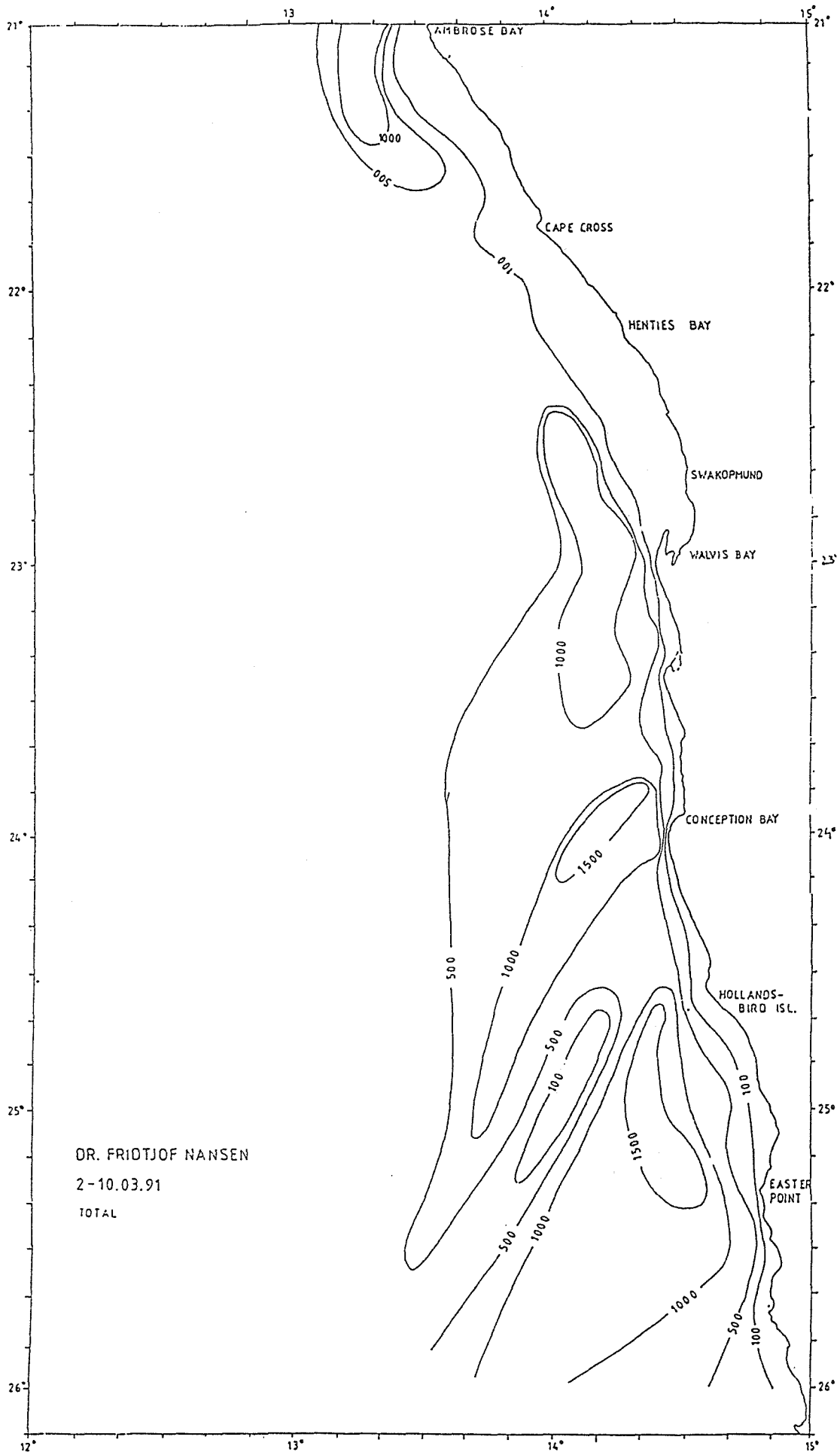

Figure 7. Total back-scattering volume values. Dolphin Head to Ambrose Bay.

A large area of dense shoals occurred at Rocky Point (19°00'). Many of these shoals were extremely large, being several cables in diameter, although their vertical extension was not as great as has been previously recorded. This concentration of pilchard occurred south of Rocky Point (19°10' to 19°00') during the preliminary survey, but was found to have moved about 15 nm northwards when it was re-surveyed three days later. The shoals were less dense during the second survey, particularly during the early part of the night.

Several dense shoals of pilchard, near Möwe Point (19°30'), were later re-surveyed intensively. The fish had moved some 10 nm southwards in the intervening four days, and were mixed with horse mackerel. Initially, the two species appeared to be completely mixed, but in the early morning some separation occurred. From trawl records and the acoustic appearance of the shoals, the species composition was determined to be approximately 75% pilchard and 25% horse mackerel (as measured by back scattering volume).

In addition to this dense area of pilchard, small, but dense, shoals occurred less frequently throughout the region from south of Rocky Point (19°10') to the Cunene River (17°15'). A number of widely dispersed small shoals of pilchard also occurred between Dune Point (20°00') and south of Ambrose Bay (21°15'). It is assumed that these shoals were distributed in a continuous narrow band throughout this area.

Most of the pilchard sampled in this region were large with modal peak of 22 to 23 cm (see Annex 1). From previous ageing studies, these are assumed to be Group-2 and older fish. Only a few recruits were found, while a small number of Group-1 (15 to 18 cm) fish were also surveyed.

Anchovy occurred in an extensive belt between 18°00' and 19°00', giving high registrations in the Rocky Point region, concurrent with the area of dense pilchard occurrence. These fish were almost entirely adult fish with a modal length of 13 to 14 cm.

An extensive area of horse mackerel occurred along the coast from north of Ambrose Bay (20°50') to the Cunene River. The density was particularly high close inshore in the region of Dune Point (20°15' to 19°45').

A few transects determined the distribution of horse mackerel in offshore waters (see Figure 1b). Horse mackerel were found beyond the 100 m depth isoline only to the north of Rocky Point. In this area, the distribution extended to 30 nm from the coast.

The size distribution of horse mackerel tended to be greater in deeper waters than inshore. In waters less than 100 m deep the horse mackerel had a bimodal size distribution, with modal peaks at 6 to 8 cm and 17 to 19 cm ranges. Samples collected in waters of 100 m deep and more consisted of 18 cm and larger fish.

Few myctophids or gobies were found in the area north of Ambrose Bay and jellyfish concentrations were considerably less than those in the south.

4.2 ABUNDANCE OF PELAGIC FISH

The biomass estimates are based on the acoustic integration technique, similar to that used in previous assessments of the same stocks. The survey coverage was assessed as being ample with increased sampling in areas of high density. The North Sea herring target strength was used for all type-1 pelagic fish.

The biomass estimates for the clupeids and anchovy are shown in Tables 1 and 2.

Owing to the uncertainty of the most appropriate horse mackerel target strength to be used during acoustic biomass estimation, a biomass range is presented. The range corresponds to the values of target strength for the North Sea Herring (lower limit) and the TS proposed by Svellingen (upper limit) for horse mackerel (see "DR. FRIDTJOF NANSEN" Cruise Report No.1). Table 3 shows the estimates for the present cruise.

Individual target strengths and length frequency of horse mackerel were logged during the cruise. These data will be analyzed later to provide a more precise mean target strength for this species.

4.2.1 Pilchard, anchovy and round herring

The biomass of pilchard and anchovy between Swakopmund and Cape Cross was estimated as about 640 000 tonnes, of which about 535 000 tonnes was considered to be pilchard and 105 000 tonnes anchovy. This relatively large concentration of fish was surveyed rather briefly (see previous section) and therefore these figures may be rather imprecise.

A further 10 000 tonnes of anchovy occurred off Hollandsbird Island, but the amount of fish at Easter Point, which appeared to be anchovy, was considered too small to make a reasonable biomass estimate.

During the northwards survey, 80 000 tonnes of pilchard were estimated as occurring at Dune Point, while 236 000 tonnes, mainly pilchard, was estimated for the Rocky Point region. A further 83 000 tonnes of mixed pilchard and round herring was found north of Cape Frio to the Cunene River. It was not possible to accurately estimate the species composition of these shoals and so separate figures cannot be attributed to each species.

Thirty thousand tonnes of anchovy were estimated to occur in a narrow belt north of Rocky Point and extending to the Cunene River.

Table 1. Species composition and biomass estimates of pelagic type-1 fish by area. In tonnes.

Area	Total Biomass 1st estimate	2nd estimate	Percentage Pilchard	Other Species
Hollandsbird Island	10 000	-	0	Anchovy
Swakopmund-Cape Cross	640 000	-	85	Anchovy
Dune Point	80 000	60 000	100	-
Dune Point-Ambrose	50 000	-	100	-
Rocky Point	236 000	172 000	95	Anchovy
Cape Frio-Cunene River	83 000	80 000	?	Round herr.
Cape Frio-Cunene River	30 000	-	0	Anchovy

It was decided to survey the areas with large dense, but dispersed, shoals more intensively during the southwards part of the cruise. These areas were off Rocky Point and at Dune Point. In addition, some few shoals of pilchard were found between Dune Point and Ambrose Bay and were also surveyed on this southwards part of the cruise.

The second and intensive survey of the Rocky Point area yielded an estimate of 172 000 tonnes, mostly pilchard, or some 64 000 tonnes less than during the northwards survey. Owing to the increased surveying intensity and the more open distribution of the fish within the shoals during the second survey of this area, the second estimate is presented with considerably more confidence than the first. Anchovy was estimated to contribute less than 10% to the total biomass on both surveys of this area, being in the order of magnitude of 10 000 tonnes.

The second survey of the Dune Point area indicated that approximately 60 000 tonnes of pilchard occurred in the area, and that the original estimate of 80 000 tonnes was an over-estimate due to insufficient coverage of the area.

The narrow belt of pilchard shoals occurring between Dune Point and Ambrose Bay was surveyed rather briefly and only a rough estimation of the biomass occurring in this area was possible. This was assessed to be in the order of 50 000 tonnes.

Table 2. Total estimated biomass of pilchard and mixed shoals of clupeids and anchovy. In tonnes.

	Dolphin Head-Ambrose Bay	Ambrose Bay-Cunene River	Total
Pilchard	535 000	270 000	805 000
Anchovy/R.herring	115 000	40 000	155 000
Pilchard/R.herring	-	80 000	80 000
Total	650 000	390 000	1 040 000

4.2.2 Horse mackerel

The present survey failed to find any horse mackerel in the inshore waters south of Ambrose Bay, while northwards over 1.5 to 3.0 million tonnes were recorded. The horse mackerel in the inshore region constituted approximately half of the total, with over 0.5 to 1.0 million tonnes occurring between Möwe Point and Ambrose Bay. The estimate for the offshore stocks is presented with caution, as the widely-spaced transects yielded few data points from which the biomass calculation was made. During Part I of the survey horse mackerel was found to be present over a much wider part of the shelf than that covered in Part II, particularly in the southern region. The estimate presented here thus represents only a part of the total stock.

Table 3. Biomass estimates of pelagic (sub-adult) Cape horse mackerel. Reported in millions of tonnes.

Dolphin Head-Ambrose Bay	Ambrose Bay - Cunene River	Total
-	1.5 - 3.0	1.5 - 3.0

CHAPTER 5 CONCLUDING REMARKS

Some surveying difficulties were encountered during the present and previous surveys of pelagic fish stocks in Namibian waters using acoustic methods. In general, however, the present survey was considered thorough and all figures are reported with a fair degree of confidence and should be considered to be reasonably accurate.

Previously noted problems, which were also encountered during the present survey, included the occurrence of large concentrations of jellyfish hampering the determination of species composition by trawling and the occurrence of widely dispersed shoals requiring tightly spaced transects to ensure an accurate coverage of such regions (see also "DR. FRIDTJOF NANSEN" Cruise Report No.2, 1990).

An additional problem occurred with the few extremely large and dense shoals of pilchard found in the Rocky Point/Cape Frio area. These are not well suited to the type of sampling used during acoustic surveys, because of the highly clumped distribution characteristic of the fish. During the present intensive survey of these shoals, the fish became more dispersed for several hours immediately after sunset. As this dispersion occurred during the period when the most dense region was surveyed, the calculated biomass estimate should be more precise than previous estimates.

Determining species composition was difficult in several areas, notably with the fish shoals occurring at Dune Point and north of Cape Frio. During certain parts of the diurnal cycle these shoals, particularly those of pilchard and horse mackerel, tended to separate, allowing an estimate of the species proportions to be made.

Round herring frequently have a similar acoustical appearance to pilchard and, during the period of the survey, were occasionally caught in the purse seine nets of commercial fishing boats during the period of the survey, particularly in the area between Dune Point and Ambrose Bay. Round herring are known to exhibit a high degree of net avoidance, and the fact that this species were largely absent from the "DR. FRIDTJOF NANSEN" trawling statistics may have resulted in an under-estimate of the biomass of this species. This may have resulted in concurrent over-estimate of pilchard biomass, but as the total round herring population is not large, this inaccuracy is probably insignificant.

Previous surveys have reported large concentrations of fish occurring in shallow waters, while other fish migrated at night to surface waters above transducer level, and thus were not available to be surveyed. Apart from a small part of the horse mackerel stock occurring in shallow waters, these behavioral traids were not detected in any of the target species during this survey.

Much time was spent searching for fish and determining the precise distribution of areas of high density, prior to an intensive survey of such areas. Commercial fishing vessels are well suited to this type of work and have been used successfully in previous cruises (see "DR. FRIDTJOF NANSEN" Cruise Report No. 2). Future acoustic biomass surveys should, if possible, make full use of such assistance.

In general, adult horse mackerel and anchovy were well dispersed and suited to biomass determination by acoustic methods, while the limitations noted above, must be placed on the pilchard estimates.

The two "DR. FRIDTJOF NANSEN" surveys of pelagic fish undertaken in 1990 reported pilchard biomasses of 235 000 tonnes and 750 000 tonnes (Table 4). The increased biomass figure of 750 000 tonnes was thought to be due to the inclusion of the large amount of pilchard, 435 000 tonnes, between Rocky Point and Cape Frio. This concentration has largely been absent from earlier surveys, probably due to its behaviour of shoaling very densely in shallow waters and thus avoiding detection.

Table 4. Comparison of biomass estimates of pelagic stocks made by "DR. FRIDTJOF NANSEN" during 1990 and 1991. Reported in thousands of tonnes

	Dolphin Head-Ambrose Bay	Ambrose Bay - Cunene River	Total
PILCHARD			
March 1990	75	160	235
June 1990	265	485	750
March 1991	535	273	805
ANCHOVY/ROUND HERRING			
March 1990	125	90	215
June 1990	115	70	185
March 1991	115	120	235
HORSE MACKEREL			
March 1990	660-1 200	780-1 500	1 400-2 700
June 1990	400- 750	1 600-3 000	2 000-3 750
March 1991	0	1 500-3 000	1 500-3 000

All pilchard stocks were found in discrete areas. Shoals were very dense and, within these areas, were occasionally widely scattered. The estimated 270 000 tonnes occurring in the north is considerably less than the 485 000 tonnes estimated in June 1990. Several problems encountered during the 1990 survey notably the movement of fish into shallow waters and the occurrence of a small number of extremely large dense shoals (see"DR.FRIDTJOF NANSEN" Cruise Report No.2) suggests that the present figure may be more reliable. Alternatively, the increased figure for the southern area could represent a southwards movement of part of the northern stock.

Almost the entire pilchard stock consisted of adult fish. No recruits were sampled. 61% (by number) of all pilchard sampled were in the 21 to 25 cm length classes, with a lesser number having a modal peak of 19 cm (see Annex 1). These length classes correspond to the modal peaks recorded during the 1990 surveys of 22 cm and 16 to 17 cm respectively. A younger cohort was recorded during the present survey, with a modal peak length of 15 to 17 cm. This represented about 20% of the fish sampled and was assumed to have come from the 1990 spawning season. While the 1991 total stock biomass may be similar to the 1990 biomass, it consists of fewer, older fish. The absence of recruits from the recent austral spring/summer period may indicate poor recruitment for 1991, although this survey may be too early in the year to determine this fact.

The size of the pilchard stock is large compared to the estimates of stock size made during the eighties. However, the small proportion of young fish and narrow age range means that this stock must be considered to be in a vulnerable state.

Owing to the mixed shoaling behaviour of anchovy and round herring, it has not been possible to report their biomasses separately. The total stock of these two species was estimated as being 215 000 tonnes and 185 000 tonnes during the 1990 "DR. FRIDTJOF NANSEN" surveys. The present figure of 235 000 tonnes also included a small amount of pilchard. The total combined biomass of anchovy and round herring must therefore be considered similar to the 1990 biomass estimate. The dominant anchove length class of 14

cm corresponds to the 11 to 13 cm cohort recorded in 1990. Few juvenile anchovy occurred and may be some cause for concern.

The previous horse mackerel biomass estimate made by the "DR. FRIDTJOF NANSEN" indicated a total biomass of 2.00 to 3.75 million tonnes depending on which TS-value is used. The offshore region south of Ambrose Bay was not surveyed during the present cruise and this is likely to have caused the present reduced total stock biomass.

The length-frequency distribution of horse mackerel exhibited three peaks. The 14 to 15 cm and 18 to 19 cm groups corresponded cohorts of the previous year measured at 10 to 11 cm and 14 to 16 cm respectively. A strong cohort of fich smaller than 11 cm indicated good recruitment from the recent austral spring/summer period.