1 INTRODUCTION

1.1 Objectives

Following an offer from NORAD extended through FAO and UNDP, an agreement was reached in Windhoek in January 1990 between the UNDP Resident Representative and Namibian authorities for the execution of a programme of surveys of the fish resources of the Namibian shelf waters during 1990 with the R/V "DR. FRIDTJOF NANSEN".

The purpose of the programme was agreed as follows:

The main objectives are descriptions of the distribution, composition and abundance of the most important resources of fish and shellfish (although little informations is expected to be obtained on lobster). The small pelagic fish horse mackerel, sardine and anchovy will be investigated by the acoustic integration method combined with sampling with mid-water and bottom trawls. A swept area trawl survey programme will be used for the demersal stocks. All catches will be sampled to species by weight and numbers and biological sampling will be made of the commercially important stocks.

Environmental studies will include recording of surface temperature on a continuous basis and occupation of hydrographic stations in a series of fixed profiles as well as studies of bottom type by grab samples and the ROXANN bottom discrimination system.

Possible taxonomic problems will be studied by sampling and examination by experts in cooperation with FAO's Fisheries Department.

1.2 Participation

The scientific staff from Namibia were:

To 4. February : Dr. Gert Cloete, Serubal Kahina and Willem Nauieb;

from 4 to 22 February: Othniel Tjiuma, David Gawaseb,Quin Hammond, Malakia Shimhanda and Christof Uirab;

from 25 February to 19 March: Bernatitus Birisamub,Serubabel Kahiha, Willem Naoiseb, Peter Schivute and Helen Smit.

The scientific staff from the Institute of Marine Research were:

G. Saetersdal (to 23 February), J. Kolding (to 23 Febrary), Tore Strømme (from 24 February), Oddgeir Alvheim (from 24 February), M.Dahl and E. Molvaer.

1.3 Narrative

Figures 1a-c show the course tracks with the fishing stations and the hydrographic profiles.

The vessel left Walvis Bay in the morning of 26 January. A planned calibration of the acoustic instruments off the entrance of the bay had to be cancelled due to unfavourable conditions. After steaming south, work started off the Orange River in the morning of 28 January. An acoustic cum trawl survey was conducted over the shelf northwards from the shore out to 300-400 m where a Spanish trawler fleet was working. Gear damage from rough bottom was experienced although special annotated Spanish charts were available. A bobbins ground line was installed. A hydrographic profile was worked from southwest 80 nm towards Panther Head. Lüderitz was visited on 4 February for exchange of participants. The survey was continued northwards with trawl stations out to 500 m and a hydrographic profile off Hottentot Point on 6 February. By 8 February the shelf up to 25°S, the part included in ICSEAF Div. 1.5 had been covered with a total of 68 fishing stations distributed at depths down to 500 m along course lines crossing the shelf with roughly 20 nm distance. In some of the inshore areas a more detailed course grid was used.

The coverage from 25°S northwards to Ambrose Bay is shown in figure 1b. Bottom conditions on the offshore shelf for the demersal trawl improved in this region and the trawl could be used without bobbins gear. A hydrographical section was worked off Conception Bay on 11 February. A problem of sampling with the demersal trawl in this area was the very soft muddy bottom found in a belt inshore along the coast some times reaching out beyond 150 m of depth. However, the successful hauls made on such bottom were almost devoid of fish. Schools and layers of pelagic fish were found in increasing abundance northwards, in inshore areas as well as over the middle part of the shelf. The basic cruise track distance of 20 nm was decreased to about 10 nm in these areas and special sampling efforts were made during nighttime in the school areas. The profile off Cape Cross was worked 17-18 February, but the two outermost stations were repeated on 20 February because of some problems with the first observations. The vessel called on Walvis Bay on 22 February for exchange of staff.

The work continued northwards on 25 February. An acoustic sampling net was laid out with transects 20 nm apart. During daytime hours random bottom trawl stations were positioned along the cruisetrack. The northbound survey served as a pilot study for a finer grid laid out on the following southward bound coverage. During the first part it proved difficult to sample acoustically the main part of the sardine and the anchovy, mainly localized in shallow waters, as it tended to move very shallow or close to the surface during daylight hours. The best tactics proved to be to sample the inshore waters during night hours, and covering the outer shelf during daylight. This sampling scheme was followed for the southward bound coverage. The 20-100 m bottom depth zone was then covered with zig-zag pattern 10 nm apart, and the shelf from 100 to 250 m with 15 nm transect interdistance. Areas where presence of sardines was spotted or reported by the fishing fleet, were covered again in order to improve the chance of detection.

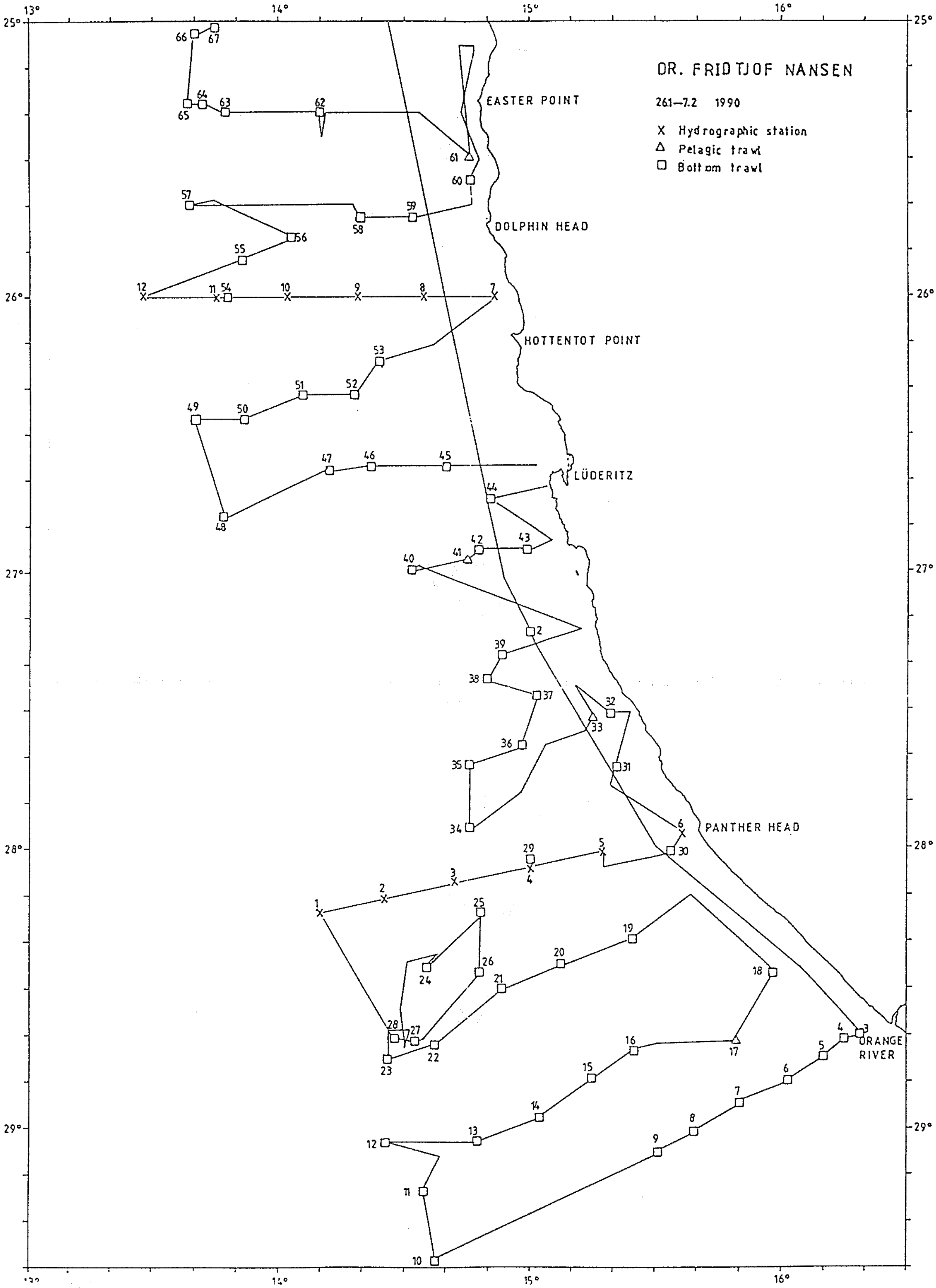
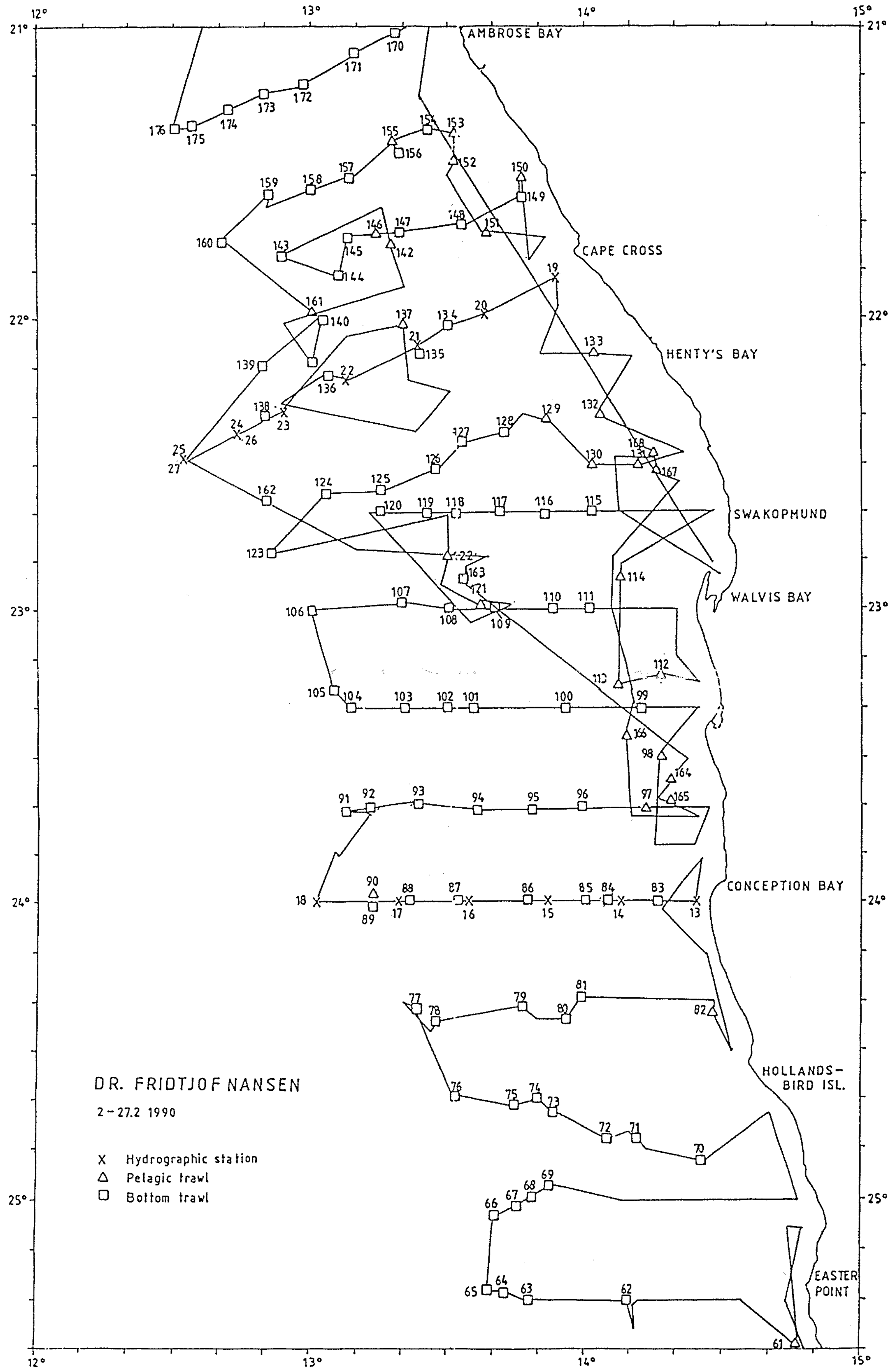


Figure 1. Course tracks with fishing stations and hydrographic profiles, a: Orange River to St. Francis Bay, b: St. Francis Bay to Ambrose Bay, c: Ambrose Bay to Cunene River.


12°
13°
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AMBROSE BAY
CAPE CROSS
HENTY'S BAY
SWAKOPMUND
WALVIS BAY
CONCEPTION BAY
HOLLANDS-BIRD ISL.
EASTER POINT
DR. FRIDTJOF NANSEN
2-27.2 1990
X Hydrographic station
Δ Pelagic trawl
□ Bottom trawl

Figure 1b.

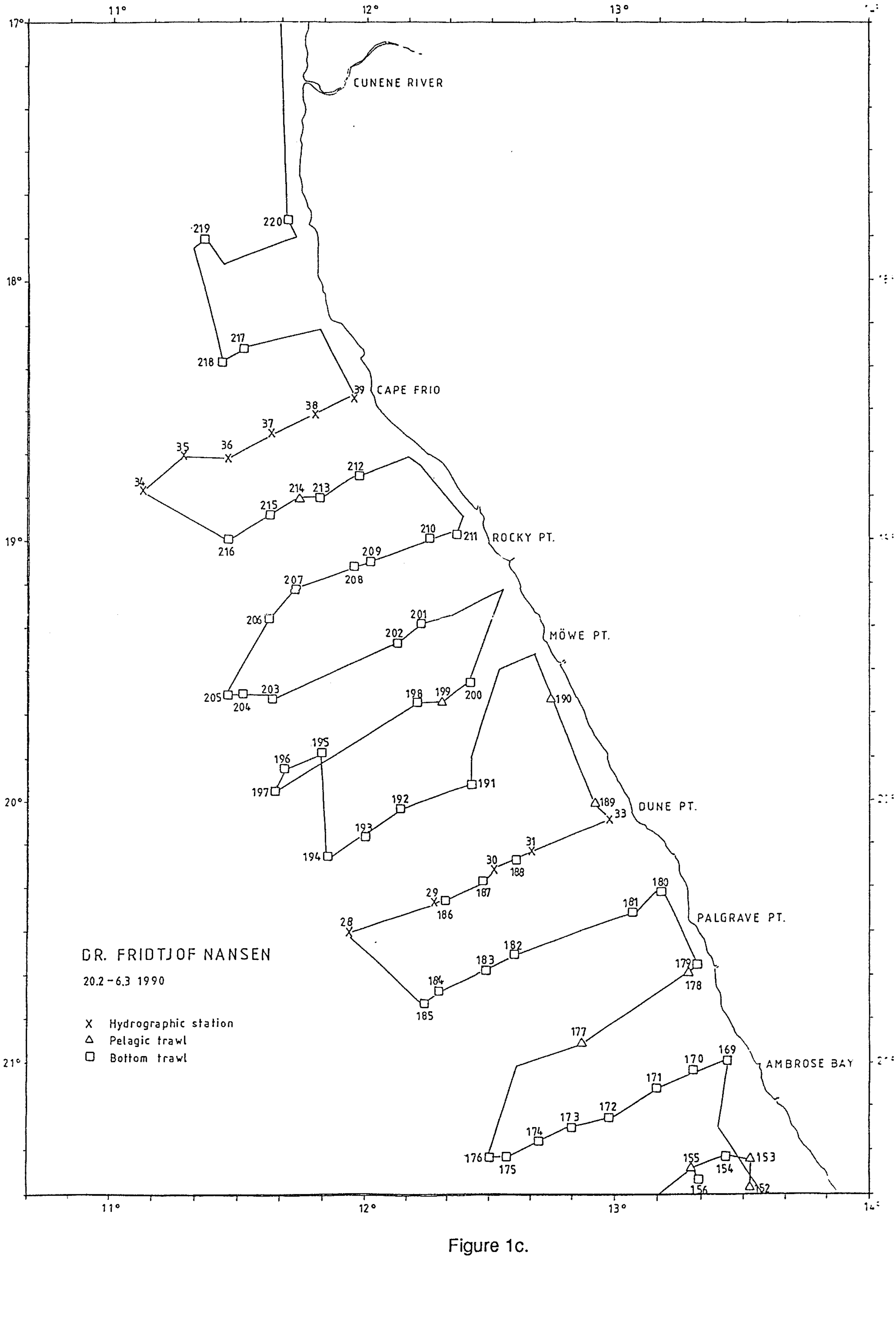
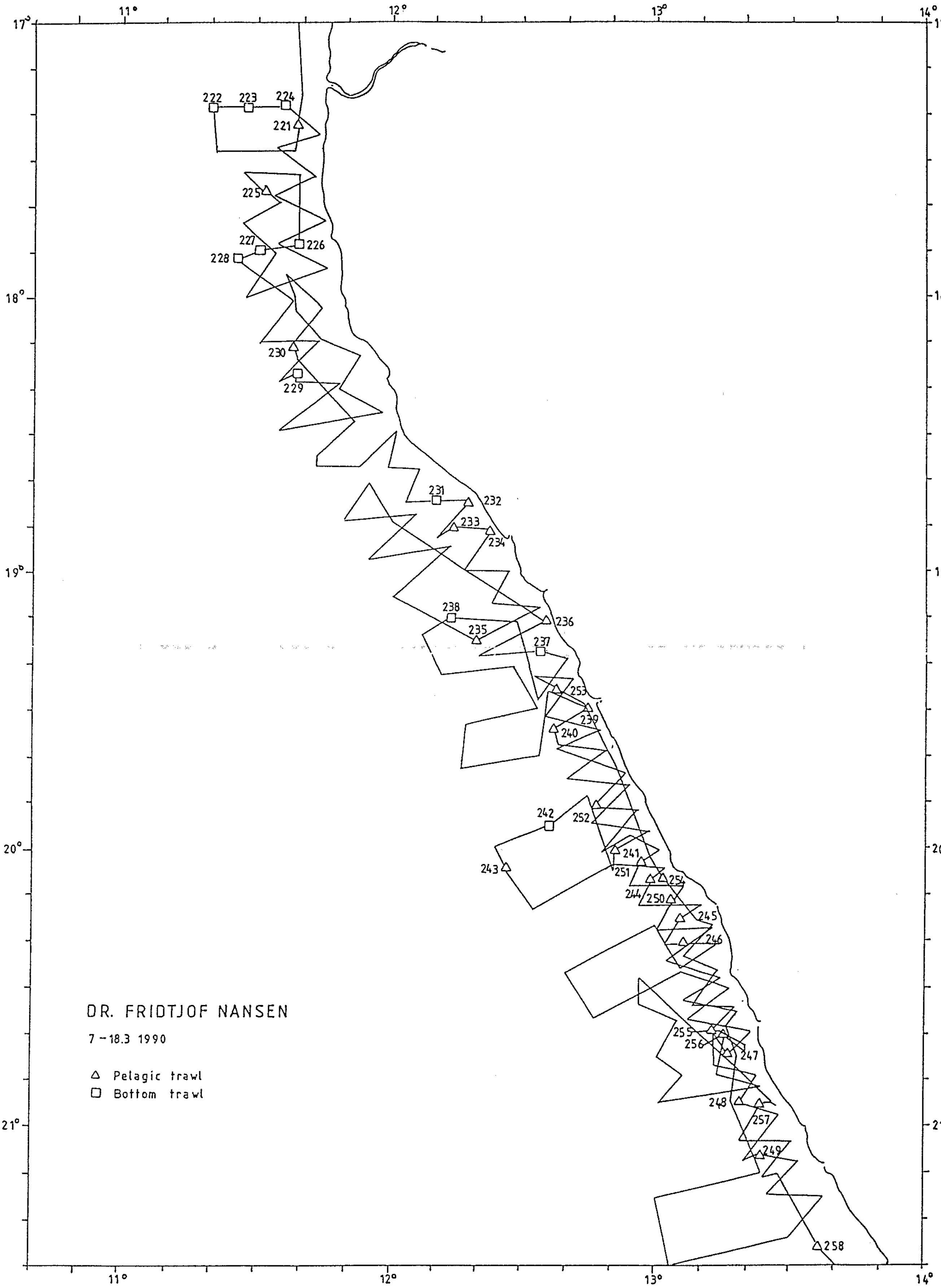

CUNENE RIVER
CAPE FRIO
ROCKY PT.
MÖWE PT.
DUNE PT.
PALGRAVE PT.
AMBROSE BAY
DR. FRIDTJOF NANSEN
20.2 - 6.3 1990
X Hydrographic station
Δ Pelagic trawl
□ Bottom trawl
11°
12°
13°
17°
18°
19°
20°
21°

Figure 1c.


DR. FRIDTJOF NANSEN
7 – 18.3 1990
△ Pelagic trawl
□ Bottom trawl
11°
12°
13°
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20°
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249
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Figure 1c.

Hydrographic profiles were worked off Dune Point and Cape Frio on 28 February and 4-5 March respectively.

The acoustic instruments were calibrated in an experiment in Bahia dos Tigres, Angola on March 7.

The vessel arrived in Walvis Bay on 18 March, ending the survey.

Annex III gives a description of the instruments and the fishing gear used.

2 THE ENVIRONMENT

2.1 The shelf and the slope

Table 1 shows the approximate extensions of the areas between various depth ranges along the coast based on estimates from own observations and use of Spanish fishing charts.

Table 1. Areal extension of shelf and slope by depth ranges, nm^2.

	100-250m	250-350m	350-450m	450 550m
Orange R.-25°	11 300	3 200	3 000	2 000
25°- 21°	8 300	3 500	1 900	1 000
21° -Cunene R.	5 100	2 700	1 600	800

From the Orange River up to Panther Head the shelf is wide with the 200 m depth 70 - 80 nm offshore. The slope is relatively steep and the 500 m line lies about 90 nm off-shore. Considerable parts of the bottom are uneven and rough, especially inshore. Hard and rough bottom was also found in the slope, especially around the 300 m range. From Panther Head up past Lüderitz the 200 m line approaches to about 20 nm off the shore, but the slope is gentler and the 500 m line lies 50-60 nm or more off the coast. Rough and uneven bottom is common over the inshore parts. In the northern part of Division 1.5 up past Easter Cliff the shelf is wide with the 500 m depth at about 70 nm from the coast and with more than half of that width consisting of a gently deepening slope from 200 to 500 m. Rough uneven bottom dominates the innermost parts of the shelf up to 20-30 nm from the coast and there is also rough ground offshore especially off Dolphins Head at 200-300 m of depth.

The broad shelf continues from 25°S northwards towards Ambrose Bay with a generally gentle slope from 200 to 400 m depth. Most of the bottom is smooth with few and limited rough parts. An inshore belt extending out past 100 m depth, somewhere to 150 m has very soft muddy bottom. At times indications of anoxic conditions were found in this type of bottom and catches were absent or low. In some hauls from this zone the trawl contained large numbers of fish bones, in other cases large amounts of dead mussels. It seems likely that this mud layer mainly derives from the intensive organic production caused by the upwelling and that anoxic conditions associated with it at times causes mass mortalities of fish and shellfish.

From Ambrose Bay up towards Cape Frio the shelf maintains a width of about 70 nm to the 500 m depth line with about half consisting of a gentle slope from 200 m outwards. From Cape Frio to Cunene the shelf narrows to about 25 nm with a steep slope from the 200 m depth line.

2.2 Hydrography

The figures 2a-c show the sea temperature at 4 m of depth as observed with the ship's thermograph and Figures 3a-e show the distribution of temperature, salinity and oxygen in the 5 hydrographic transects worked. The position of the transects are shown in figure 1a-c.

In the profile off Hottentot Point the surface temperature shows the shorewards decline typical for this area of coastal upwelling. From about Lüderitz northwards past Hottentot Point there is an increase of cold upwelled water. This is probably related to the configuration of the shelf with its westwards turning slope at about this latitude. The Hottentot profile shows isotherms sloping upwards from about 200 m of depths. Also the salinities of the surface layers indicate an origin of water from a depth of about 200 m. The oxygen content of the bottom water layer is less than 1 ml/l over the whole shelf.

As shown in figure 2b the cold surface water, lower than 19°C was found out to the shelf edge also further north up to about Walvis Bay, but from here on this isotherm was located well inside the shelf, from a few up to 20-30 nm from the shore. The hydrographical transects off Conception Bay and Cape Cross, figure 3c demonstrate active upwelling from about 200 m of depth. The oxygen content of the bottom water of the entire shelf is below 1 ml/l.

The surface temperature between Ambrose Bay and Cunene River is pictured in figure 2c, and the profiles of the two hydrographic sections in the same region, off Dune Point and Cape Frio, are shown in figure 3c. The surface temperature shows two clear centers of coastal upwelling, between Palgrave Point and Møwe Point and between Cape Frio and the Cunene River. The temperature falls below 17°C in the first center and below 16°C in the second. The picture is confirmed in the profiles, which also portraits low-oxygen bottom conditions on most of the shelf. Off Dune Point the whole shelf is supplied with less than 1 ml/l oxygen, and off Cape Frio the values are less than 2 ml/l, with the 1 ml/l isoline at 100 m bottom depth. In the pelagial over the shelf the oxygen content is relatively high down to 50 m depth, except in the very coastal zone where the deep water rises to surface.

The period of hydrographic observations cover more than a month and the description is thus not very synoptical. Viewed as a whole the findings indicate a largely average situation for this late summer season. The locations of upwelling correspond to the main upwelling cells described for this region: the Lüderitz- Walvis Bay- and Namibia cells. Late summer and autumn is the season when in some years warm tropical water intrudes from the north and northwest onto the northern and central Namibian coast. This type of

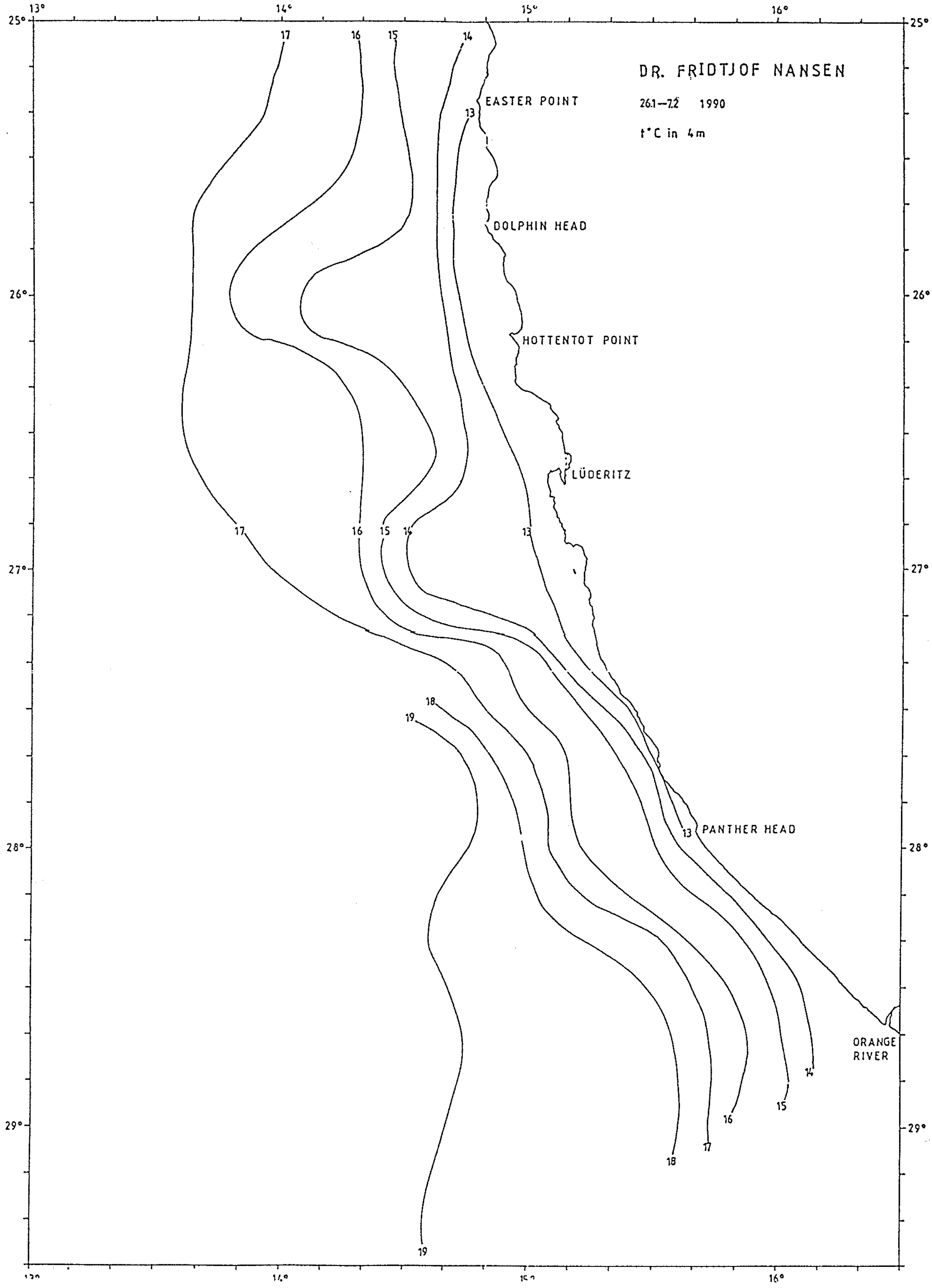
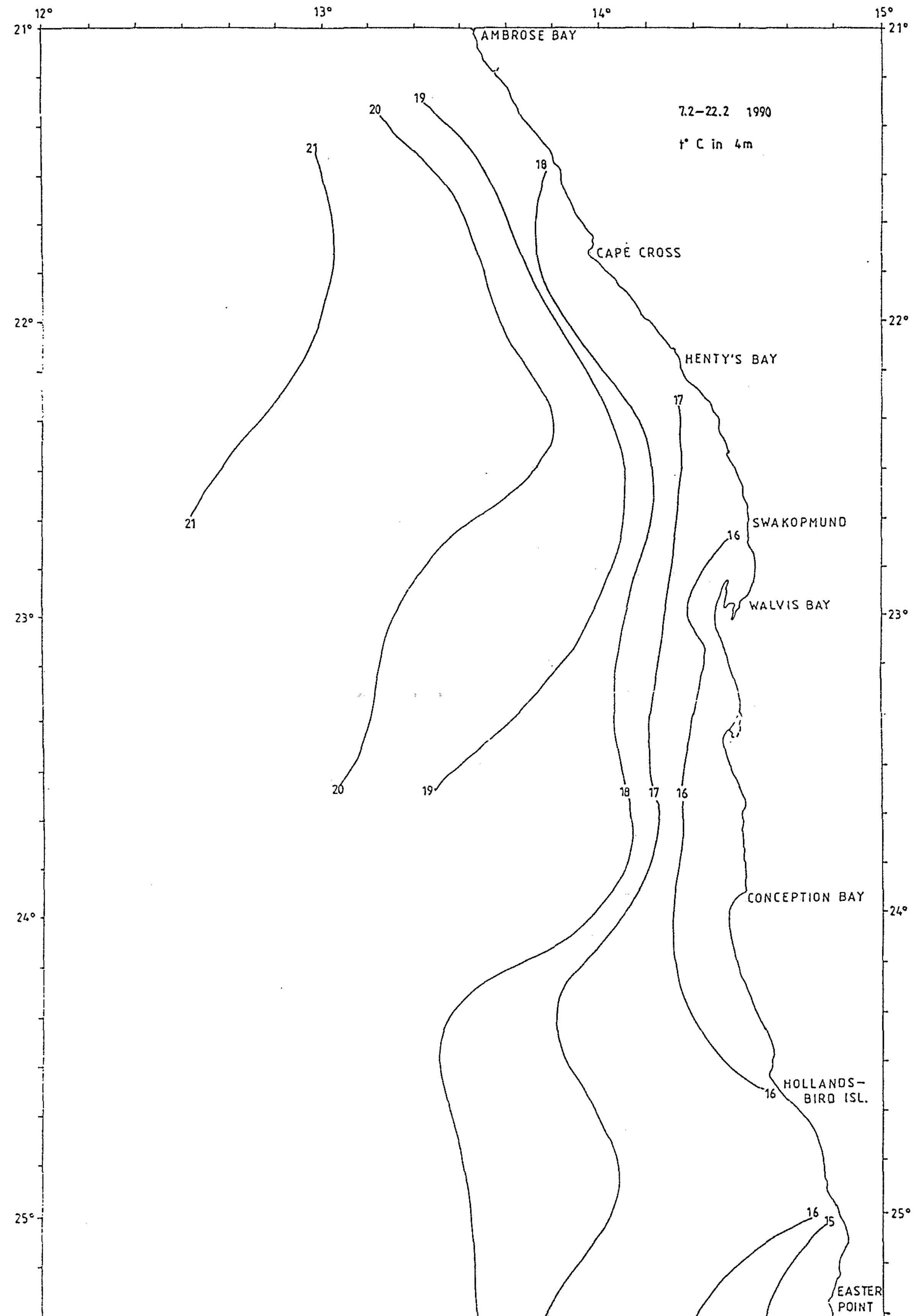


Figure 2. Temperature at sea surface. a:Orange River to St. Francis Bay, b: St. Francis Bay to Ambrose Bay, c: Ambrose Bay to Cunene River.


12°
13°
14°
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22°
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24°
25°
AMBROSE BAY
CAPE CROSS
HENTY'S BAY
SWAKOPMUND
WALVIS BAY
CONCEPTION BAY
HOLLANDS-
BIRD ISL.
EASTER
POINT
7.2–22.2 1990
t° C in 4m
21
20
19
18
17
16
15

Figure 2b

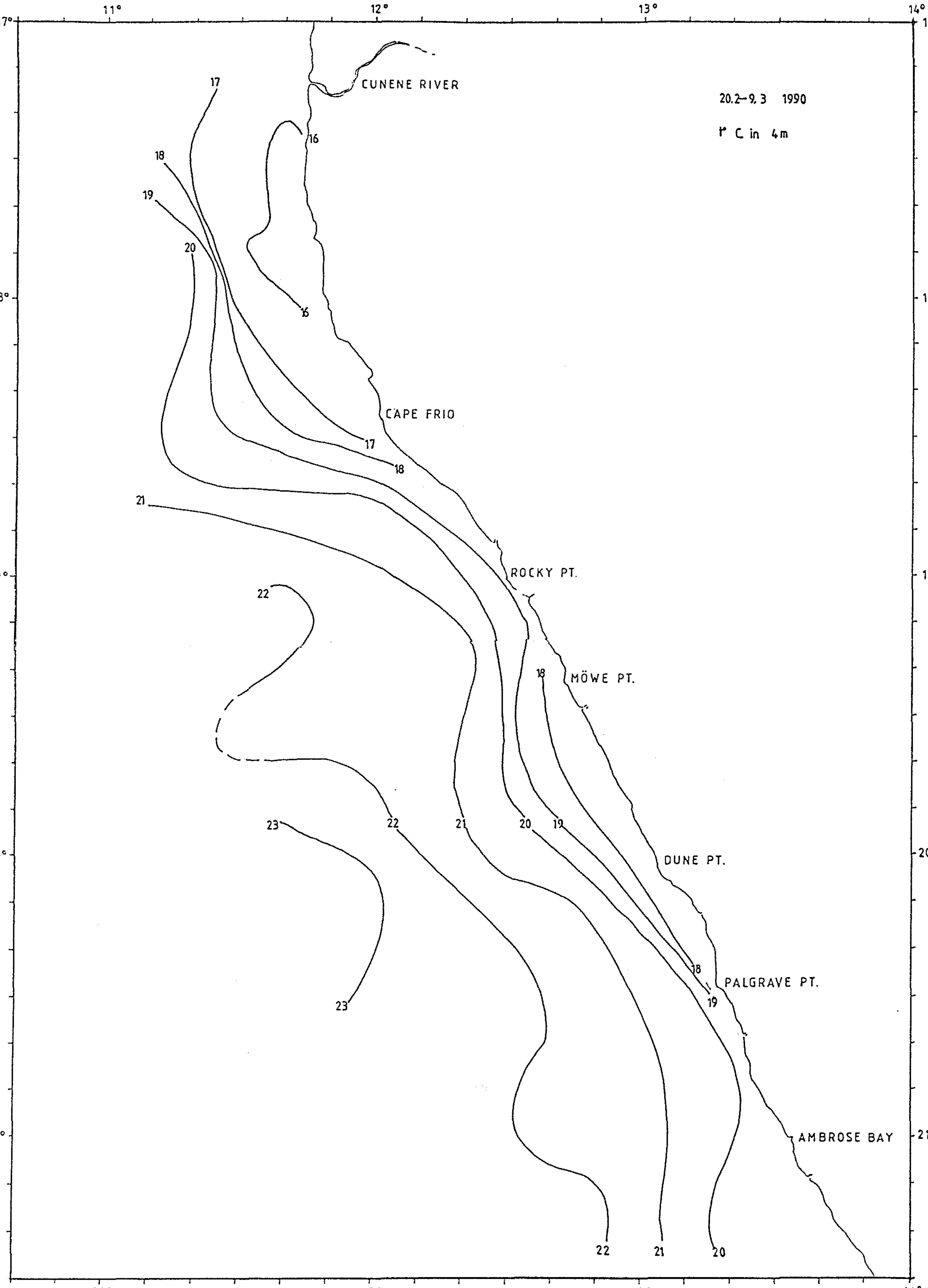
20.2–9.3 1990
°C in 4m
CUNENE RIVER
CAPE FRIO
ROCKY PT.
MÖWE PT.
DUNE PT.
PALGRAVE PT.
AMBROSE BAY
11°
12°
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Figure 2c

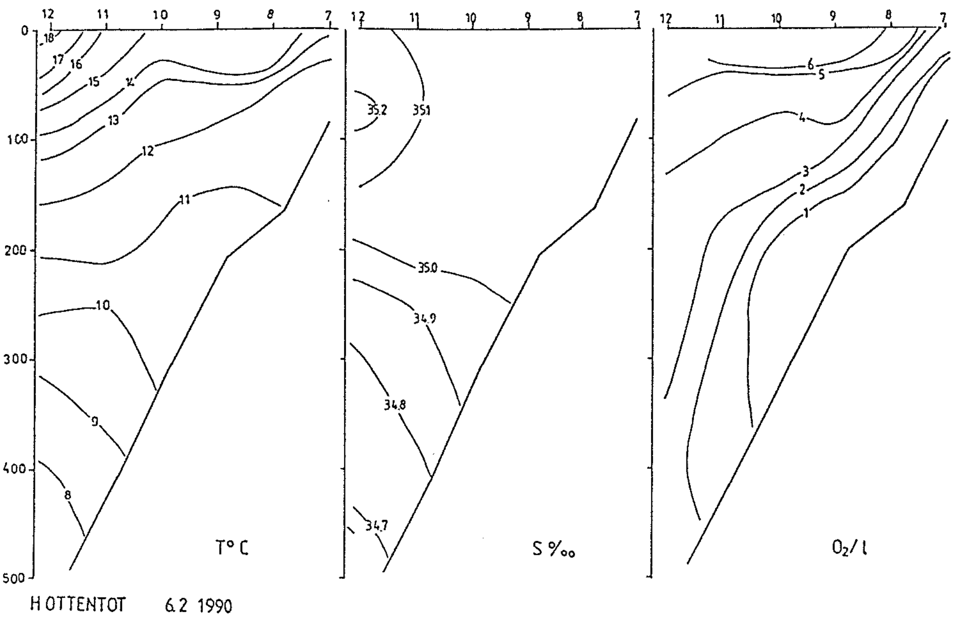


Figure 3. Hydrographic profiles. a:Orange River to St. Francis Bay, b: St. Francis Bay to Ambrose Bay, c: Ambrose Bay to Cunene River.

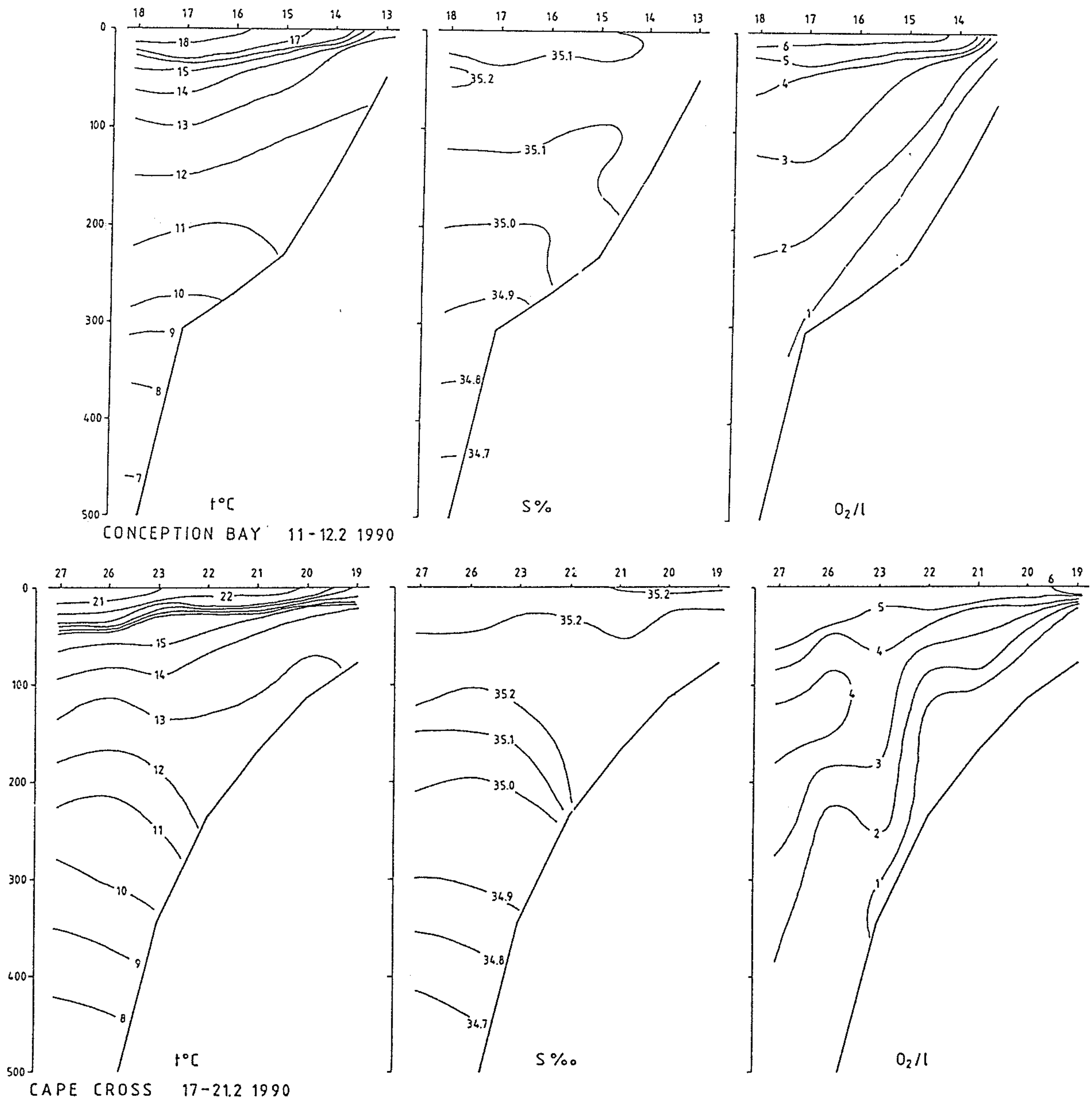


Figure 3b.

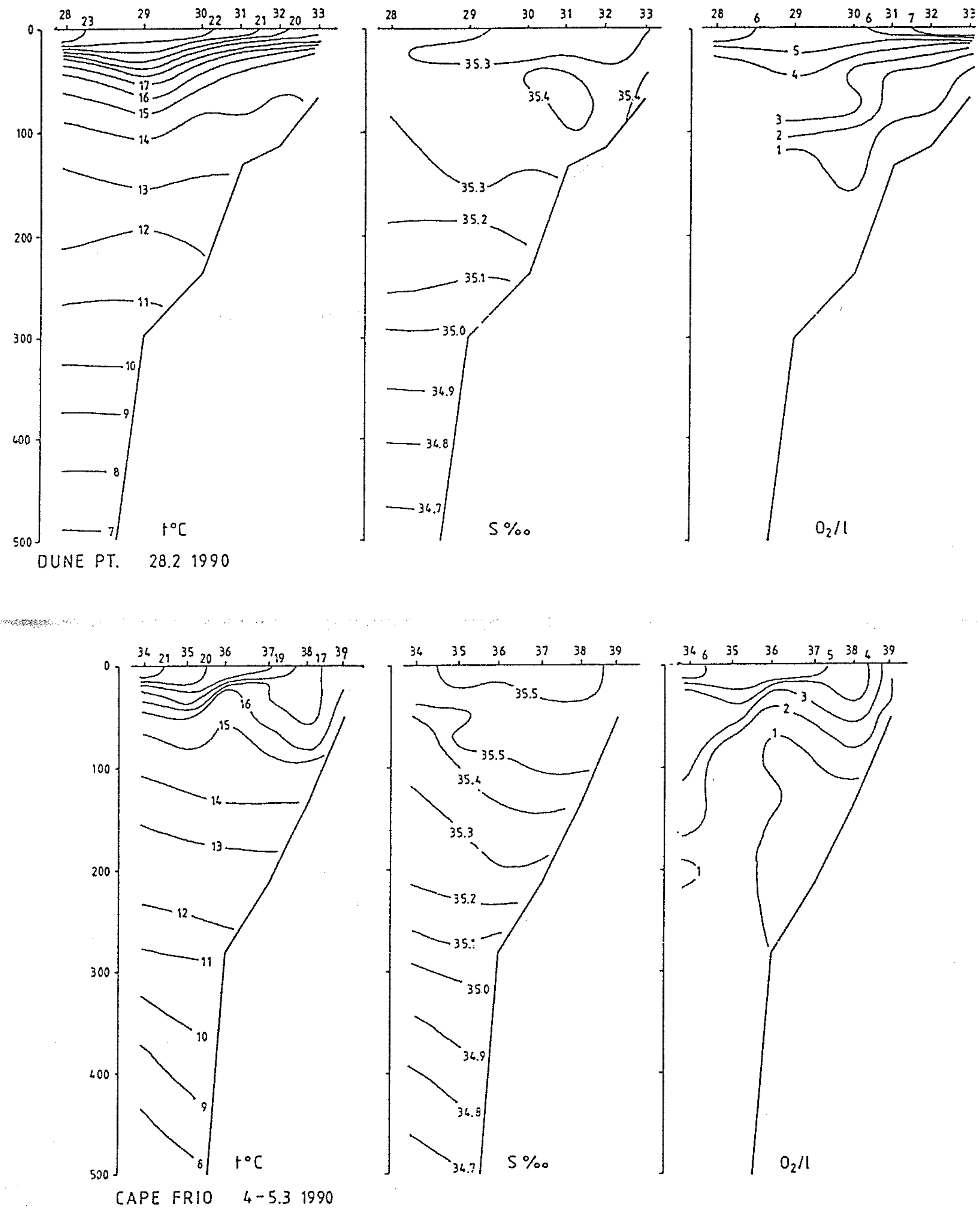


Figure 3c.

water is characterized by salinities of 35.5 $^{o}/oo$ and higher and as we see from the northernmost profiles of this survey, water of this salinity extended southwards towards 19 to 20°S by early March this year. This is similar to the situation in 1985 which was a year of limited intrusion (Boyd et al, 1987). But years of strong intrusion has maximum surface penetration in March-April such as occurred in 1984 with its Benguela type of "El Nino" and partly in 1986. Thus further data are needed to complete the description of the current oceanographical conditions of the Namibian Sea.

3. DISTRIBUTION AND ABUNDANCE OF PELAGIC FISH FROM THE ACOUSTIC OBSERVATION SYSTEM

The acoustic integration system provides observations of fish densities. The units of acoustic reflection used is 0.1 x m2/nm^2 reflecting surface. The integrator values from fish targets are allocated to the following groups on the basis of trawl sampling and characteristic behaviour:

Pelagic fish type 1: clupeids and anchovies

Pelagic fish type 2: carangids, scombrids a.o.

Non-commercial pelagic fish: myctophids, gobies.

An arbitrary scale is used in the distribution charts to illustrate different levels of concentration.

3.1 Orange River to St.Francis Bay

Figure 4a shows the observed distribution of the pelagic fish types 1 and 2 which were only found in a few small areas and in generally low densities. The offshore patch near the southern border was identified as a mixture of southern rover, *Emmelichthys nitidus,* horse mackerel, snoek and chub mackerel. The inshore patch north of Panther Head was mainly round herring, *Etrumeus whiteheadi* with some pilchard and snoek. Identification of the small inshore aggregation off Easter Point was complicated by jellyfish, but the fish were probably pilchard and anchovy.

Various non-commercial pelagic fish were a source of extensive echo recordings over large parts of the shelf. Figure 4b shows the density distribution of such recordings which are believed mostly to refer to myctophids and the pelagic goby *Sufflogobius bibarbatus.* Myctophids were not as in many other areas limited to the outer parts of the shelf, but could some times be caught close inshore. The highest densities are, however, found over the slope and near the shelf edge. In the dense patch off Lüderitz, a 15 minute pelagic haul yielded about ten tons of myctophids. These species no doubt play an important role in the food chain. In addition to euphaucids which were also recorded and caught in quantities they must represent an important food source for the hakes.

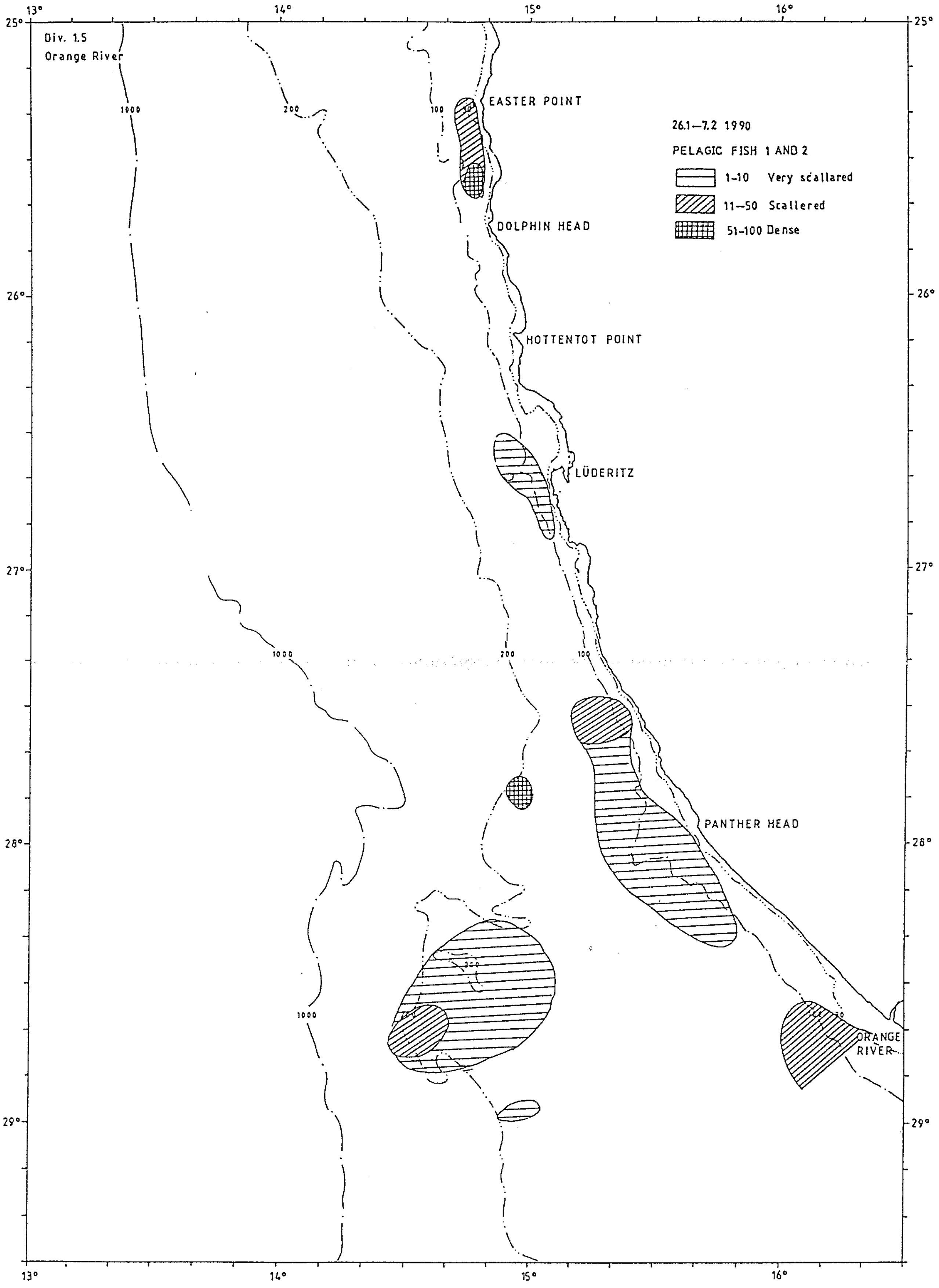


Figure 4. a: Distribution of pelagic fish types 1 and 2 , and b: distribution of non-commercial fish, myctophids and gobids, Orange River to St.Francis Bay.

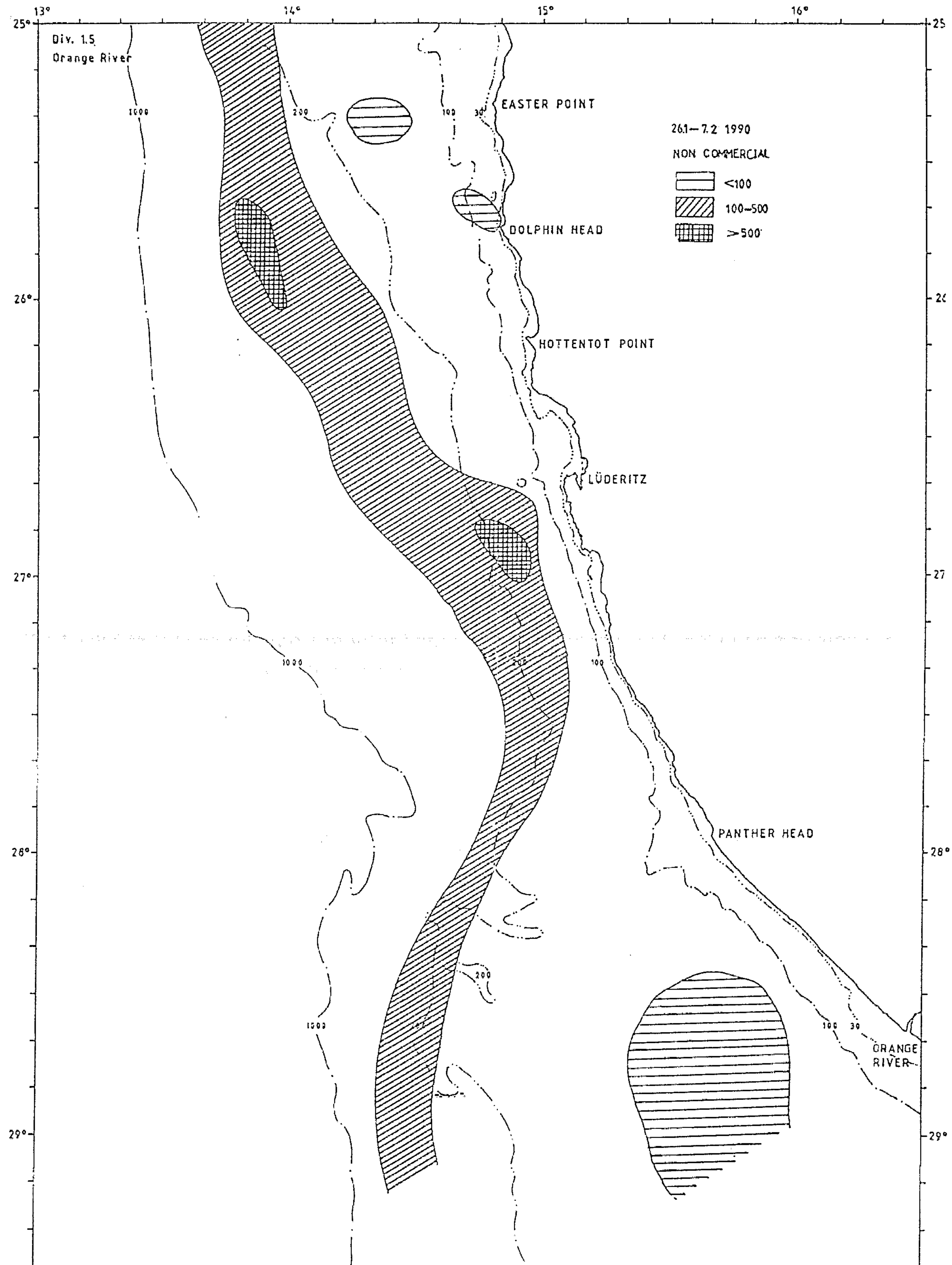

Div. 1.5
Orange River
EASTER POINT
26.1—7.2 1990
NON COMMERCIAL
<100
100–500
>500
DOLPHIN HEAD
HOTTENTOT POINT
LÜDERITZ
PANTHER HEAD
ORANGE RIVER
1000
200
100
30
13°
14°
15°
16°
25°
26°
27°
28°
29°

Figure 4b.

Jellyfish occurred in inshore waters in high densities especially from south of Lüderitz northwards. Densities seemed to increase shorewards as indicated by visual observations in the surface and by catches in the trawls. Catching of pelagic fish for identification and sampling in these areas was complicated since trawl hauls had to be limited to a few minutes towing time in order to avoid gear damage by the jellyfish.

3.2 St.Francis Bay to Ambrose Bay

High densities of jellyfish were encountered also in this area, creating problems for the sampling of pelagic fish with mid water trawl. The special mid water trawl was damaged by jellyfish catch and sampling was under such conditions attempted by 5-10 minute hauls with the bottom trawl equipped with floats. The high densities of jellyfish persisted up to about Cape Cross.

An inshore distribution consisting of schools and layers of anchovy, round herring and pilchard was located from Conception Bay northwards past Cape Cross, see figure 5a. These species were, however, not found in aggregations of high density in this area. Pilchards were identified in schools off Henty's Bay and Cape Cross, but appeared in small numbers in the catches in several locations. The size composition of the pilchard has a single mode around 20 cm and that of the anchovy a mode around 13 cm, see Annex I. Juveniles of these species were not found.

Schools of small Cape horse mackerel were found inshore from Hollands Bird Island northwards, see distribution map figure 5b. From about Walvis Bay on the Cape horse mackerel was also found over the middle and outer parts of the shelf. The size of the horse mackerel over this part of the shelf was closely related to the distance from shore, with only one modal size of abt 14 cm found out to a bottom depth of 100 m, two modal sizes of about 16 cm and 25 cm between 100 and 200 m depth and two groups of 26 cm and 38 cm over the outer shelf, see size compositions Annex I.

Small aggregations sometimes in the form of shools of snoek was commonly found in the area.

3.3 Ambrose Bay to Cunene River

Figure 6a shows the distribution of anchovy and pilchard in this area. No heavy aggregations of either of these species were located. Small school areas of pilchard were found between Ambrose Bay and Dune Point with a few small patches up towards Cape Frio. The pilchards were typically found in single large schools between 30 m and 90 m bottom depth, and usually only one or two schools contributed to a 5 nm reading, often with several zero readings before and after. It is clear that this very discrete distribution pattern complicates an assessment with the acoustic method, especially when the abundance is low. Precision of the estimate will suffer from such a school pattern, and have to be compensated with much higher sampling intensity. Periods when the pilchard form smaller schools or more scattered distributions will give more precise estimates.

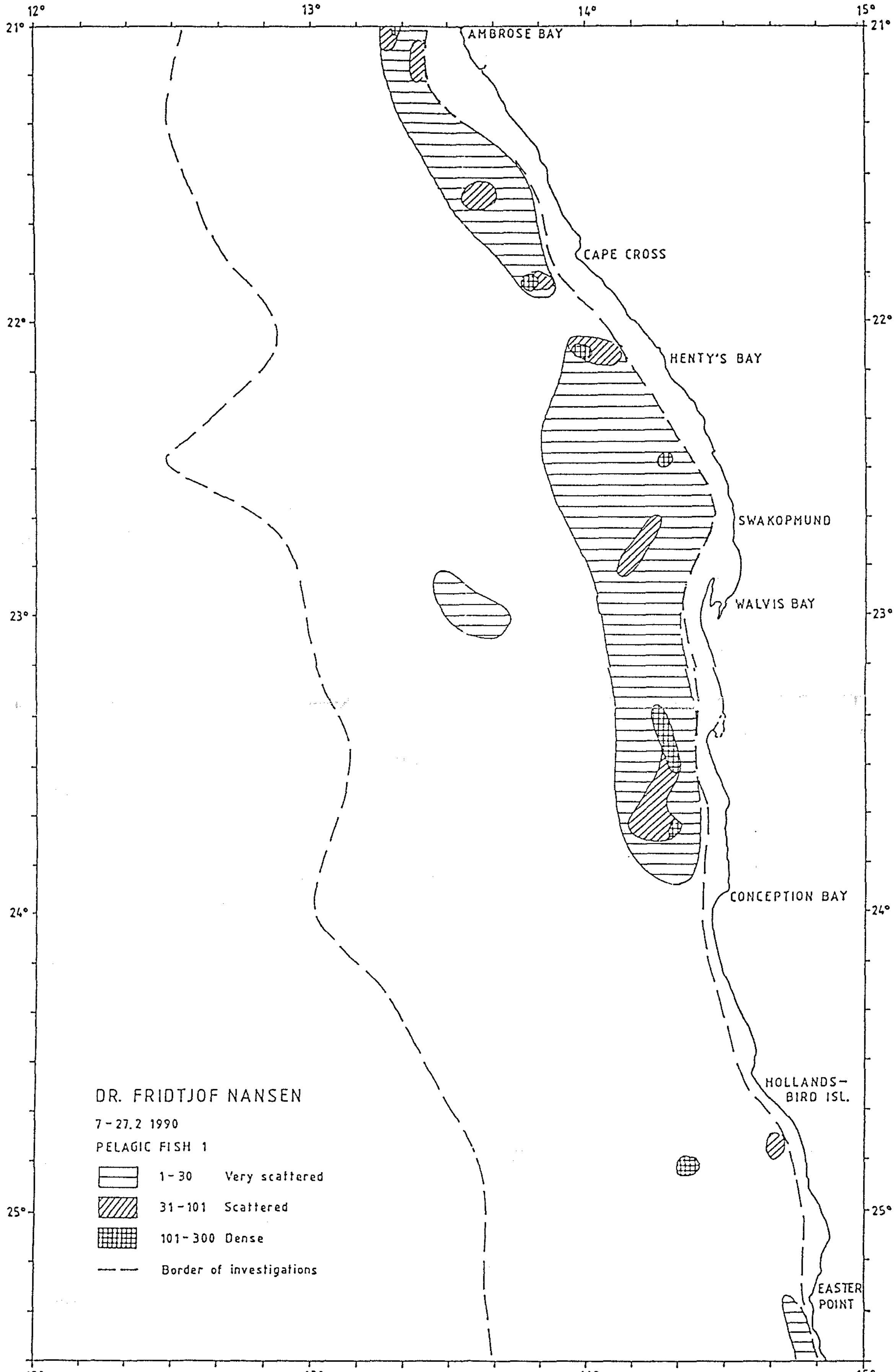
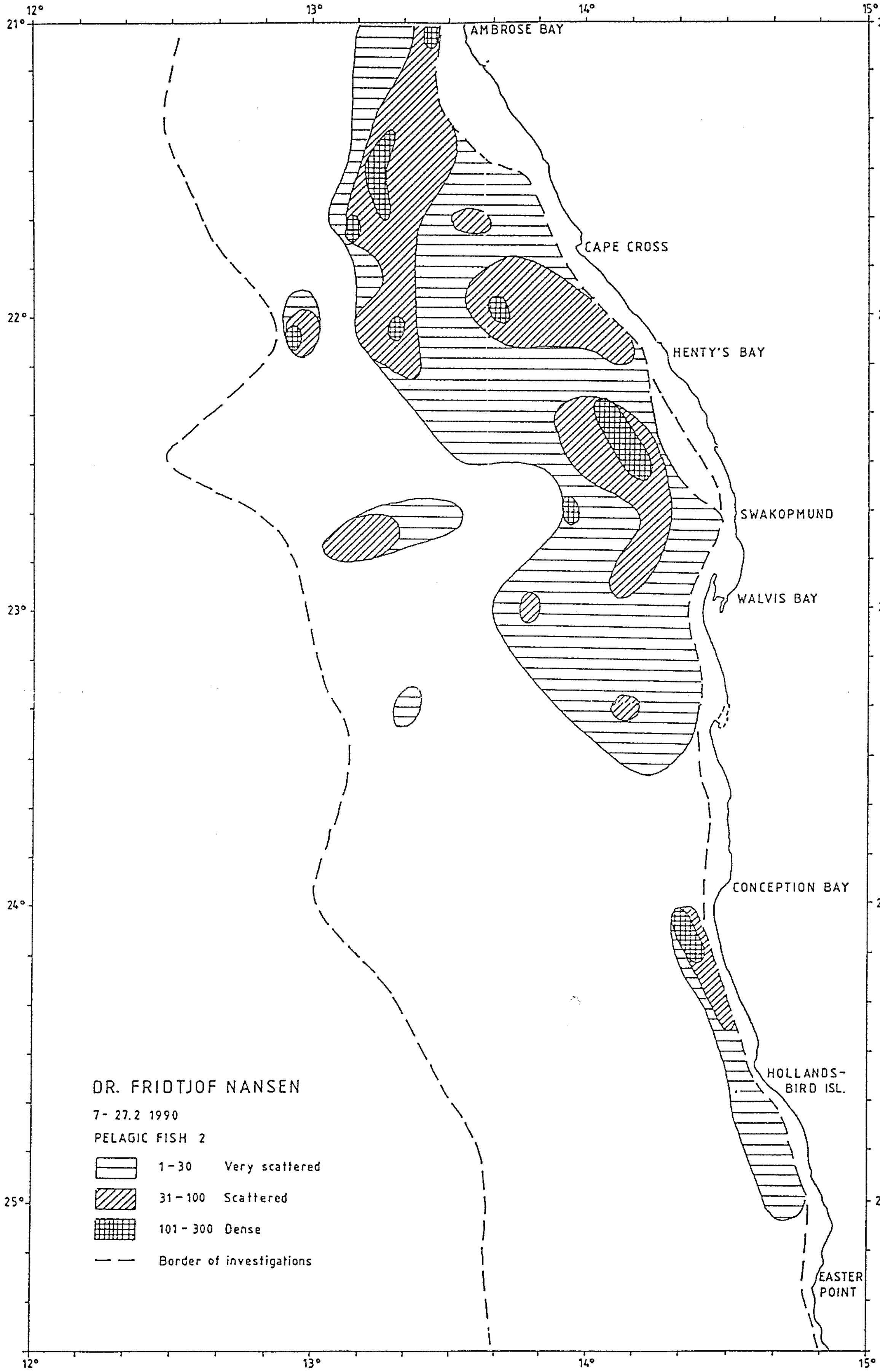


Figure 5. a: Distribution of pelagic fish type 1 and b: distribution of pelagic fish type 2, St. Francis Bay to Ambrose Bay.


12°
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25°
AMBROSE BAY
CAPE CROSS
HENTY'S BAY
SWAKOPMUND
WALVIS BAY
CONCEPTION BAY
HOLLANDS-BIRD ISL.
EASTER POINT
DR. FRIDTJOF NANSEN
7- 27.2 1990
PELAGIC FISH 2
1-30 Very scattered
31-100 Scattered
101-300 Dense
Border of investigations

Figure 5b.

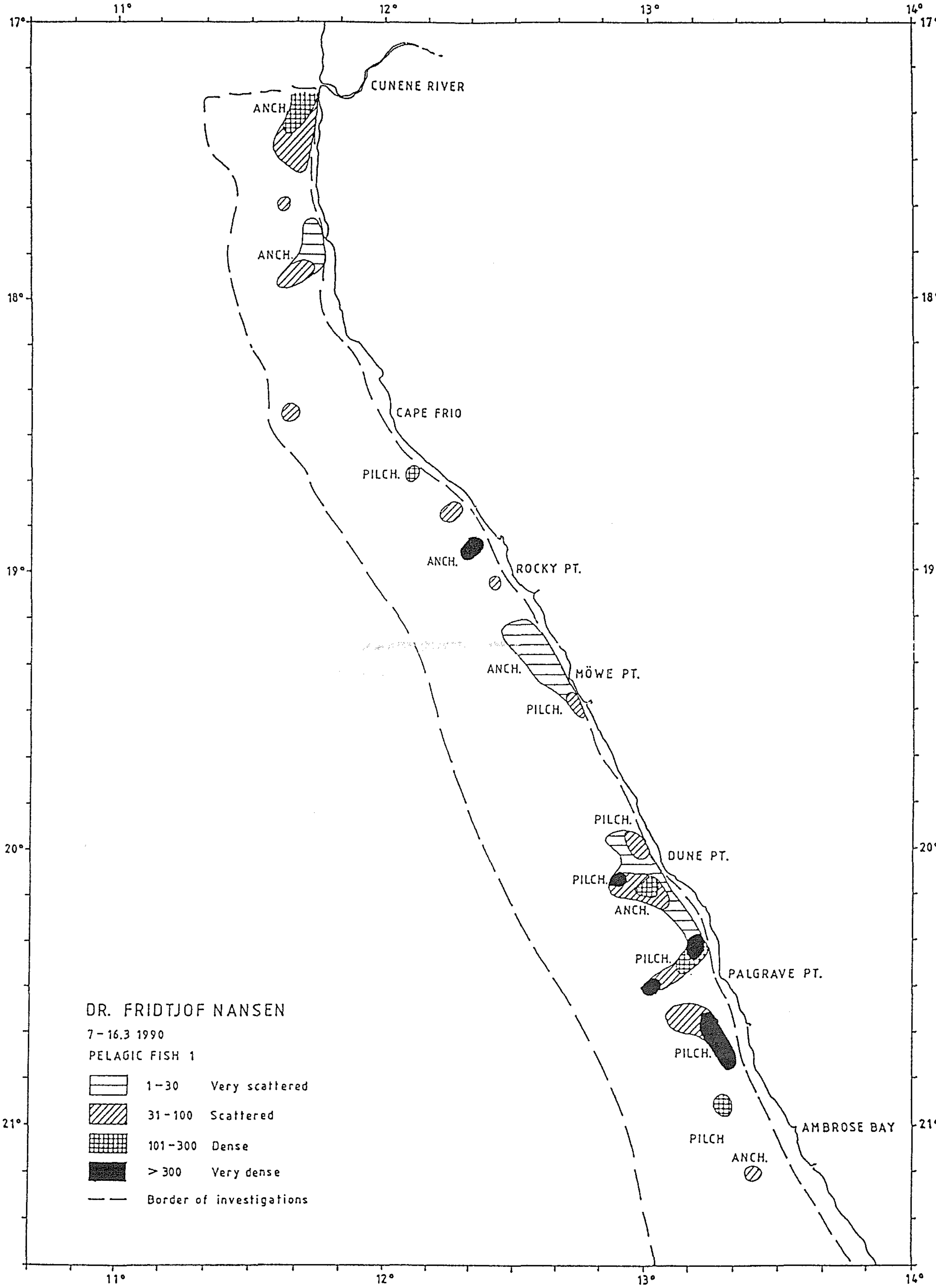
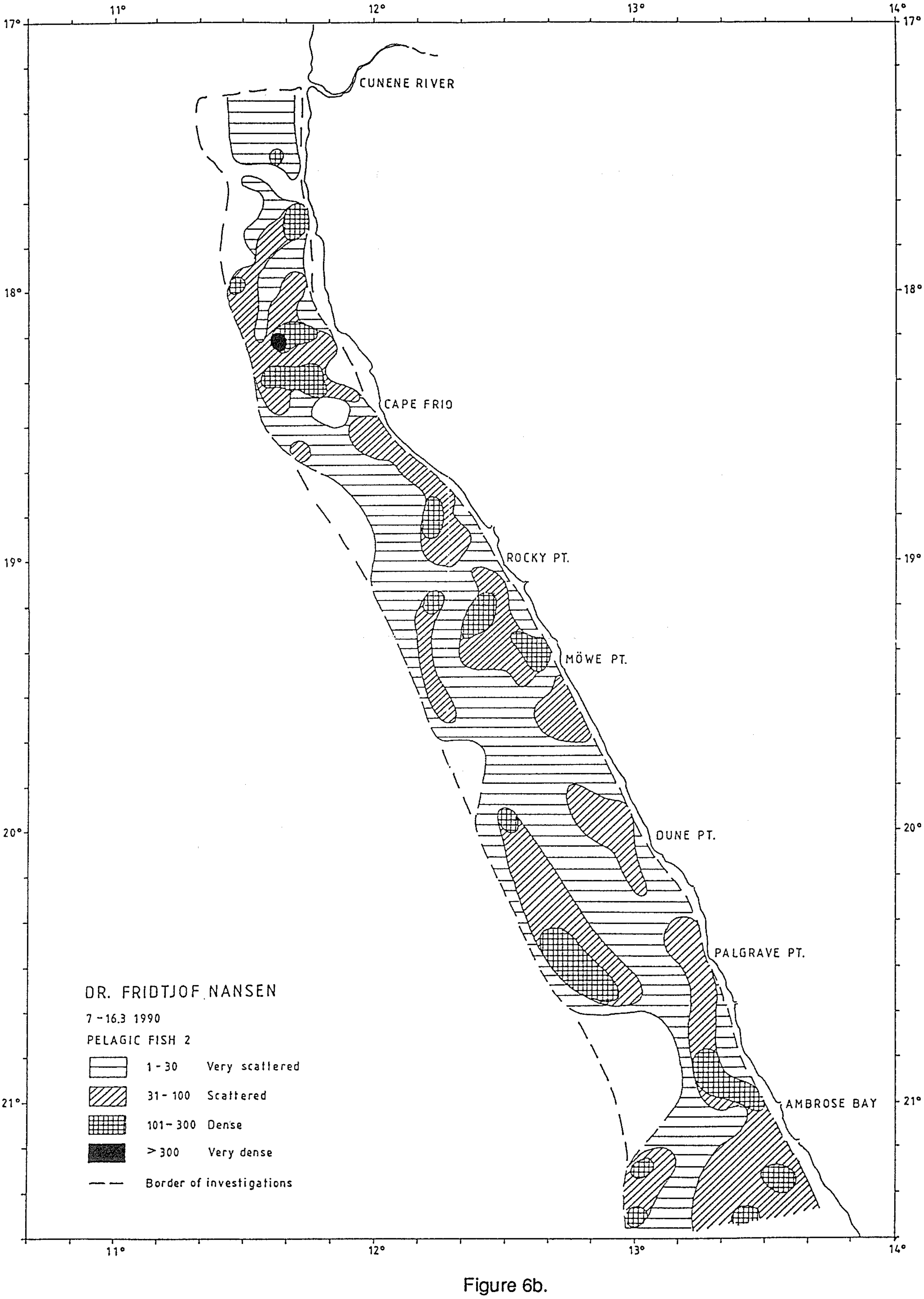


Figure 6. a: Distribution of pelagic fish type 1 and b: distribution of pelagic fish type 2, Ambrose Bay to Cunene River.


11°
12°
13°
14°
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19°
20°
21°
CUNENE RIVER
CAPE FRIO
ROCKY PT.
MÖWE PT.
DUNE PT.
PALGRAVE PT.
AMBROSE BAY
DR. FRIDTJOF NANSEN
7 - 16.3 1990
PELAGIC FISH 2
1 - 30 Very scattered
31 - 100 Scattered
101 - 300 Dense
> 300 Very dense
Border of investigations

Figure 6b.

The anchovy appeared in very limited separate areas up to the Cunene River.

Also in this area the pilchard was represented by only one modal group, but with the slightly lower modal size than further south, see Annex I. The size of the anchovy was similar to that of the southern area.

The area was clearly dominated by the Cape horse mackerel, the main species from about 200 m shelf depth to about 50 m, sometimes as shallow as 20 m, see distribution chart figure 6b. There was a greater domination in this area of the small sized horse mackerel with a mode of about 15 cm, but some increase of size with bottom depth was evident also here, see size distributions, Annex I.

3.4 Biomass estimates of small pelagic fish

The estimates are based on the acoustic integration technique which has also been used in similar previous assessments of the same stocks. The survey coverage was assessed as being ample with several coverages of main areas, an important measure in view of the behaviour of the pilchard in appearing in large and dispersed schools. The North Sea herring target strength relations (TS=20 log l - 71.2) was used for pilchard and anchovy. The target strength used in the horse mackerel estimate is discussed below.

Pilchard and anchovy

The biomass estimates for these two stocks are shown in Table 2.

Recent estimates of the pilchard stock reported by the Sea Fisheries Researsch Institute of South Africa were 60 000 t in July 1989 and 120 000 t in 1988. The present findings of 235 000 t is thought to lie within the limits of variance of estimates of stock size at this low level of abundance and does not represent evidence of a recovery of the stock.

The anchovy stock was estimated at 175 000 t in July 1989 and no significant increase of the stock can thus be reported with our estimate of 215 000 t, as this also includes some round herring.

Table 2. Biomass of inshore stocks by areas. Tons.

	St.Francis Bay-Ambrose Bay	Ambrose Bay-Cunene River	Total
Anchovy	125 000	90 000	215 000
Pilchard	75 000	160 000	235 000

Horse mackerel

For converting the acoustic observations of fish echoes into biomass information on the acoustic properties of the species in question is required. As mentioned above it is assumed that for pilchard and anchovy these properties are similar to those of the better studied herring. Studies of the shape and size of the swim bladder (the source of about 95% of the reflection) of these species seems to corroborate this assumption. The relative size of the swim bladder of the horse mackerel is, however, significantly smaller than that of the clupeoids. A study of this subject (Svellingen, 1989, in manuscript) indicate that the resulting effect would be a nominal target strength nearly 3 dB lower than that used for the North Sea herring. Further investigations of this subject will be given priority, but in the meantime we feel that the uncertainty should be indicated by presentation of the range of biomass corresponding to the two values of target strength. Table 3 shows the estimates by areas.

Table 3. Biomass estimates of Cape horse mackerel by areas. Range corresponds to different assumptions regarding target strength. (1 000 tons).

St.Francis Bay - Ambrose Bay	Ambrose Bay - Cunene River	Total area
660 - 1 200	780 - 1 500	1 400 - 2 700

The size compositions showed a difference between the areas with a higher representation of the older age groups in the southern area. A size composition for the total stock has been estimated, see Annex I. Based on this composition one may conclude that the juvenile fish of size below 19 cm (the 1+ group) represent about 65% of the stock by numbers. After conversion to weight one finds, however, that fish larger than 18 cm represent about 80% of the total biomass.

4. RESULTS OF THE FISHING EXPERIMENTS, CATCH COMPOSITIONS AND SWEPT AREA BIOMASS ESTIMATES OF DEMERSAL FISH

Some of the results of the fishing experiments are commented on below. One should note, however, that most of the fishing forms part of a programme for "swept area" biomass estimation, and for this purpose the trawl stations are positioned in advance more or less randomly and with no intention of obtaining high catch rates. The catch rates thus do not simulate those of a commercial fishery.

All catches were sampled for composition in weight and numbers by species, and size sampling was made of important species using total length. The complete records of fishing stations are shown in Annex II.