# PART II

# SURVEY OF THE PELAGIC STOCKS
## 1 June - 23 June 1994

# TABLE OF CONTENTS

ANNEXES

# CHAPTER 1 INTRODUCTION

## 1.1 OBJECTIVES

- To estimate the biomass of four of the commercially important pelagic and mesopelagic fish species in the northern Benguela system; pilchard *Sardinops ocellatus*, anchovy *Engraulis capensis*, round herring *Etrumeus whiteheadi*, juvenile (inshore) and adult (mid-water) Cape horse mackerel *Trachurus capensis*.

- To estimate the biological condition of pilchard, anchovy, round herring and horse mackerel, length, weight, reproductive stage and age.

- To conduct an intercalibration of the scientific acoustical systems of the RV 'Dr. Fridtjof Nansen' and RV 'Welwitschia'.

- To conduct *in situ* target strength measurements on the surveyed fish, using a new split beam sonde, and to perform measurements of schools using the scientific SA950 sonar, dependent on time available, weather conditions and fish distribution.

- To collect data on basic oceanographic parameters, namely dissolved oxygen, temperature and salinity, for correlation with pelagic fish distribution and densities.

- To obtain data on vertical distribution of phytoplankton and sea surface chlorophyll in order to assess the applicability of the satellite biomass estimation programme (SEAWIFS).

- To obtain data on the distribution of planktonic food in relation to hydrography and planktivorous fish.

- To perform smaller experiments as opportunities arise (e.g. if the vessel remains semistationary in an area for hours, short-term fluctuations in phytoplankton biomass would be monitored). If time allows, alternative pathways in chlorophyll extraction would be tested.

- To determine densities of zooplankton for preliminary estimates of zooplankton biomass and to identify the most dominant zooplankton organisms and their relative distributions. This programme is to be regarded as a trial.

## 1.2 PARTICIPATION

The scientific staff from Namibia on the RV 'Dr. Fridtjof Nansen' were:

from 1/6/94 to 23/6/94: David Boyer, Heidrun Plarre, Mari du Plooy, Deon Louw and James Cole (Warwick University, U.K.),
from 1/6/94 to 10/6/94: Graca D Almeida and Sielfried Gowaseb,
from 10/6/94 to 24/6/94: Ann-Lisbeth Agnalt, Michael Evenson and Victor Hashoonga
from 17/6/94 to 23/6/94: Janet Botha

From Angola:
N'Kossi Luyeye and Alphonso Pedro Kingombo joined the cruise until 10/6/94.

The scientific staff from the Institute of Marine Research were:
Egil Ona, Ingvald Svellingen, Valantine Anthonypillai and Erling Molvær.

## 1.3 SCHEDULE

The RV 'Dr. Fridtjof Nansen' left Walvis Bay at 18h00 on 1st June and conducted a preliminary survey from Walvis Bay northward to Angola. The 18, 38 and 120 kHz echo-sounders and the split-beam sonde were calibrated using standard targets in Baía dos Tigres on 5th and 6th June. Trials of calibrating the SA950 sonar were also performed in Baia dos Tigres. The entire area southwards to 26°S was surveyed between 6th June and 19th June. An intercalibration exercise was conducted with the RV 'Welwitschia' on 8th June (Annex X). The RV 'Dr. Fridtjof Nansen' met with the RV 'Welwitschia' on 10th June and exchanged Namibian staff. The two vessels met a second time on 19th June to transship another Namibian scientist. The RV 'Dr. Fridtjof Nansen' arrived in Walvis Bay on 23rd June at 08h00. A total of 3 900 nautical miles were steamed and 83 trawl stations worked.

The RV 'Dr. Fridtjof Nansen' was assisted between 17th and 20th June by the Namibian purse seiner 'Fiskeskjer', which served as a scouting vessel using a medium range 50 kHz Furuno multi-beam sonar and fish-finding echo-sounder.

Since the present project began in 1990, this survey was the first pelagic survey to start in the north and work southwards. This was in order to accommodate the participants from Angola during the Angolan section of the survey as they were unable to participate later in the survey period.

# CHAPTER 2 METHODS

## 2.1 HYRDOGRAPHIC AND PLANKTON SAMPLING

### 2.1.1 Hydrographic sampling methods

A total of 58 hydrographic profiles were worked along 10 hydrographic sections (Annex II) using a Seabird 911+ CTD probe, also carrying a sensor for dissolved oxygen. At each station, water samples were taken at 5 m and at the bottom. These were analyzed for dissolved oxygen using the Winkler method for a check on the measurements made with the sensor. Earlier calibration factors between sensor and Winkler seemed to fit well with the measurements made. Some of the Winkler analysies were, however, regarded as inaccurate, as analysed by untrained personnel.

### 2.1.2 Plankton sampling methods

At each environmental station, namely at 20m depth, 2, 5, 10, 15 and 25 nautical miles from the coast along each latitudinal degree line, the CTD rosette was used to obtain water samples for chlorophyll analysis. Biomass will be estimated for the following depths: 0m (sampled with a bucket), 5m, 10m, 25m, 50m, 75, bottom of water column.

Chlorophyll was estimated fluorometrically, based on the applied recommendations of the SCOR - UNESCO Working Group as reported in "Recommended Procedures for Measuring the Productivity of Plankton Standing Stock and Related Properties" by the U.S.A. National Academy of Sciences (1969). In short, the analysis entailed:

a. Removal of the algae from the sample by filtration through a 45 micrometer membrane filter.

b. Extraction of the pigment with acetone.

c. Measuring the chlorophyll level against a chlorophyll standard of known concentration, using a Turner 10-AU Fluorometer.

The zooplankton sampling methods were based on those used by Sea Fisheries Research Institute in Cape Town. A vertical Calvet haul was taken at every CTD station on the 10 hydrographic lines. The net was attached to the CTD cable just above the CTD frame and was lowered with the CTD to the bottom. The Calvet and the CTD were retrieved at 1.0 m/s. Before and after each haul, the reading of the flowmeter was recorded. After each haul, the net was thoroughly washed down with a strong jet of seawater. The contents of the cod-end bucket were then transferred to a labelled jar and preserved with 5% formalin.

The samples were taken to Swakopmund for sorting and identification of the most dominant zooplankton groups.

The flowmeter was calibrated at the beginning of the cruise by lowering the net (without buckets at the cod-ends) several times to 70m in order to obtain an average recording the flowmeter reading each time.

A separate report on the plankton results will be presented later.

## 2.2 DISTRIBUTION AND ABUNDANCE ESTIMATION

### 2.2.1 Survey area

The limits of the survey area were determined from the previous data of pelagic fish distribution and from reports of commercial fishing vessels prior to, and during, the survey. Previous surveys have extended in the south either from the boundary of the northern and southern Benguela systems, the Lüderitz upwelling cell, or from the border between South Africa and Namibia. Immediately prior to the present survey the South African RV 'Africana' surveyed the Namibian region south of the Lüderitz upwelling cell, and it was therefore regarded as unnecessary for the

RV 'Dr. Fridtjof Nansen' to survey this far south. The southern extent of the survey was therefore taken as the Lüderitz upwelling cell, 26° S. Since the pelagic fish distribution also extends into Angolan waters, permission was obtained from the Angolan authorities to survey northward to the area west of Tombua (16° S).

The inshore limit of the survey was determined by the vessel draught and was normally about 15 m sea depth, or 10 m below the transducer. The offshore limit was determined from a preliminary investigation survey which covered the area to the 150 m isobath. As the schooling species pilchard, anchovy and round herring were found within the 100 m isobath, a larger part of the effort was allocated to this zone. Less frequent transects extended offshore to a depth of about 350 m to cover the more dispersed concentrations of horse mackerel.

To allow comparison with previous pelagic fish surveys, the region was divided into three areas:

| | |
|---|---|
| 26 00' to 21 00'S | Dolphin Head to Ambrose Bay |
| 21 00' to 17 15'S | Ambrose Bay to Cunene River |
| 17 15' to 16 00'S | Cunene River to Tombua |

The course tracks with the fishing stations for the three areas are shown in Figures 1a-c respectively.

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

### 2.2.2 Sampling methods

The acoustic echo-integration system provided measurements of fish area densities, usually averaged over 5 nm distances. However, in areas of high fish concentrations and large along-track variability, an output resolution of 1 nm was used. The acoustic unit measured by a calibrated echo-integrator system is the area back-scattering coefficient, $s_A$, defined as the integral of the volume back-scattering coefficient between the depth limits $Z_1$ and $Z_2$, normalized to $[m^2/nm^2]$:

$$s_A = 4\pi(1852)^2 \int_{z_1}^{z_2} s_v \, dz$$

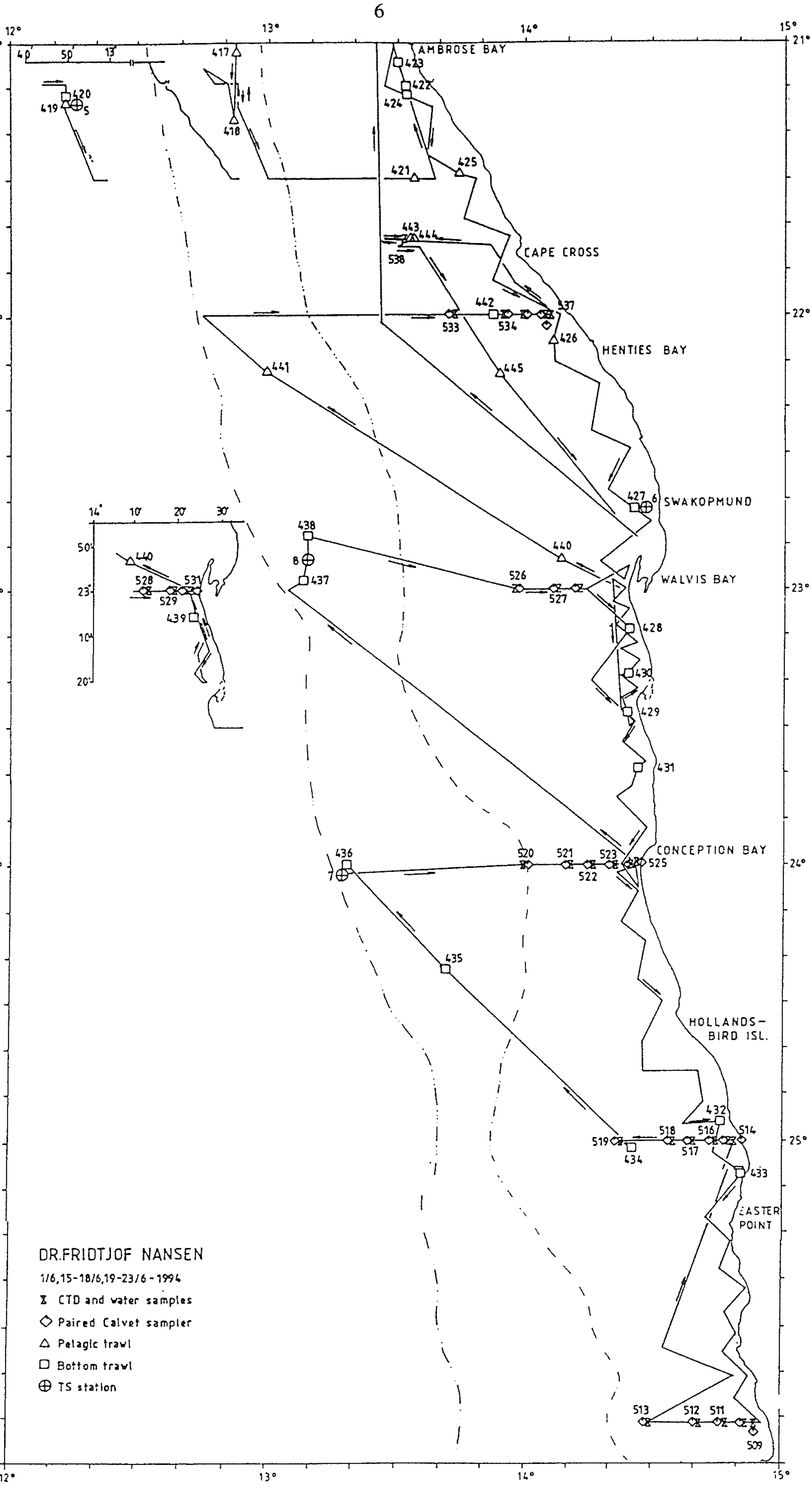


Figure 1a Course track and fishing stations, Easter Point to Ambrose Bay.

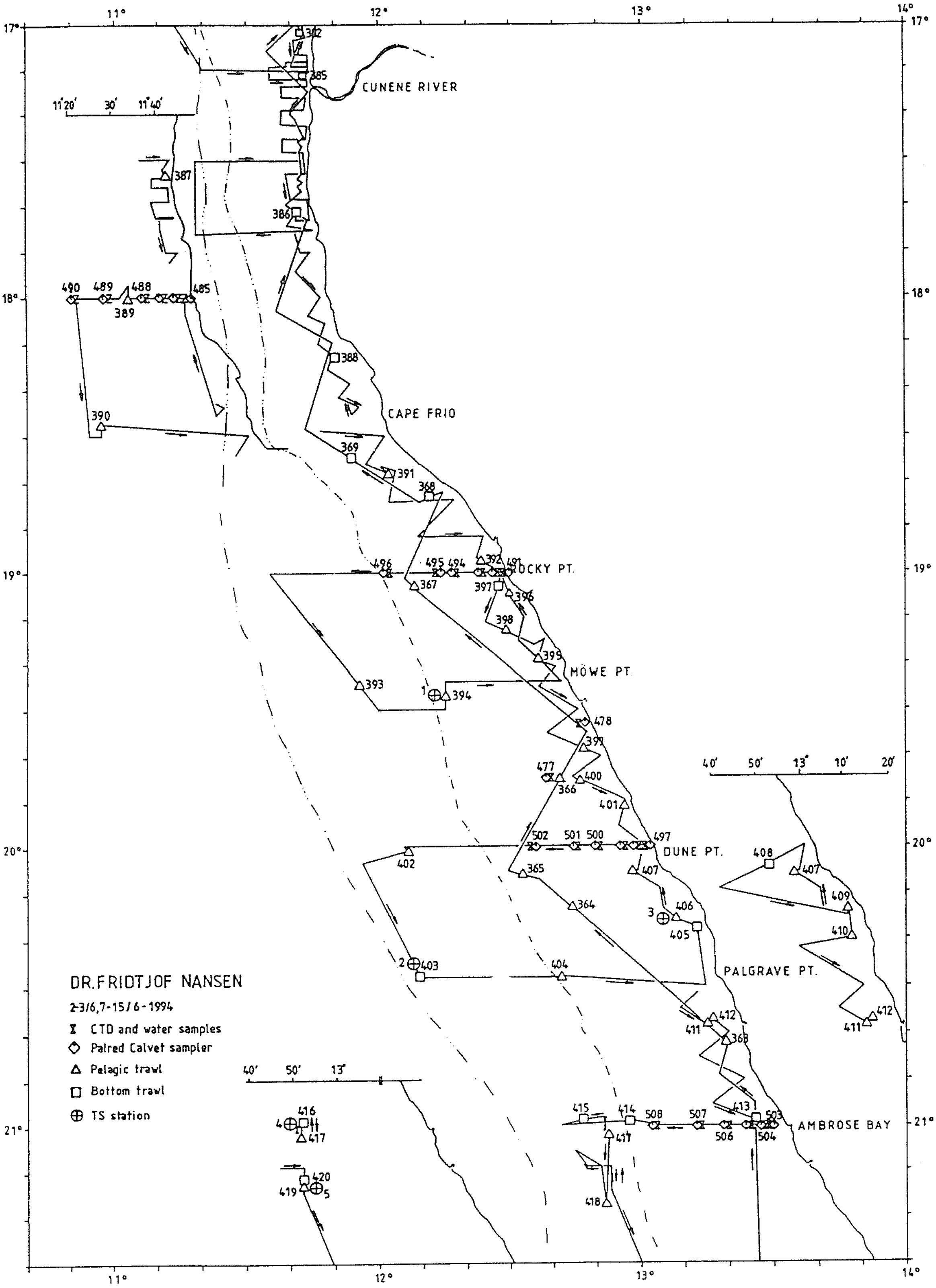


Figure 1b Course track and fishing stations, Ambrose Bay to Cunene River.

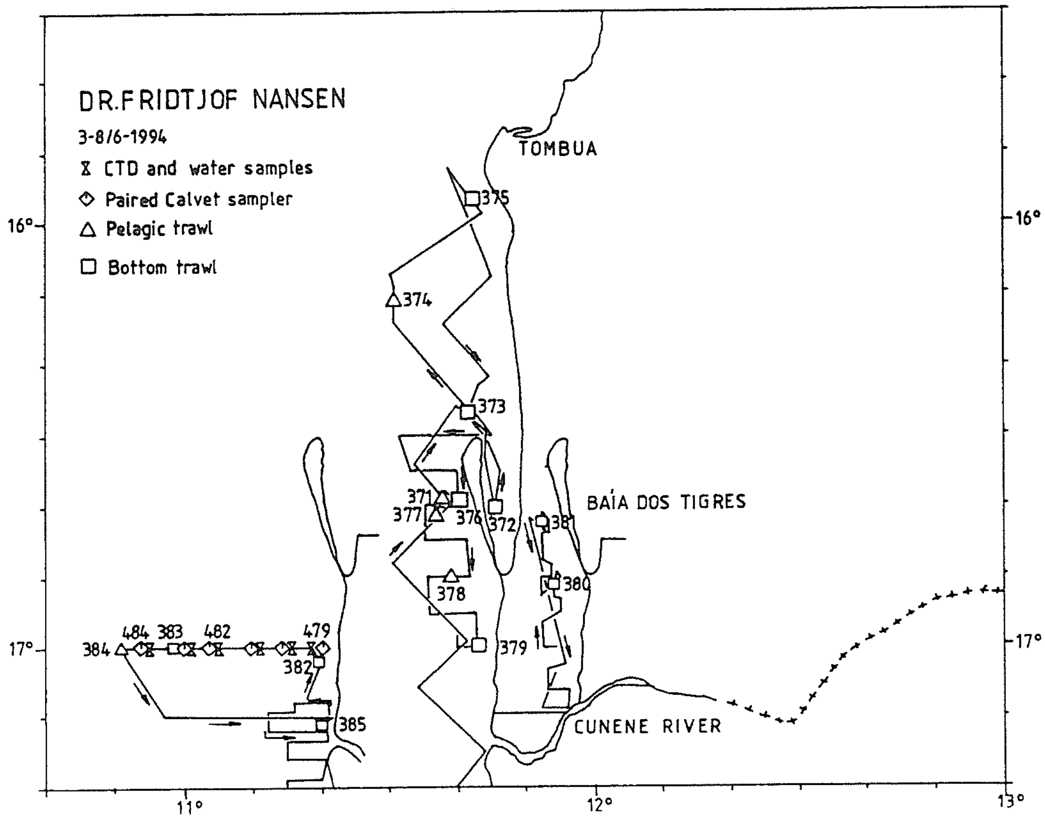


Figure 1c Course track and fishing stations, Cunene River to Tombua.

The integrator data from fish targets were allocated to the following groups on the basis of trawl sampling and acoustic character, as recognised from the echo recordings:

Pilchard
Anchovy
Horse mackerel
Non-commercial pelagic fish, mainly myctophids and gobies
Plankton, including jellyfish
Other demersal species, e.g. hake, sharks, etc.

In general, the integrator data was partitioned to species or species groups by separating the echo recordings horizontally or vertically in the scrutinizing process on the Bergen Echo Integrator, BEI, (Knudsen, 1990). However, where several species or groups of species occur as mixed recordings, their relative contribution to the total integrator reading were computed from the trawl data, assuming a catch efficiency equal for all species and length groups. The correct way to partition the integrator reading when assuming similar target strength-to-length relations for the different species may then be determined from:

$$k_j = s_{A_T} \frac{\sum_{i=1}^{n} n_{ij} L_i^2}{\sum_{j=1}^{m} \sum_{i=1}^{n} n_{ij} L_i^2}$$

where $k_j$ is the relative contribution to the total area backscattering coefficient, $s_{A_T}$ from species $_{ij}$. If the length differences between the different groups are small, the relative contribution may with care be simplified by determining the factor directly from its relative contribution to the total weight of the catch. During this survey, the latter simplification has been used in the partitioning of the integrator data on mixed recordings.

The sampling intensity, or degree of coverage, was determined from the approximate density distribution of fish determined during the course northward, reports from the fishing fleet and the accompanying fishing vessel.

The survey strategy used was essential similar to the one used in previous surveys:

1 All available prior information on fish density and distribution was assessed and used to estimate the probable distribution and density of each region surveyed.

2 The effort was increased in areas with high fish densities.

3 When possible, the most important areas were covered both during day and night.

4 In regions of expected low densities zig-zag transects were surveyed from inshore of the distribution, where possible, to the offshore edge of the distribution. In areas of high expected densities parallel transects were surveyed, also from the inshore to offshore limits of the distribution, perpendicular to the fish density gradient.

5 The widely dispersed mid-water horse mackerel were mainly surveyed using parallel transects.

Information from the fishing fleet and from the preliminary coverage of the area by the RV 'Dr. Fridtjof Nansen' and 'Fiskesjer' indicated that the current fish densities were low in most regions and that a zig-zag type of survey pattern would give an appropriate degree of coverage.

In one area, however, in southern Angola, an increased frequency of recorded schools on the northward track indicated that parallel transects would provide the most appropriate coverage of this area.

The weather was favorable for an acoustic survey during most of the cruise, although some echoes were lost during rough weather on 8th and 9th June off Cape Frio. The fish densities in this area were low and air bubble attenuation has not unduly affected the survey results.

Trawl sampling of fish was generally successful, although some hauls were disrupted by high concentrations of jellyfish, as experienced in some previous surveys. This was particularly serious in the mid-water horse mackerel targeted trawls. It was not established whether the jellyfish concentrations were close to the surface and caught during setting or hauling the net, or at the same depth as the horse mackerel. Dense layers of jellyfish also occurred south of Walvis Bay and disrupted trawling in that region.

Mixed species tended to occur in fairly open, low density, shoals and the allocation of species proportions was based solely on the results of trawls in adjacent areas. Some pilchard occurred in these mixed shoals, but in general most of the pilchard stock occurred in small, dense monospecific schools which were easy to identify from the echo recordings. The identification of these schools was confirmed by a number of trawls.

All catches were sampled for composition by weight and numbers of each species and the size distribution of commercially important species, using total length, was determined. The length frequencies of these species are given in Annex V. The complete records of fishing stations are shown in Annex IV.

The distributions of the target species are shown in Figures 2a-c, 3a-c, 4a-c and 5a-c. The scale used in the distribution charts to illustrate different levels of density is in absolute acoustic units, the area back-scattering coefficient, $s_A$ [$m^2$/ $nm^2$]. This ensures the maps to be comparable from survey to survey. Note that in earlier surveys, the scale used was 0.1x $s_A$ . The conversion of the area back-scattering coefficient to biomass, i.e to [tons/$nm^2$], is dependent of the average size of

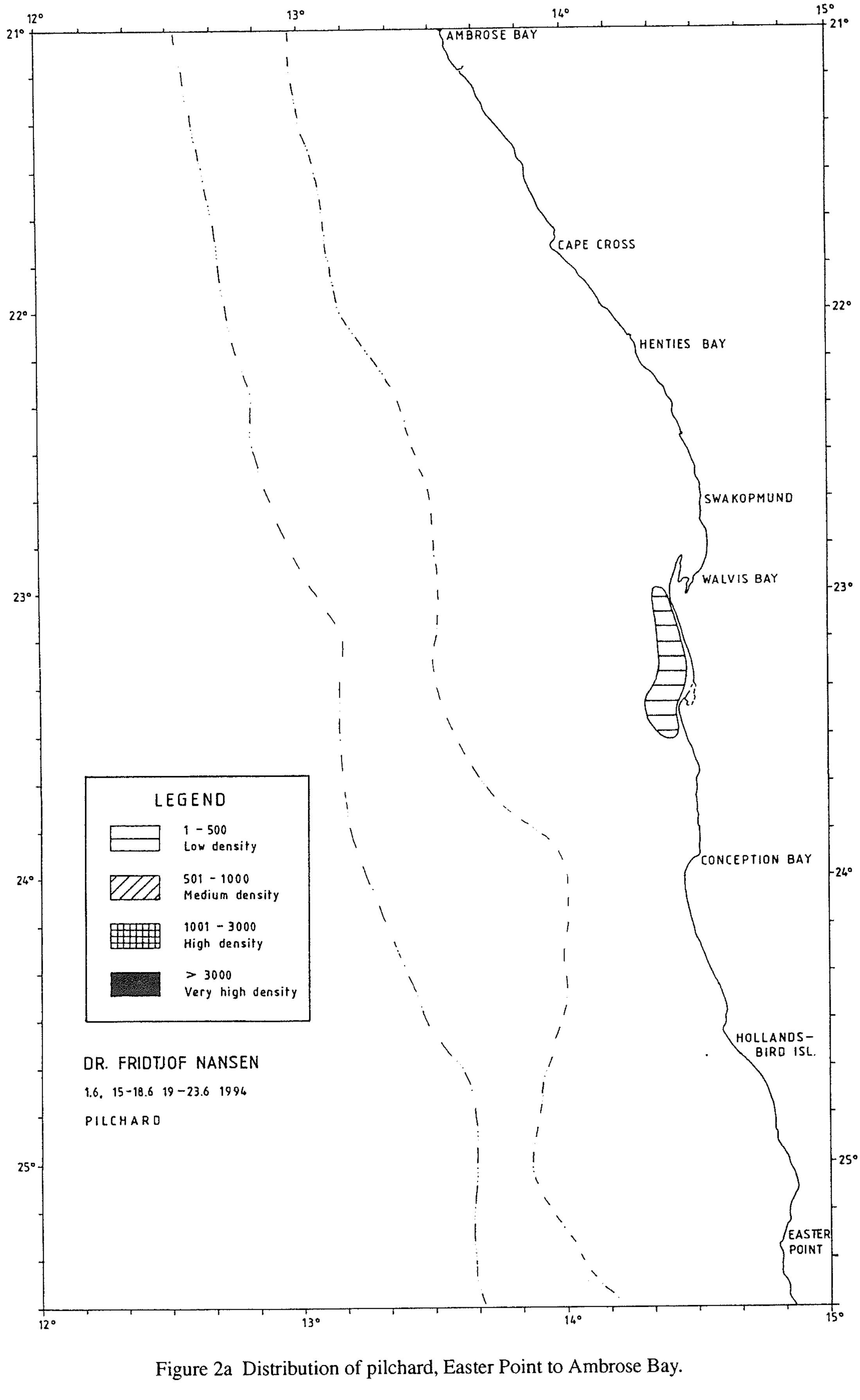


Figure 2a Distribution of pilchard, Easter Point to Ambrose Bay.

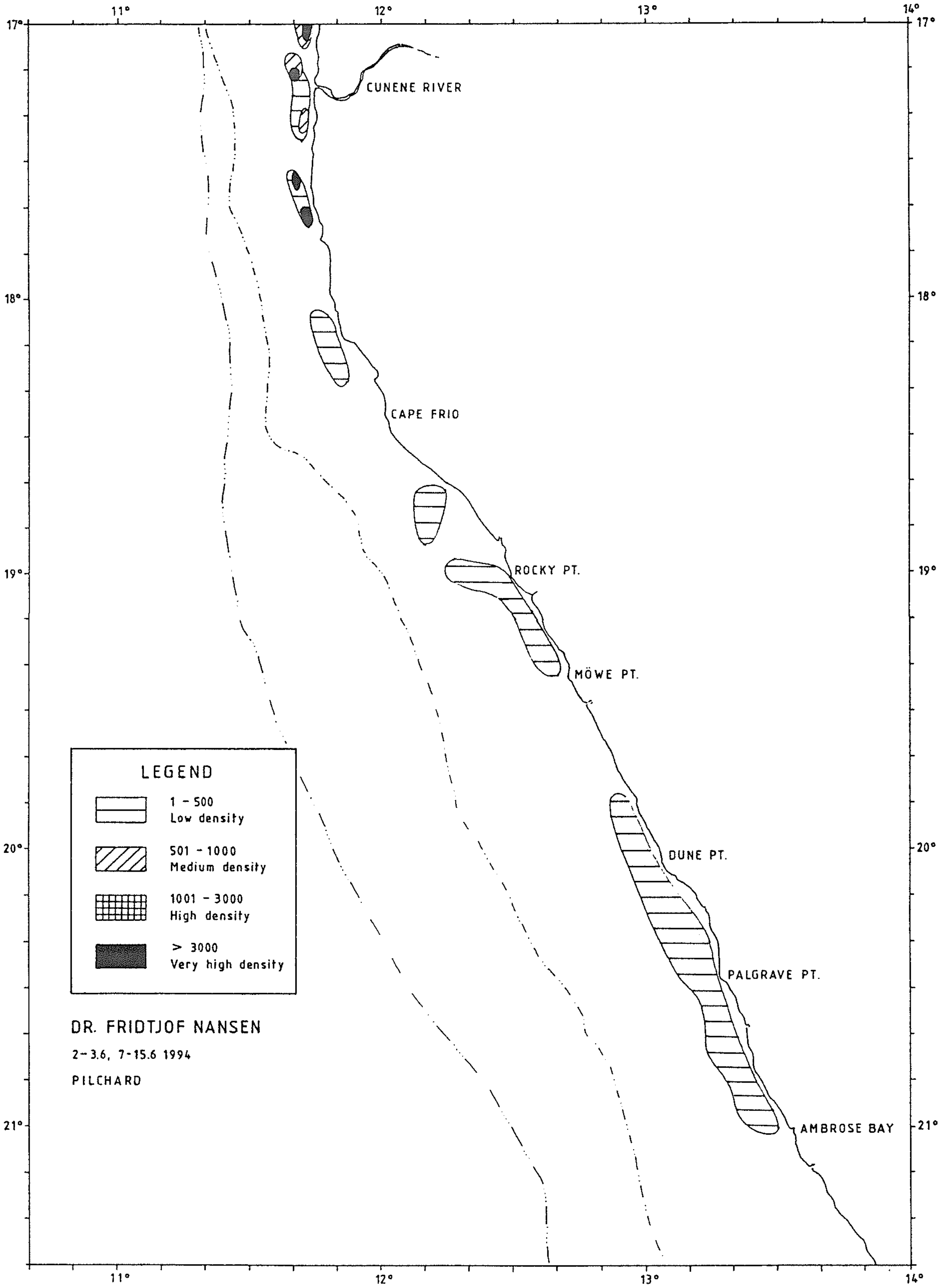


Figure 2b Distribution of pilchard, Ambrose Bay to Cunene River.

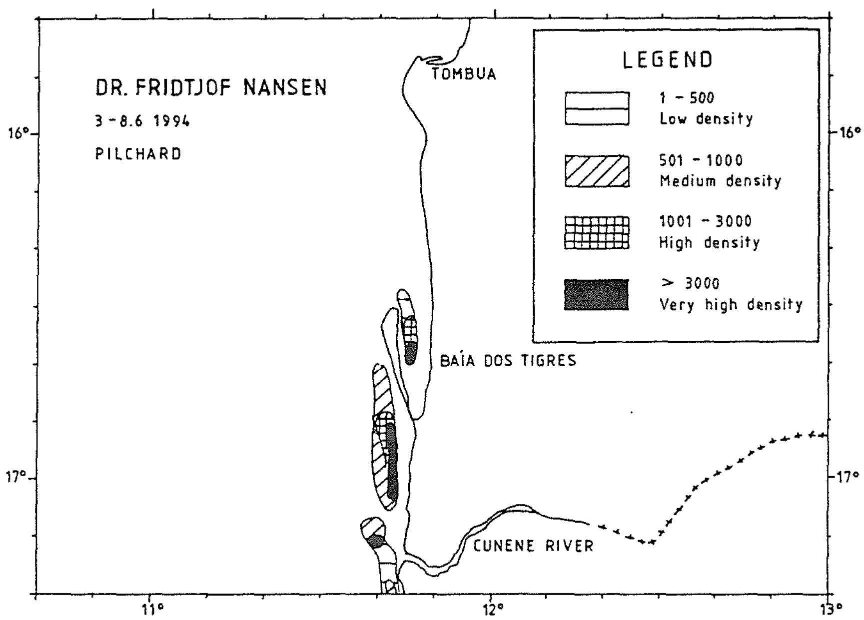


Figure 2c Distribution of pilchard, Cunene River to Tombua.

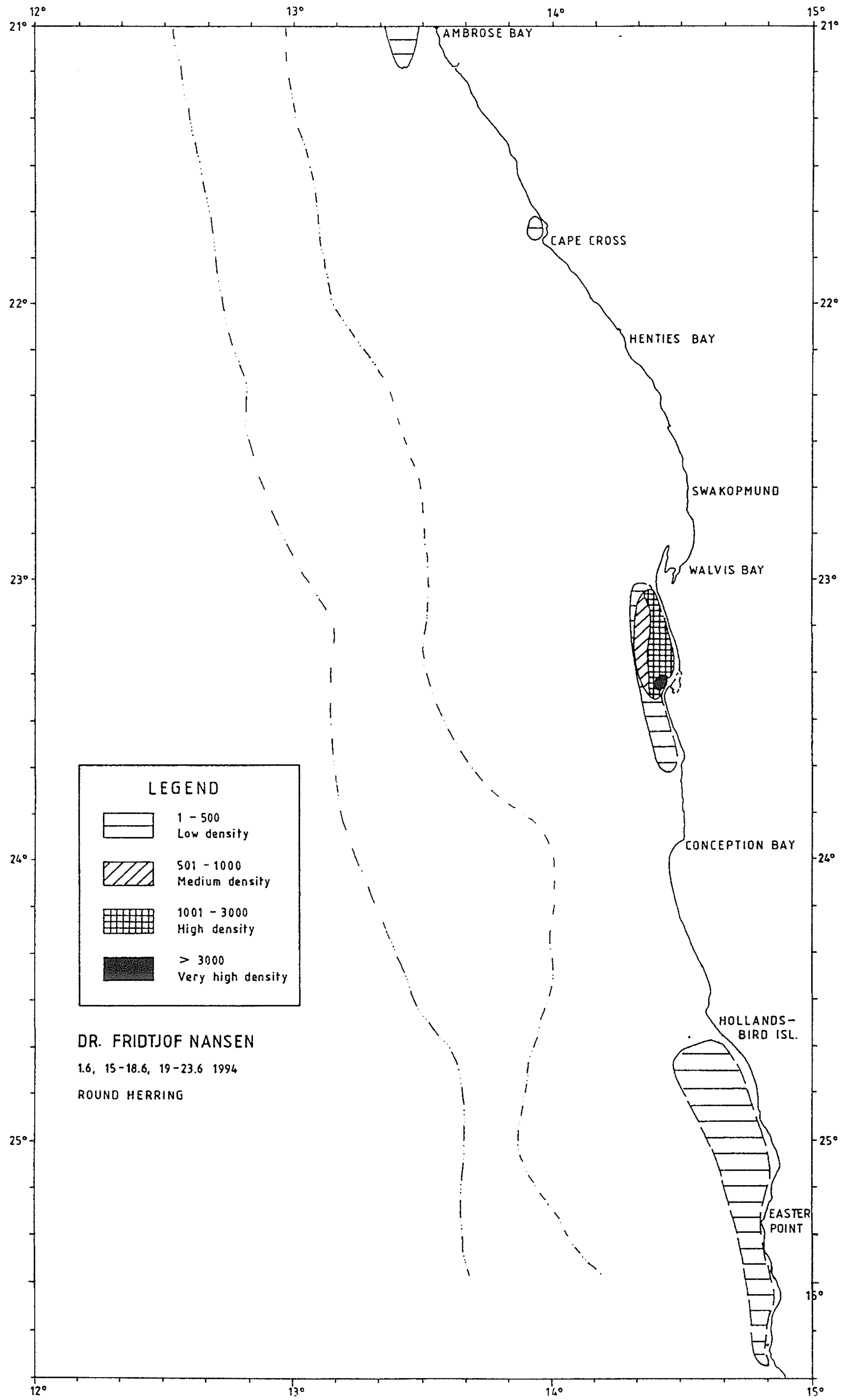


Figure 3a Distribution of round herring, Easter Point to Ambrose Bay.

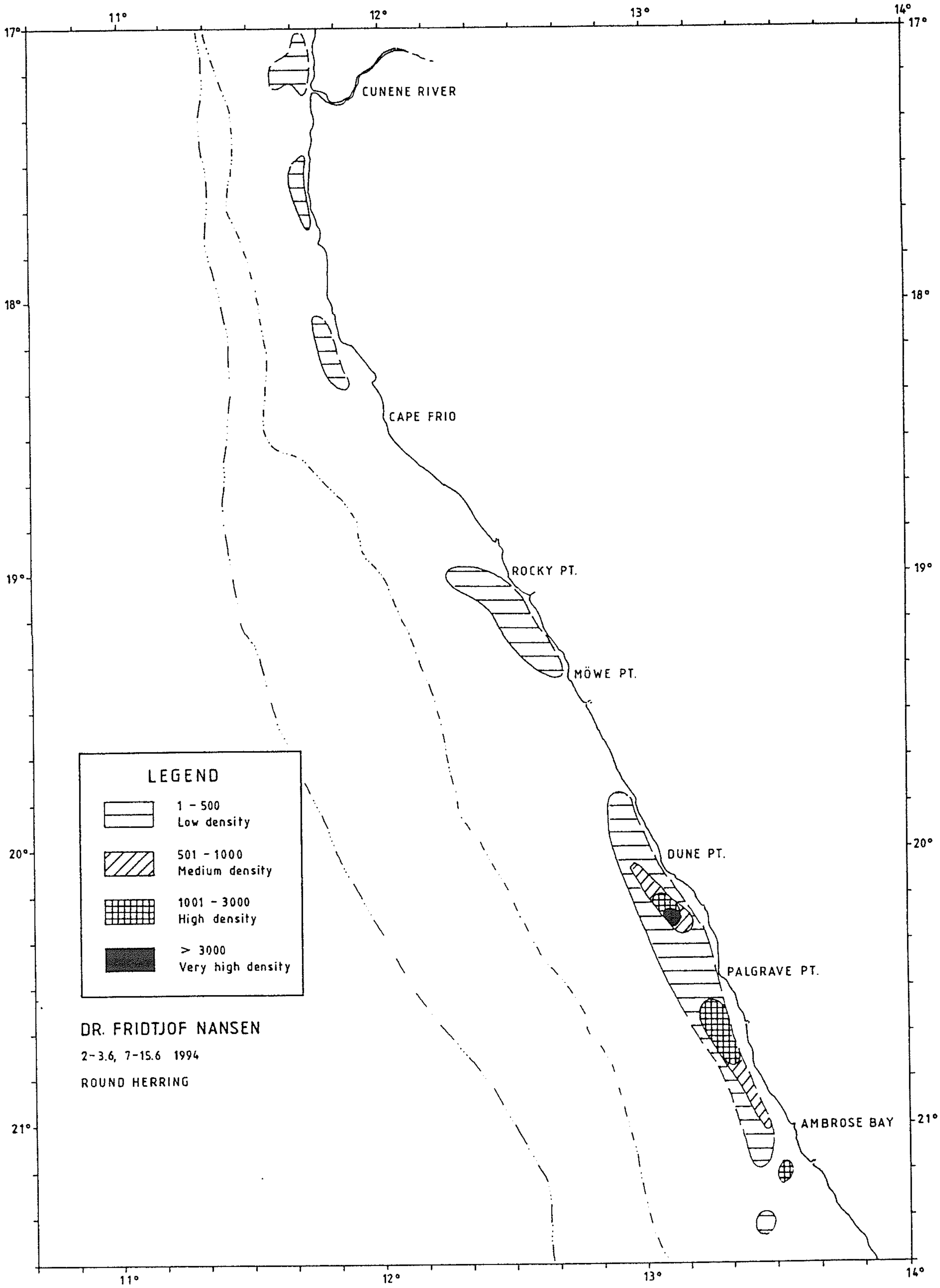


Figure 3b Distribution of round herring, Ambrose Bay to Cunene River.

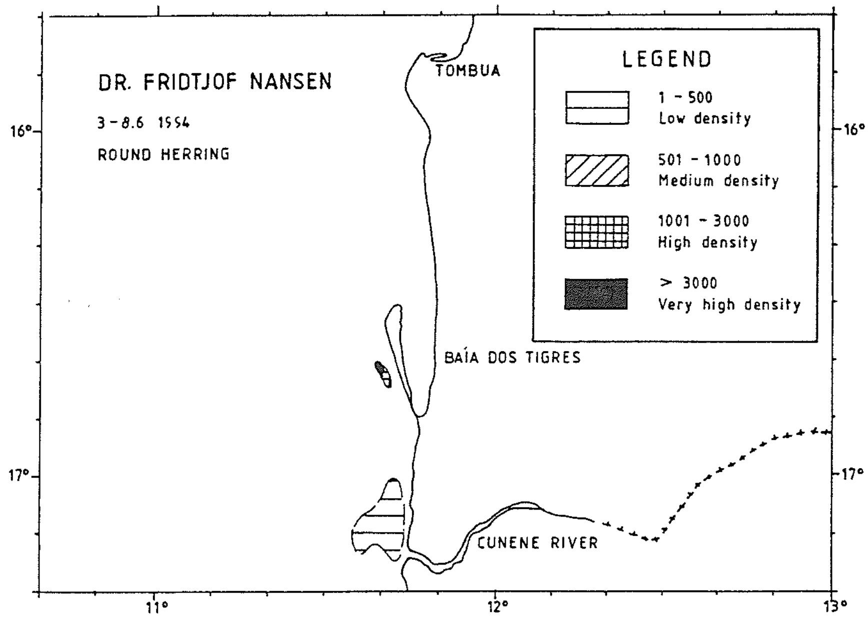


Figure 3c Distribution of round herring, Cunene River to Tombua.

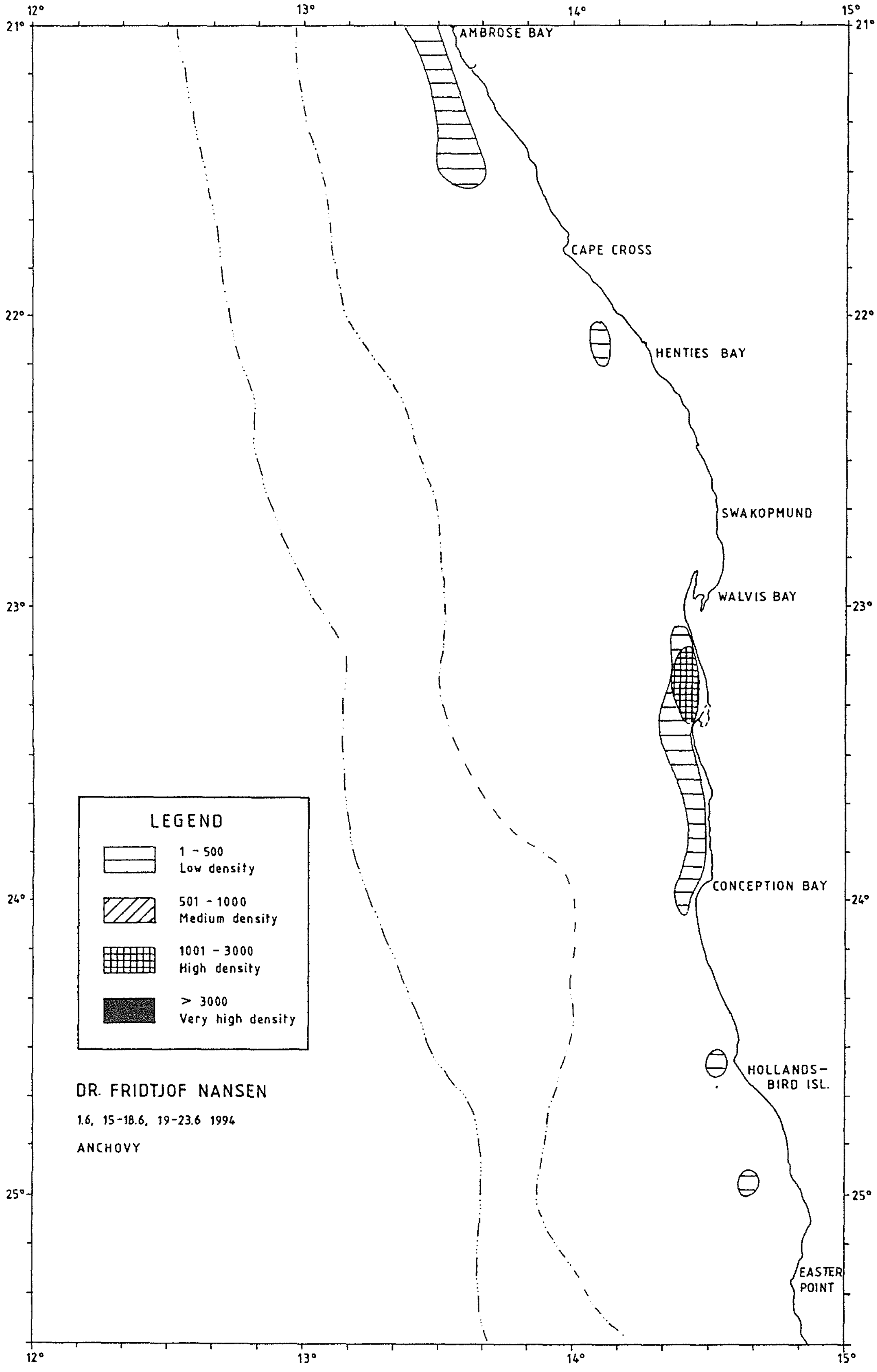


Figure 4a Distribution of anchovy, Easter Point to Ambrose Bay.

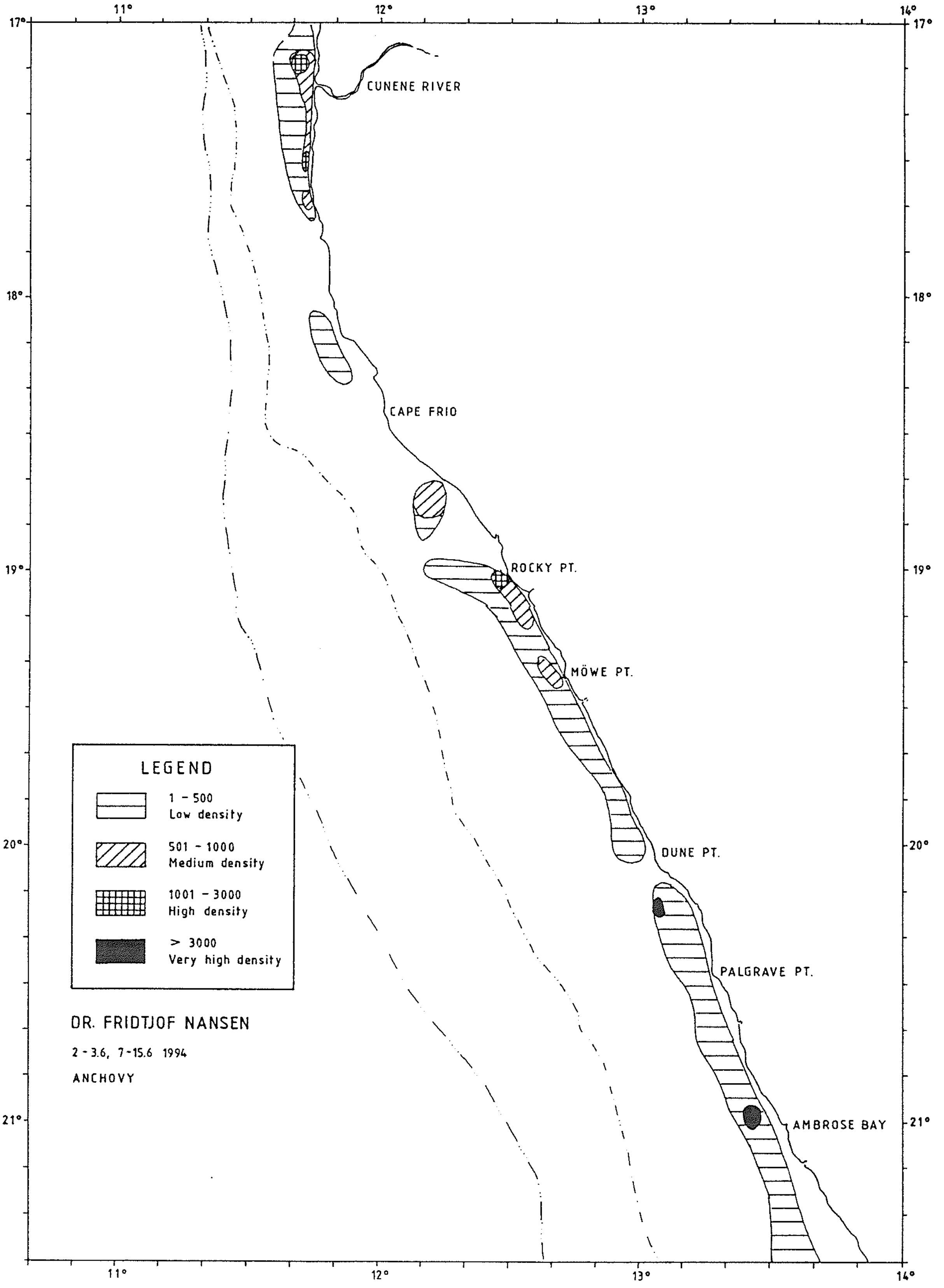


Figure 4b Distribution of anchovy, Ambrose Bay to Cunene River.

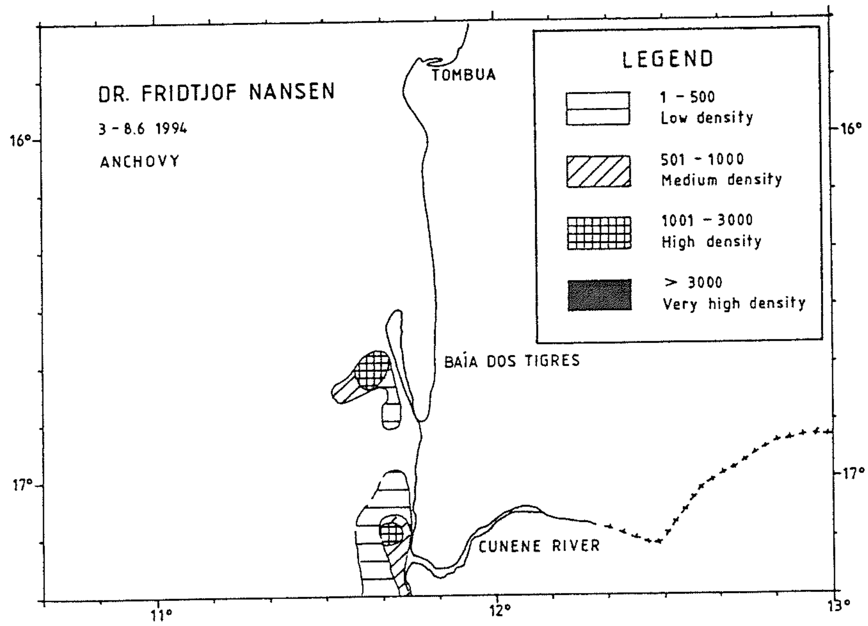


Figure 4c Distribution of anchovy, Cunene River to Tombua.

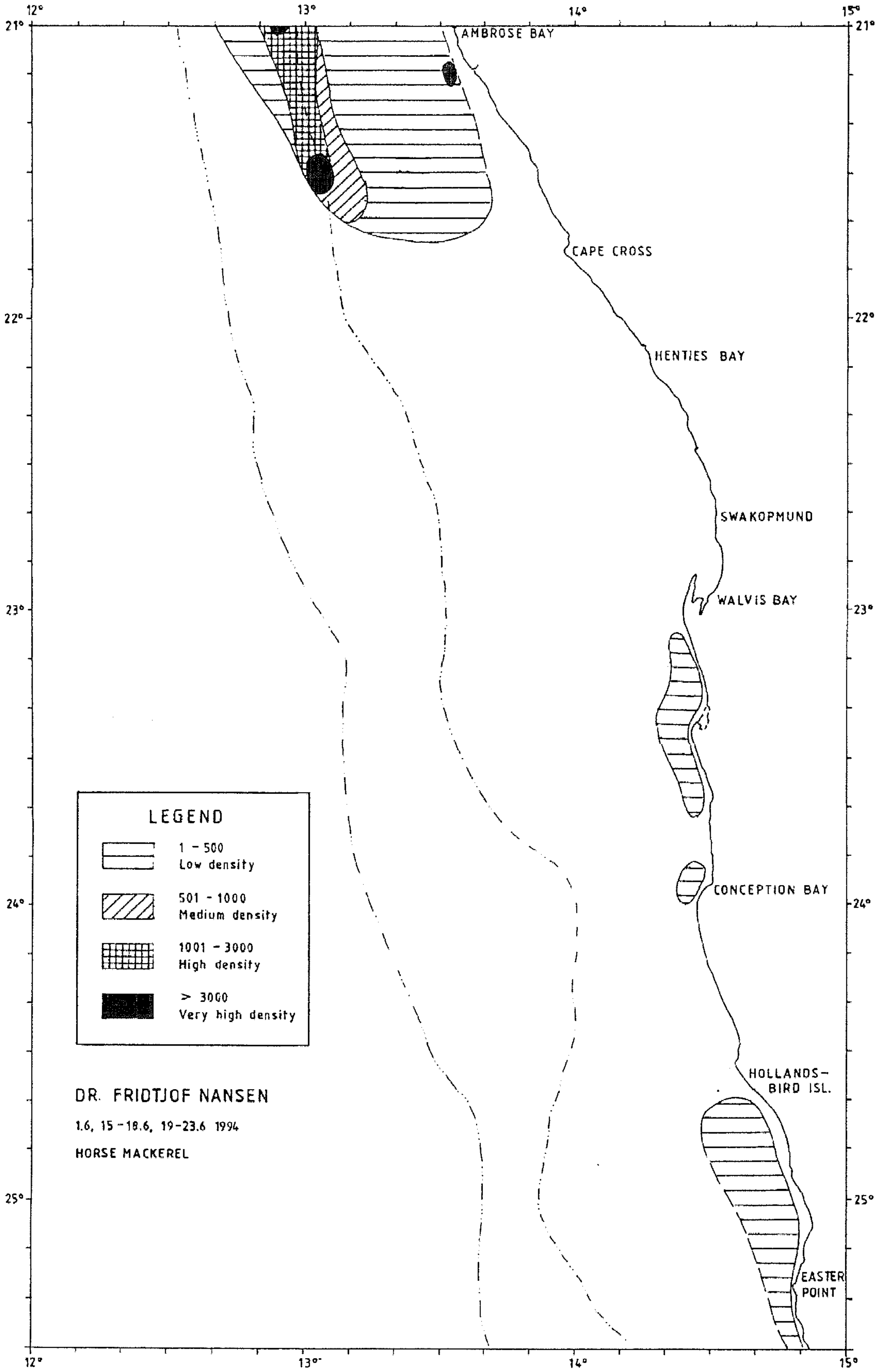


Figure 5a Distribution of horse mackerel, Easter Point to Ambrose Bay.

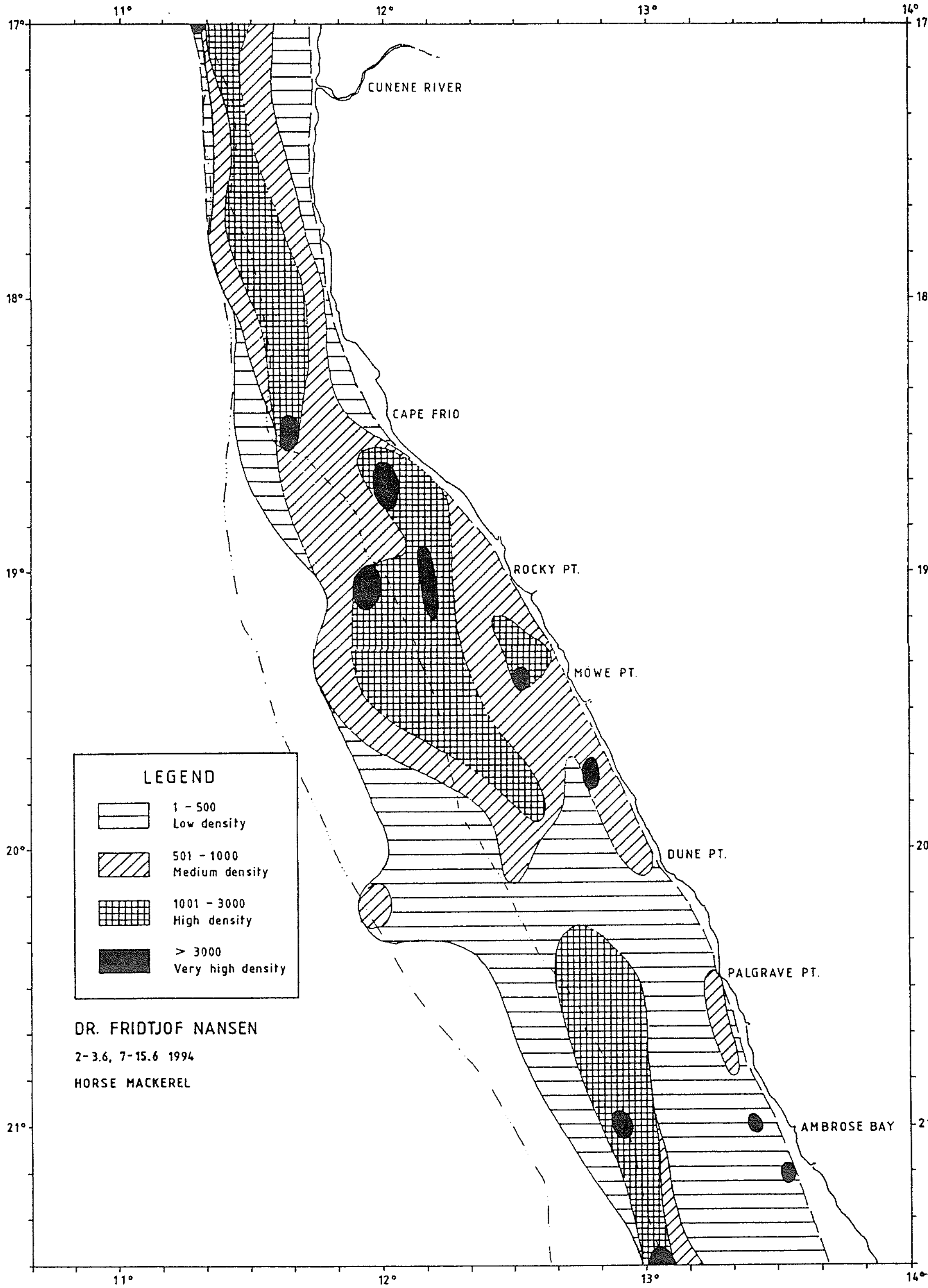


Figure 5b Distribution of horse mackerel, Ambrose Bay to Cunene River.

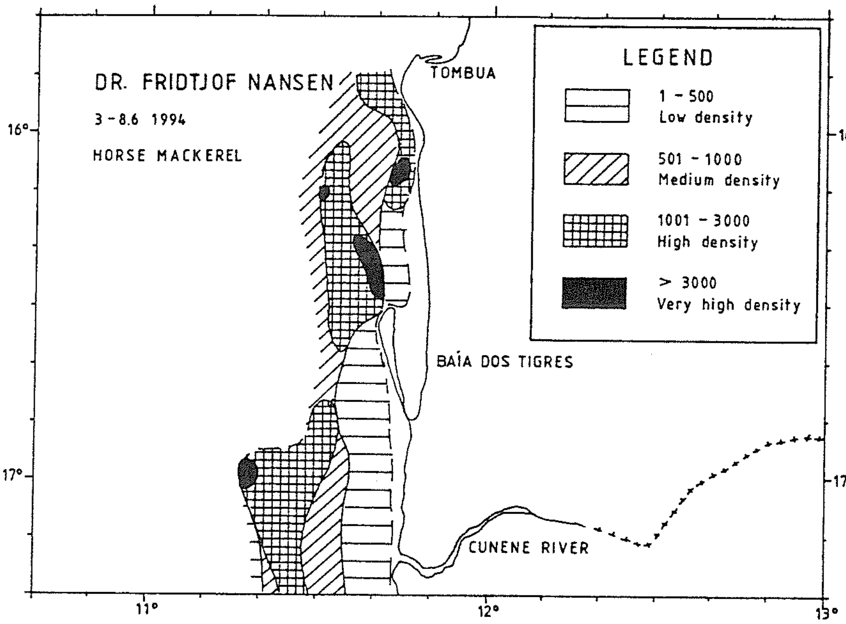


Figure 5c Distribution of horse mackerel, Cunene River to Tombua.

the surveyed fish. An aproximate conversion factor for three fish sizes, 10, 20 and 30 cm, and average values in the density scales used are given in the table below, asuming a target strength of TS = 20logL - 72 [dB]. As the actual mean density within the scale are not indicated in the charts, it is not possible to compute the total biomass directly from the distribution maps, using the indicated conversion, but may help in the interpretation of the distribution maps.

| Density ($s_A$) | 1-500 | 501-1000 | 1001-3000 |
|---|---|---|---|
| Fish length (cm) | | | |
| 10 | 20 | 60 | 130 |
| 20 | 47 | 140 | 380 |
| 30 | 115 | 230 | 460 |

### 2.2.3 Data analysis

The area density of fish as determined by the hydroacoustic method is:

$$\rho_A = \frac{s_A}{<\sigma>}$$

where $s_A$ is the area backscattering coefficient, and $<\sigma>$ is the average acoustic cross section of one fish of the measured species.

The mean area backscattering coefficient, $s_A$, for each surveyed area was obtained by averaging all data measured during the coverage of that area, excluding those values obtained during trawling. The 95% confidence intervals of the mean $s_A$ values were also computed for some areas and comparisons between the different types of transects will be made in a separate report.

The average acoustic cross-section for the fish surveyed was derived from the target strength to size relation earlier used during the surveys conducted by RV 'Dr. Fridtjof Nansen':

$$TS = 10 \log \left(\frac{<\sigma>}{4\pi}\right) = 20\, logL\ -72$$

where the total length of the fish is expressed in centimeters. This target strength to size relation has been used for a number of fish species (pilchard, anchovy and round herring), although originally derivated from early measurements of North Sea herring. In earlier reports, the relation is also referred to as the fish conversion factor:

$$C_F = \frac{1}{<\sigma>} = 1.26\,E6 \times L^{-2.0}$$

However, recent studies using split-beam echo-sounders indicate that the target strengths of these species may be higher than assumed above (Ona and Svellingen, *pers. comm.*). Until a reliable, *in situ* target strengths have been established, the indicated TS has been used to enable comparison with previous estimates. It is therefore important to note that if a more realistic target strength of TS =20 log L - 70 [dB] is used the total biomass will be reduced for all species by about 40%.

The length distribution of pilchard within an element area was computed by weighting the length-frequencies obtained in each trawl sample within the area by the measured area backscattering coefficient, $s_A$ , during trawling and close to the trawl station. This was done mainly because the trawling was directed on schools and layers for identification purpose, and that the CPUE varied from haul to haul. For species with a looser schooling behaviour, often registered as shoals or in layers, such as anchovy, round herring and horse mackerel, the length-frequency of each trawl was weighted by the CPUE.

The following formula was applied to calculate the number of fish in each length frequency group (cm) in an area:

$$n_i = s_A \times A \times \frac{p_i}{\sum_{i-1}^{n} \sigma_i . p_i}$$

| where | | |
|---|---|---|
| | $n_i$ | = number of fish in length group i |
| | A | = area in $nm^2$ |
| | $s_A$ | = mean acoustic backscattering coefficient in the area |
| | $p_i$ | = proportion of fish in length group i in samples from the area |
| | $\sigma_i$ | = acoustic cross section for one fish in length group i |

The number per length group was then summed and the total number of fish obtained. The total biomass of fish was computed using the length-weight relationship obtained from trawl samples.

The biomass estimates for all the target species are shown in Table 2.

## 2.3 BIOLOGICAL SAMPLING

Total length (Lt.), body weight, and gonad weights were recorded for pilchard, anchovy, and horse mackerel to the nearest ½ cm or 1 g below, respectively. Sex and reproductive stage were described by macroscopic examination, scoring each individually sampled fish according to the following categories:

1 Juvenile
2 Inactive
3 Active
4 Ripe
5 Spent

Otoliths were removed for ageing at a future date.

Sampling was standardized across 2° latitudinal intervals according to the following rules:

1 The minimum size of anchovy sampled was 10.0 cm Lt., and for horse mackerel and pilchard 14.0 cm Lt.
2 Up to 10 individuals were sampled per 0.5 cm length class in each 2 latitude interval.
3 Not more than 3 individuals were sampled per 0.5 cm length class per trawl.

Separate from the above parameters, length and weights for each of the four species were recorded by selective sampling across the full range of fish sizes found in trawls. The actual length-weight relationships were determined by fitting power curves to the regressions of weight against length. These relationships were determined for the whole region, as well as for each latitude interval where there was a sufficient spread of lengths among the samples.

The length-weight data of fish above the minimum size (see above) were also used to calculate the fish condition factor, (weight X 100)/length$^3$, of pilchard and anchovy. The condition factors of individual samples were pooled and averaged for each 2° latitude interval in which suitably sized fish were found. For pilchard this included areas 16° - 17°S and 20° - 21°S, and for anchovy: areas 16° - 17°S, 18° - 19°S, and 20° - 21°S.

Significance tests were performed to evaluate differences in fish condition between areas for each species. The type of test depended on the number of areas being compared; for a comparison of the two 'pilchard areas', a two-tailed F-test followed by a Student's t-test on the differences between the means was used. Whereas for a comparison of the three 'anchovy areas' a Model-I Anova for 'unplanned' comparisons between means was used (see Sokal & Rohlf, 1987).

Time limitations prevented similar calculations for horse mackerel and round herring to be done during the survey. These will be available at a later stage.