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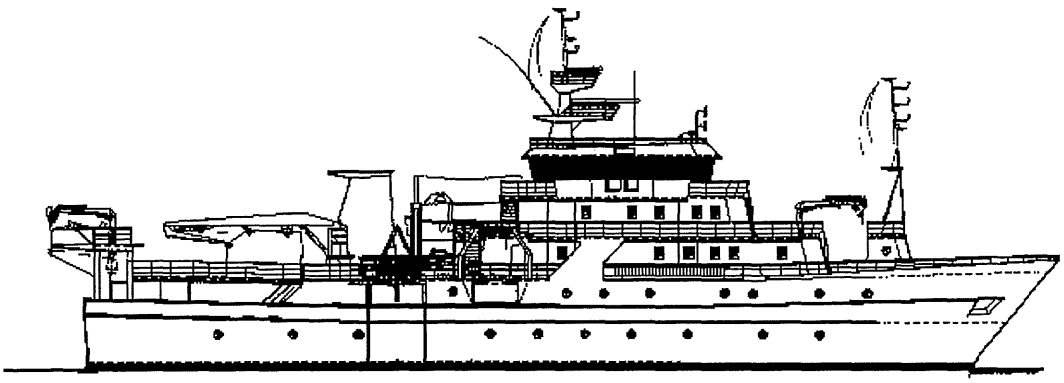
CRUISE REPORTS "DR. FRIDTJOF NANSEN"



SURVEYS OF THE FISH RESOURCES OF ANGOLA

Preliminary Cruise Report No 2/2000

Survey of the pelagic resources
28 July - 20 August 2000

Institute of Marine Research
IMR, Bergen

Institute of Fisheries Research
IIM, Luanda

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by

Bjørn Erik Axelsen
Magne Olsen

IMR

Bomba Sangoloy
Filomena Vaz-Velho

IIM

Institute of Marine Research
IMR, Bergen

Institute of Fisheries Research
IIM, Luanda

TABLE OF CONTENTS

CHAPTER 1 INTRODUCTION

1.1 Objectives

This survey is one of a series aimed at monitoring the pelagic fish resources of Angola, as agreed with the Instituto de Investigação Marinha (Luanda).

The main objectives of the survey were the following:

- To estimate the abundance and map the distribution of the main commercially important pelagic and semi-pelagic fish species in Angolan waters, including the two sardinella species *Sardinella aurita* and S. *maderensis*, the Cunene horse mackerel *Trachurus trecae*, the Cape horse mackerel *Trachurus capensis*, the pilchard *Sardinops ocellata* and other pelagic species, mainly carangids.

- To study the biological condition of the main species, including length weight-relationships, reproductive stages and stomach fullness.

- To collect gonads, stomachs and otoliths from both horse mackerel species for later studies. Horse mackerel feeding biology will be investigated by relating the stomach contents to estimated zooplankton density.

- To map the general meteorological, hydrographical and biological conditions in the survey area by means of continuous recording of weather data and stationary CTD-casts (Temperature, Salinity and Oxygen), ADCP measurements (Acoustic Doppler Current Profiler) and plankton sampling along the acoustical and the standard hydrographical transects. Extensive coverage will be carried out in the Benguela front area in the southern and central regions.

- On-the-job training for the Angolan participants on the main survey routines, including using the NAN-SIS database and software package, scrutinizing acoustical data and producing acoustical biomass estimates.

The aim of these surveys is to build a time series to allow for a better understanding of the fluctuations in the main pelagic stocks and of the biology of the main species.

1.2 Participation

The scientific staff consisted of:

From IIM, Luanda: Bomba BAZIKA SANGOLOY, Silvi Edith NSIANGANGU, Domingos PEDRO, Francisco DE ALMEDA, Agostinho DUARTE, André MIGUEL, Lutuba NSILULU, Filomena VAZ-VELHO.

From IMR, Bergen: Bjørn Erik AXELSEN (Cruise leader), Martin DAHL, Magne OLSEN, Jarle WANGENSTEN.

1.3 Narrative

The vessel departed Walvis Bay (Namibia) 20 July at 1600 and steamed northwards to Cunene River at the Angolan border, arriving 21 July at 0130. The sampling trawls, including the mid-sized (15 m vertical opening) pelagic trawl fitted with the codend multisampler, the smallest (10 m) pelagic trawl and the demersal trawl (5 m), were prepared during the steaming and were ready for deployment at the time of arrival. All transducers were recently calibrated (12.06.00), and consequently no calibration was carried out during the survey. The first transect line commenced at the Cunene River estuary at 17° 15'S (20 m bottom depth) heading westwards. The survey track largely followed the ones used during the most recent pelagic surveys, i.e. parallel longitudinal transects from the 20 m isobath to minimum 500 m bottom depth, but conforming with the survey practice of previous years, systematic triangular transects were applied in areas where the continental shelf is particularly narrow, on this survey between Pta. Albinas (Tombua) and Lobito. In areas where horse mackerel were distributed offshore the transect lines were extended to the 1000 m isobath. The parallel transect lines were spaced with 5 NM in most of the surveyed area (17 ° 15' S to 16 ° S and 12 ° S to 8 ° S), except in the low-density areas in the north (8 ° S to 6 ° S), where the distance was increased to about nine NM (varying from eight to 10 NM depending on oil platforms etc.). The spacings between the endpoints of the triangular transects were about 5 NM in the in the latitudinal direction. Unfortunately, like previous years, the shallowest parts of the shelf between Nzeto and the Congo River were inaccessible due to platforms and activities of the oil industry.

CTD (Conductivity-Temperature-Depth) and ADCP (Acoustic Doppler Current Profiler) recordings were carried out along the acoustical transects and the standard hydrographical sections. Comprehensive CTD and ADCP coverage was ensured in the main distribution area of the horse mackerel species (Cunene – Baía dos Tigres). Vertical plankton hauls were carried out using a WP II plankton sampler. The vessel reached the endpoint of the Congo River section in the afternoon August 19 and started steaming southwards, docking in Luanda 20 August at 0800.

Following established practice, the surveyed area was divided into three regions: Congo River - north of Pta. das Palmerinhas (9 ° S) - ANGOLA NORTH - was covered from 14 to 19 August. The region between 9 ° S and 13 ° S - ANGOLA CENTRAL - was surveyed from 4 to 14 August. The region limited by the parallel of 13 ° S and Cunene River - ANGOLA SOUTH - was covered from 30 July to 4 August.

1.4 Survey effort

Figures 1a-c show the cruise tracks with fishing and hydrographic stations, and figures 2a-b show the plankton hauls. Table 1 summarizes the survey effort in each region.

Table 1 Number of demersal (BT) and pelagic (PT) trawl hauls, CTD casts, plankton stations (2-3 hauls) and the distance surveyed (NM) in each region.

Area	BT	PT	CTD	Plankton	Distance surveyed
Congo River - Pta. Palmerinhas	8	17	26		1510
Pta. Palmerinhas - Benguela	12	18	33	13	1410
Benguela – Cunene River	10	18	61	21	905
Total	30	53	120	34	3825

Figure 1a. Course track with fishing and hydrographic stations, Congo River - Pta. das Palmerinhas.

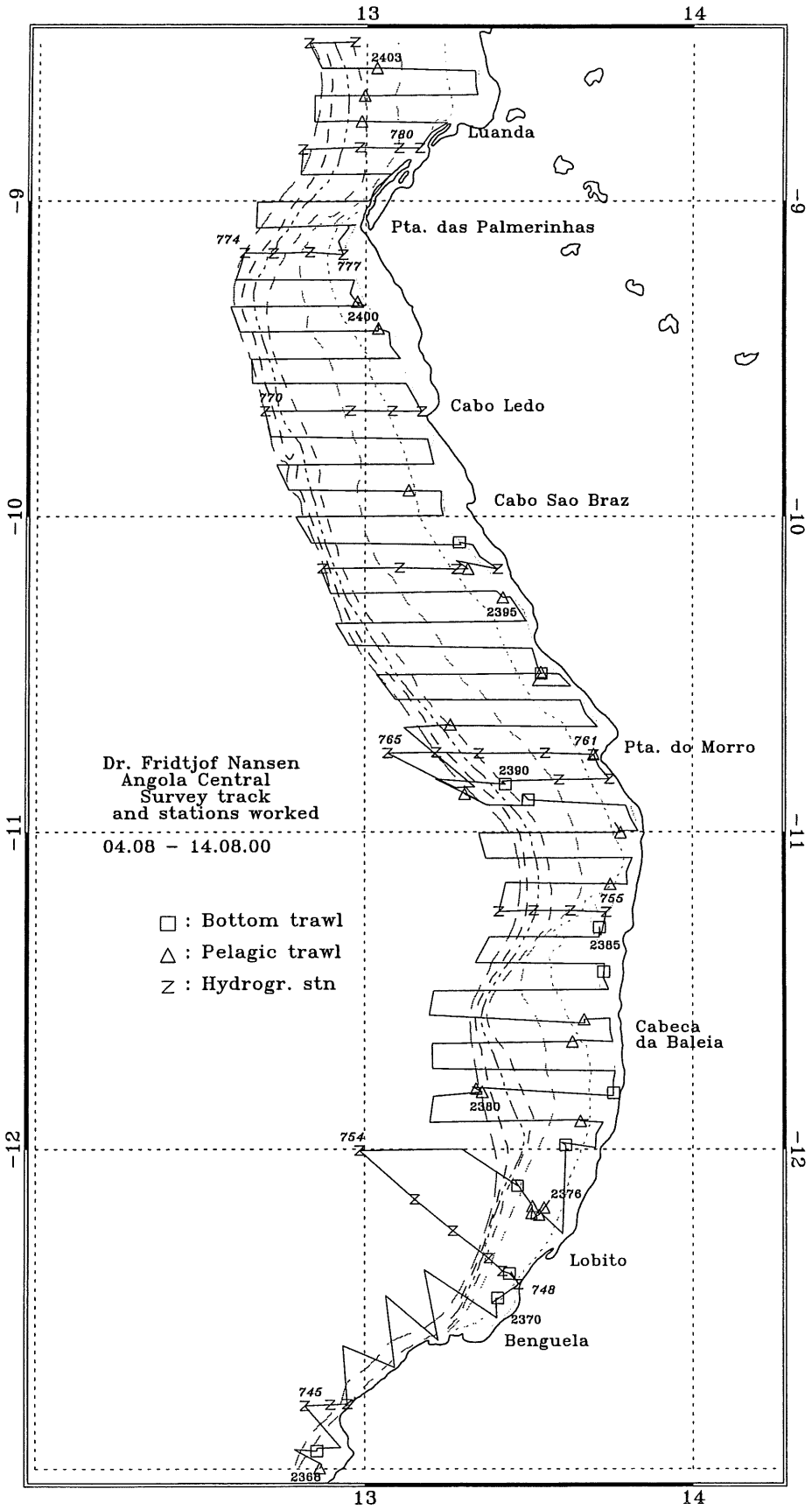


Figure 1b. Course track with fishing and hydrographic stations, Pta. das Palmerinhas - Benguela.

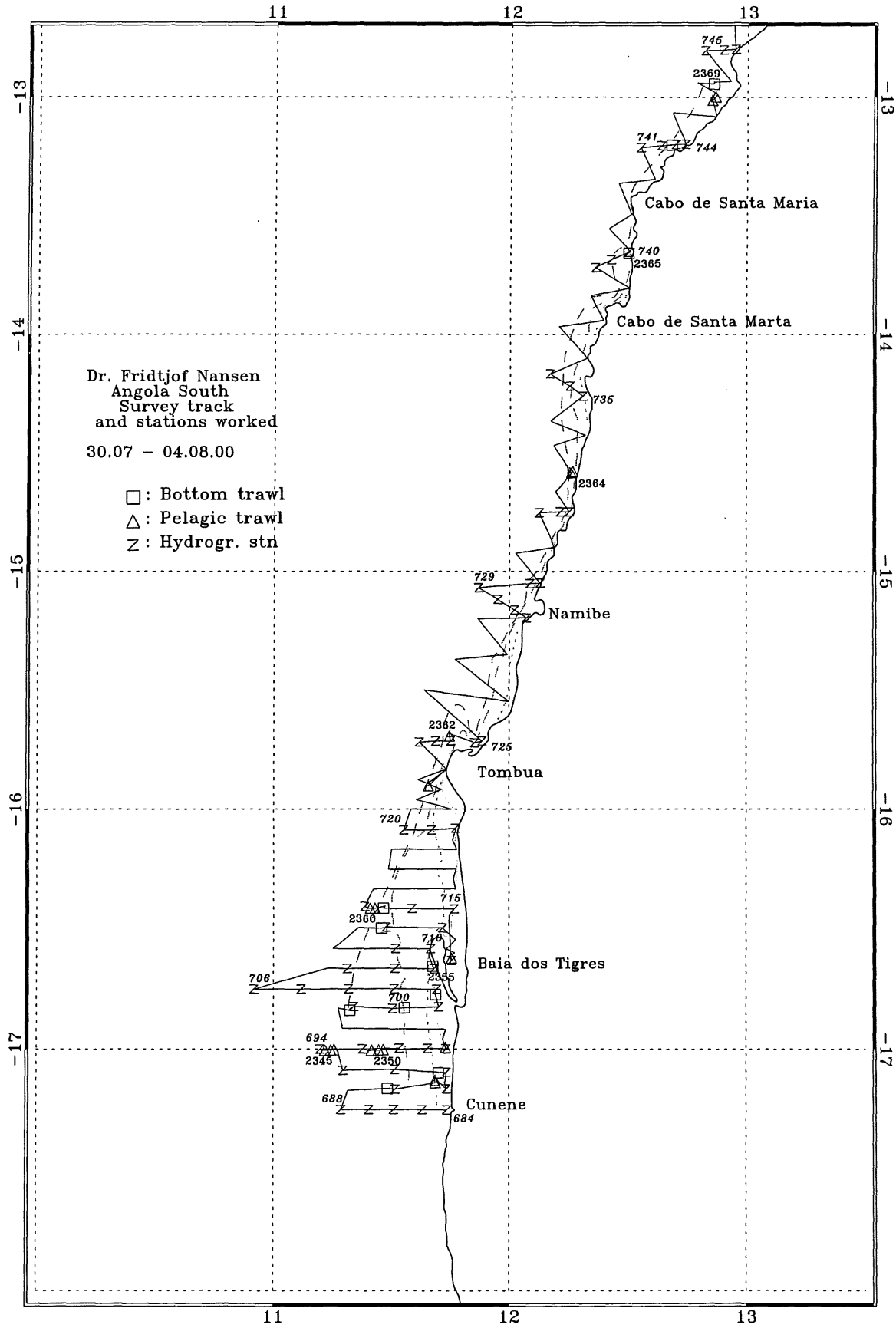


Figure 1c. Course track with fishing and hydrographic stations, Benguela-Cunene.

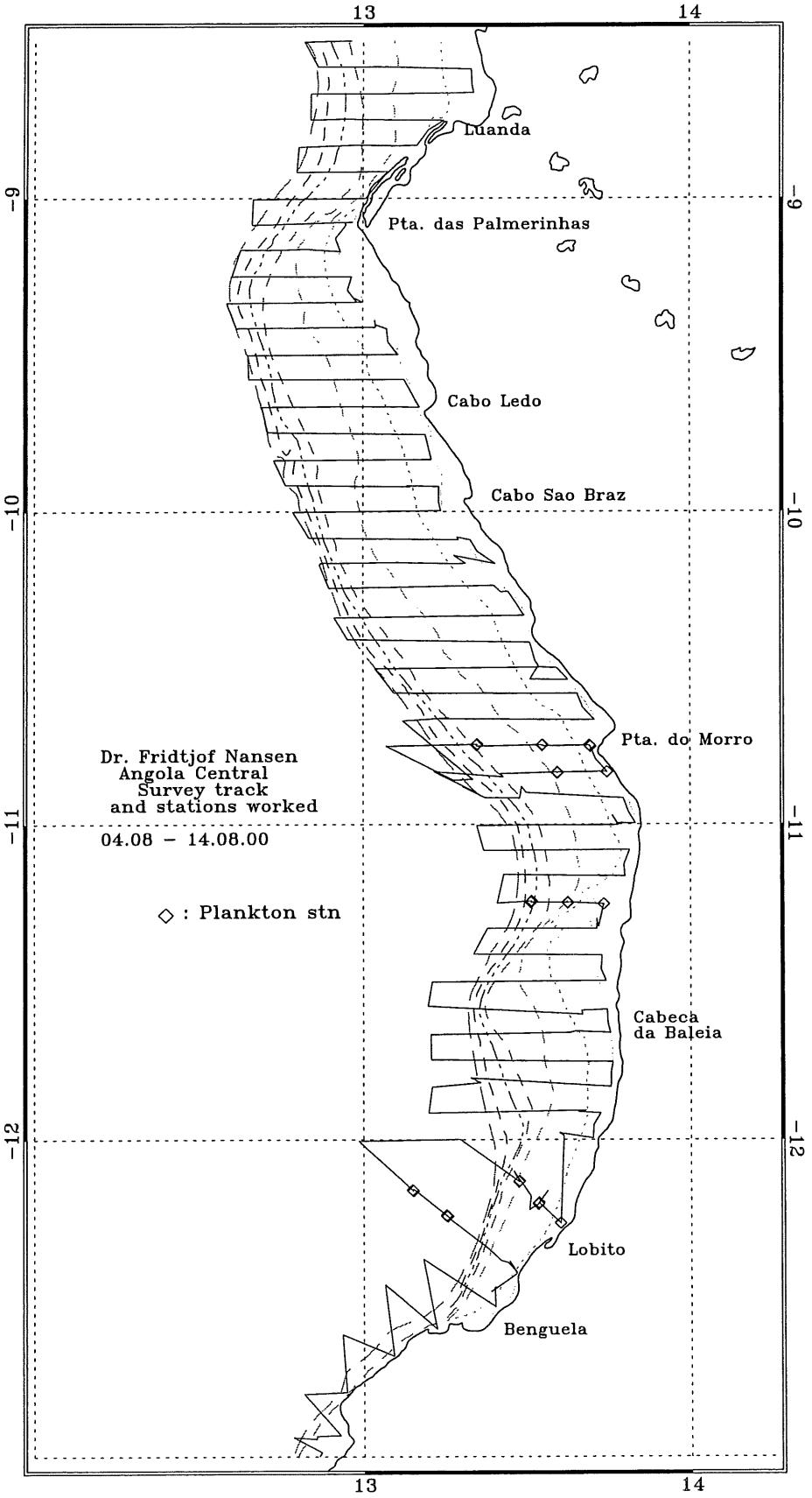


Figure 2a. Course track with plankton stations, Pta. das Palmerinhas - Benguela.

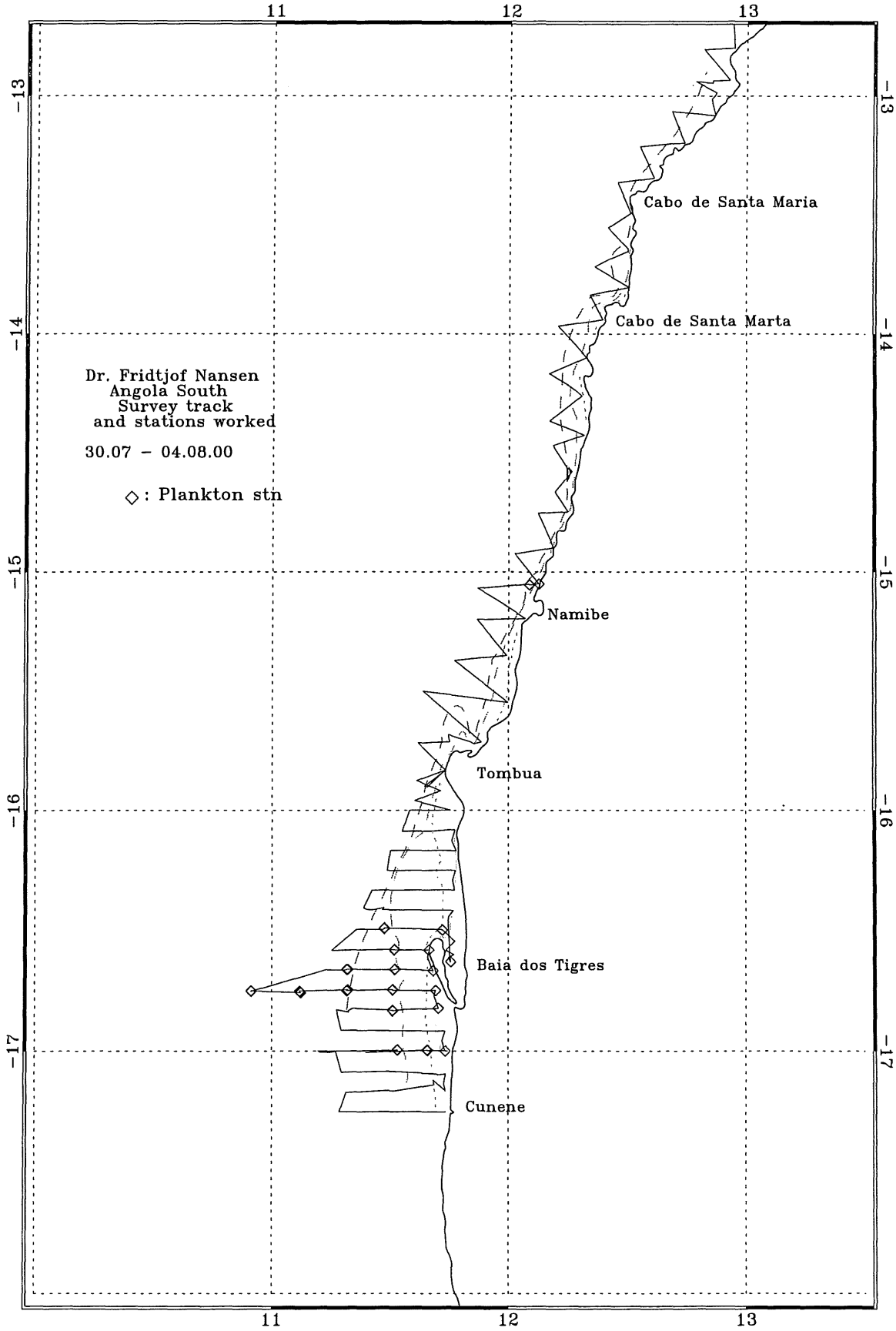


Figure 2b. Course track with plankton stations, Benguela-Cunene.

CHAPTER 2 METHODS

2.1 Hydrographic sampling

A Seabird 911+ CTD probe was used to obtain vertical profiles of the temperature, salinity and oxygen. Real time plotting and logging was carried out using the PC based Seabird Seasave software. CTD casts were conducted along the cruise track in transects at about 20 NM distance. The casts were stopped a few meters above the bottom, at 500 m depth. In the Cunene – Baía dos Tigres area, CTD casts and vertical plankton hauls were carried out on each transect line (5 NM distance) in order to obtain an extensive coverage of the environmental factors in the primary horse mackerel area. Two water samples, one near the surface and near the bottom, were collected using Niskin bottles at stations corresponding to the standard IIP profiles. The samples were analysed for dissolved oxygen using the Winkler method in order to calibrate the oxygen sensor. Salinity of water samples could not be measured as the Guildline Portasal salinometer was out of order.

A total of 119 samples were accepted for oxygen calibration. A linear regression of the Winkler determinations on the CTD values produced the following correction equation:

$$O_2 = 0.9724 * O_2CTD + 0.09006$$

Current measurements were carried out with the hull-borne Acoustic Doppler Profiler (ADCP) at each CTD station. The ADCP was set to ping every 8 seconds, the depth bins were set to 8 m and the number of bins was 40. Data were averaged at 300 seconds intervals and stored on an IBM compatible PC using Transect v. 2.70 software.

Meteorological data from the Anderaa meteorological station included wind direction and speed, air temperature, global radiation and sea surface temperature (SST). All data were averaged every nautical mile and logged automatically.

2.2 Biological sampling

Fish sampling

A brief description and illustrations of the sampling trawls are provided in Annex I. The trawl catches were sampled for species composition, by weights and numbers. Records of catch rates for all trawl stations are given in Annex II.

Biological samples, i.e. length and weight compositions, were obtained for the target species. Total length and body weight were determined for both species of sardinella and horse mackerel to the nearest 1 cm and 1 g below, respectively. Sex and reproductive stages were determined by means of macroscopic examination, scoring each individually sampled fish according to the following predefined categories:

1	Juvenile
2	Inactive
3	Active
4	Ripe
5	Running/ Spent

Stomach samples of both horse mackerel species were collected for further analysis at the IIM of Luanda. Horse mackerel feeding biology will be investigated by relating the stomach contents to estimated zooplankton density. Gonads and otoliths were collected from both horse mackerel species for later studies.

Plankton sampling

Extensive depth-stratified sampling of the zooplankton community was to be carried out in the main distribution area of the horse mackerel species (Cunene – Baía dos Tigres) by means of HYDROBIOS Multinet in order to map available food items for the horse mackerel. However, after rigging, it turned out that the release unit was removed from the ship for repair, and no spare was available. Consequently, depth-stratified sampling was impossible, and the plankton was sampled using simple WP II net with circular mouth opening (55 cm diameter). In order to obtain some information about the vertical distribution of the plankton, samples were obtained from three different depths on each station: ~3 m above bottom depth, ~2/3 of the bottom depth and ~1/3 of the bottom depth.

2.2 Acoustic sampling

All transducers were recently calibrated (12.06.00) and the drifts then were within the limits of acceptance (s_V gain was adjusted from 27.45 dB to 27.39 dB, TS gain from 27.65 dB to 27.52 dB, see BENEFIT Cruise Report 4/2000). Consequently, no calibration was carried out during the survey. The settings of the acoustic instruments are given in Annex III. Based of familiar echograms characteristics and targeted trawling, recorded 5 NM mean area backscattering coefficients, s_A (m^2/NM^2) were allocated to the following species categories:

- sardinella (S. *aurita* and S. *maderensis*)
- horse mackerel (T. *trecae* and T. *capensis*)
- pilchard (*Sardinops ocellata*)
- big-eye grunt (*Brachydeuterus auritus*)
- PEL 1 (other clupeiformes, i.e. *Engraulis encrasicolus*, *Ilisha africana*, *Etrumeus whiteheadi*)
- PEL 2 (carangids other than *Trachurus* sp., scombrids, barracudas and hairtails)
- other demersal fish (i.e. sparids)
- mesopelagic fish (myctophiids)
- plankton.

Biomass estimation

The following target strength (TS) function was applied to convert mean area backscattering coefficient, s_A (m^2/NM^2), to number of fish:

$$TS = 20 \log L - 72 \text{ dB} \quad (1)$$

corresponding to

$$C_F = \frac{10^{\frac{72}{10}}}{4\pi} \cdot L^{-2} \approx 1.26 \cdot 10^6 \cdot L^{-2} \quad (2)$$

where C_F is the conversion factor from acoustic density to fish biomass and L is total fish length. This target strength to body length relationship was originally established for North Sea herring, but has been attributed to clupeids in general (Foote et al. 1986, Foote 1987). Since no specific target strength relations presently are available for the species at hand, equation (2) was applied for all targeted species.

The boundaries of encountered fish aggregations were determined *ad-hoc* by means of contouring within 0-value limits of the transect lines. Only along-transect values were to be included in the estimations of the 5-NM mean integrator value (s_A) for the areas with parallel transects, but due to the short spacing between the parallel lines (5 NM) in most of the area survey with parallel lines (16 ° S to 17 ° 20' S and 12 ° S to 7 ° 50' S) it was not possible to exclude the values on the inner shelf without removing substantial of the on-line contributions, which for Sardinella sp. were particularly high on the inner part of the shelf. Due to the narrow spacing in these areas, it is however thought that the potential positive bias introduced by including between line-values is negligible, and that bias from excluding (high) on-line contributions would be greater. A slight positive bias in the estimate of Sardinella sp. caused by inclusion of between-transect values may be compensated by the probably larger negative bias induced by the extremely shallow distribution of this group (partly above the integration limit). Similarly, end-point values on the triangular transects (12 ° S to 16 ° S) that may have been subject to some autocorrelation were included. In the area with parallel transects with eight to 10 NM spacings (northern region 7 ° 50' S to 6 ° S), all 5 NM value that were positioned between the lines were excluded.

The overall length frequency distributions of the target species within the strata was estimated by weighting each sample with the mean of the 5-NM integrator value allocated to that species immediately before and after the trawl hauls. Target species belonging to the same genus, *Sardinella aurita*/ S. *maderensis* and *Trachurus trecae*/ T. *capensis*, are not acoustically distinguishable, and the s_A values recorded for these groups were therefore allocated to the respective genus (Sardinella sp. or Trachurus sp.). The combined estimates for each genus were then split for each length group according to the fraction of each species present in the catches. The number of fish in each length group i ρ_i was estimated for each species and stratum using:

$$\rho_i = < s_A > \cdot \frac{p_i}{\sum_i \frac{p_i}{C_{F_i}}} \cdot s_i \cdot A = \frac{\frac{10^{7.2}}{4\pi} \cdot < s_A > \cdot p_i \cdot s_i \cdot A}{\sum_i n_i \cdot L_i^2} \qquad (3)$$

where:
- $<s_A>$ = recorded mean area backscattering coefficient (m^2/NM^2)
- p_i = proportion of fish in length group i
- s_i = proportion of species s in length group i
- C_{Fi} = fish conversion factor for length group i

Li = mid-length in group i
A = stratum area.

The strata were digitized using a CalBoard III digitizing board connected to an IBM compatible PC equipped with Atlas Draw v. 2.03 software. Plotting of distributions and calculation of stratum areas were carried out using IDL 5.0 software on a SUN-UNIX workstation. The biomass of each length group were calculated by multiplying the number of fish by their mean weight as determined by the length to total weight relationship. Length-weight relationships were established through linear regression between log-transformed values of total length and total weight. Separate length-weight relationships were calculated for each region (north, central, south) pooling the data from all stations within the regions. The total numbers and biomass in each fish stratum were obtained by summing over the length groups. The numbers and biomass per length group were summarized for each region and for the entire survey area.

CHAPTER 3 OCEANOGRAPHIC CONDITIONS

Surface distribution

Figures 2 a and b show the surface distribution of temperature and salinity for the northern region (Congo River-Pta das Palmerinhas), respectively. The usual same characteristics were evident; steep gradients of temperatures (increasig) and salinities (decreasing) towards the mouth of Congo River.

In the central region Pta das Palmerinhas-Benguela (figure 3a-b), isolines of both parameters (temperature and salinity) ran parallel to the coast line, characteristic for the southward flow of the Angolan current. Temperatures ranged from 19 °C to 21 °C, while the salinity was between and 35.6 and 35.8 psu.

Figures 4 a and b show the horizontal distribution of temperature and salinity for the southern region (Benguela to Cunene river). In this region, the frontal area of the Angola – Benguela currents seemed to be divided in two parts around Baía dos Tigres; one of them between 15 ° S and 15 ° 50´ S and an other from 16 ° 40´ S to 17 ° 05´ S. The extended mid-part of the frontal system (15 ° 50´ S to 16 ° 40´ S) suggests moderate dynamics of both Angolan and Benguelan water masses. The temperatures were generally within the ranges of 1999, but in the frontal area south of Baía dos Tigres, the temperatures varied between 15 ° C and 18 ° C, which is slightly higher than last year (14-16 ° C). South of Tombua, the salinity was extremely low in inshore waters (35.1 to 35.5 psu) compared to last year (> 35 psu), suggesting extensive inflow of freshwater from the Cunene river. North of Baía dos Tigres, temperatures generally ranged from 17 ° C to 20 ° C, and the temperature generally increased towards deeper waters, as indicated by isolines parallel to the coast.

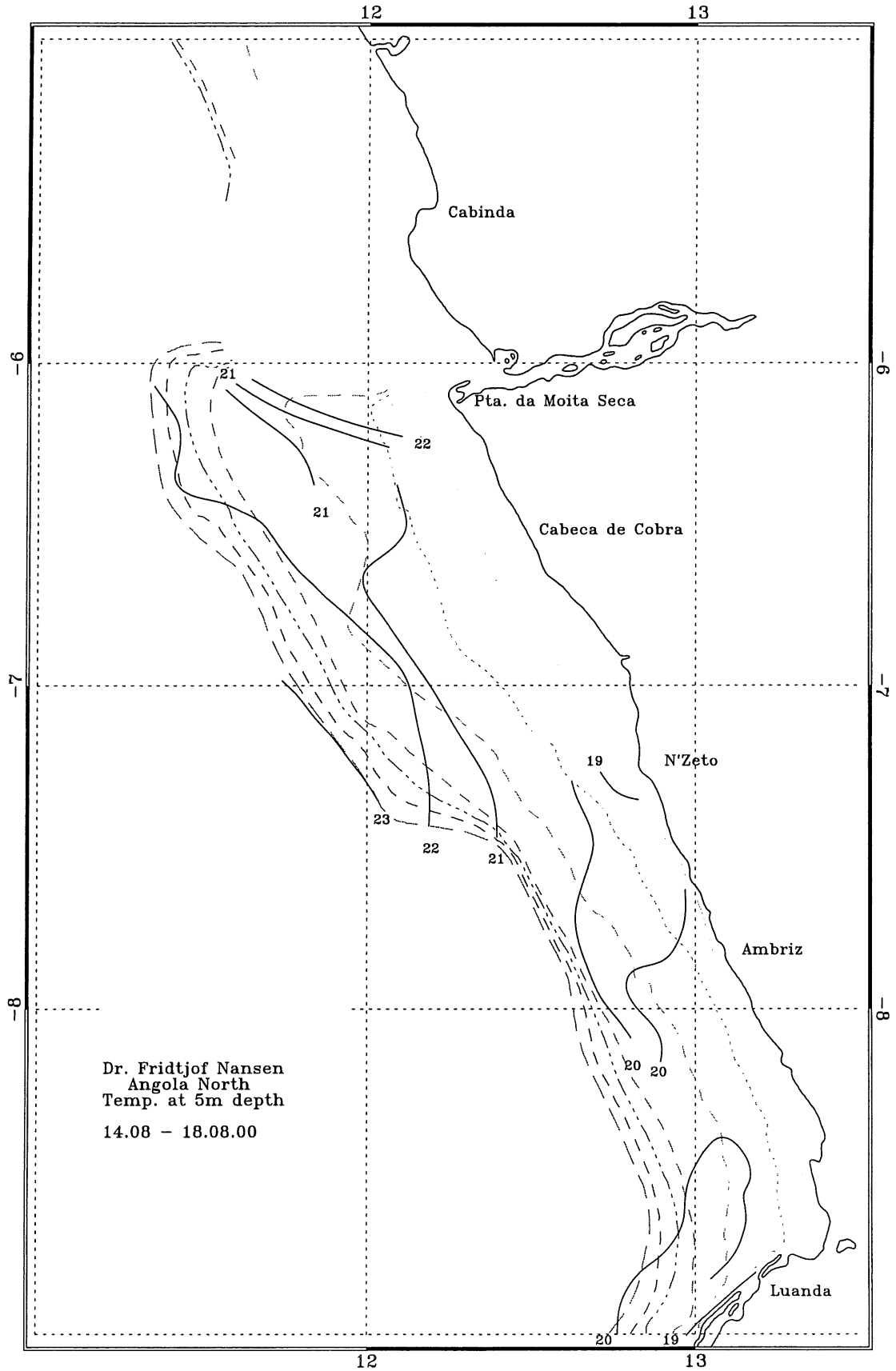


Figure 2a. Horizontal distribution of temperature (°C), Congo River – Pta das Palmerinhas.

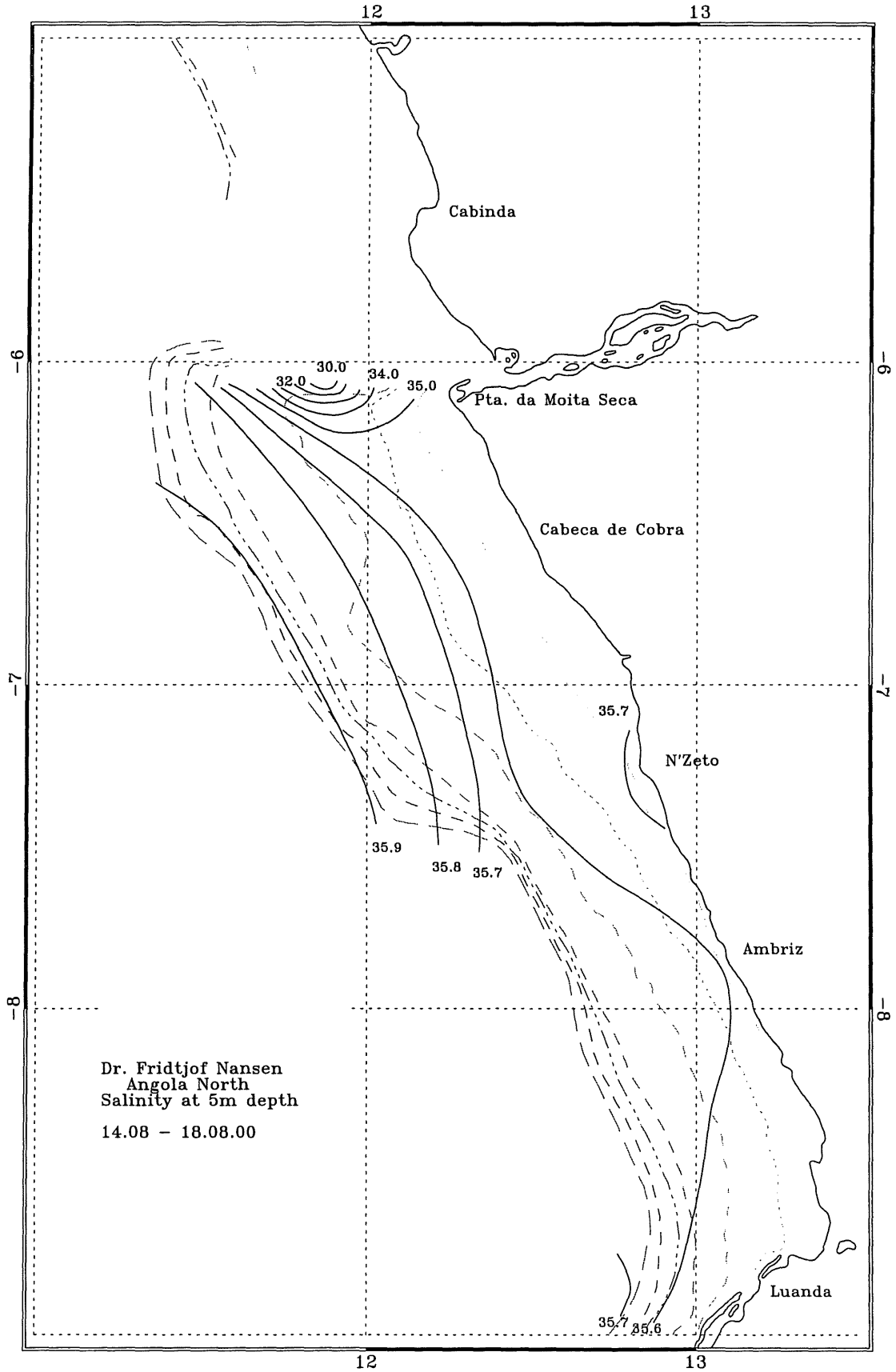


Figure 2b. Horizontal distribution of salinity (‰), Congo River – Pta das Palmerinhas.

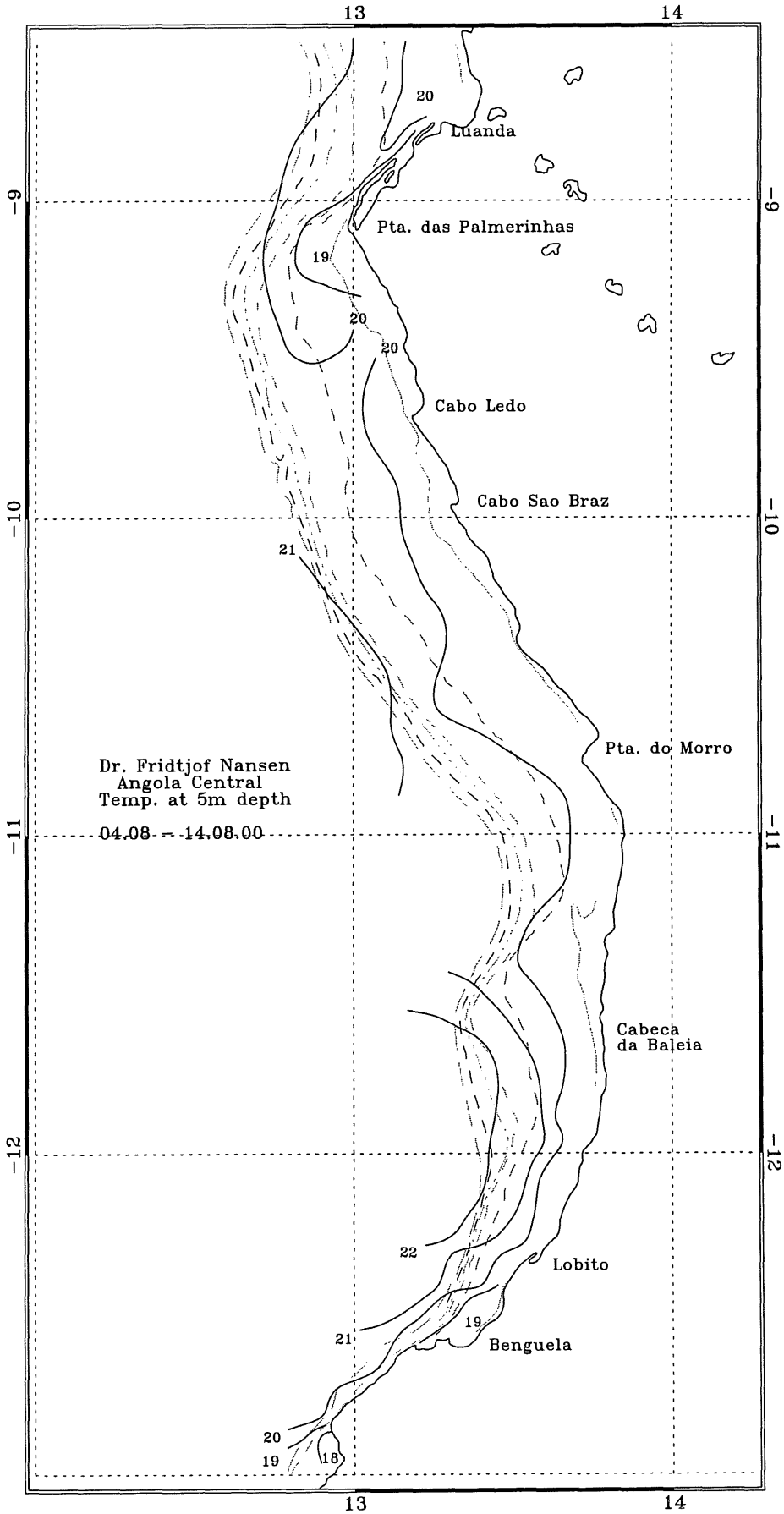

13
14
-9
-10
-11
-12
20
Luanda
Pta. das Palmerinhas
19
20
20
Cabo Ledo
Cabo Sao Braz
21
Pta. do Morro
Dr. Fridtjof Nansen
Angola Central
Temp. at 5m depth
04.08 - 14.08.00
Cabeca
da Baleia
22
Lobito
19
21
Benguela
20
19
18

Figure 3a. Horizontal distribution of temperature (°C), Pta das Palmeirinhas – Benguela.

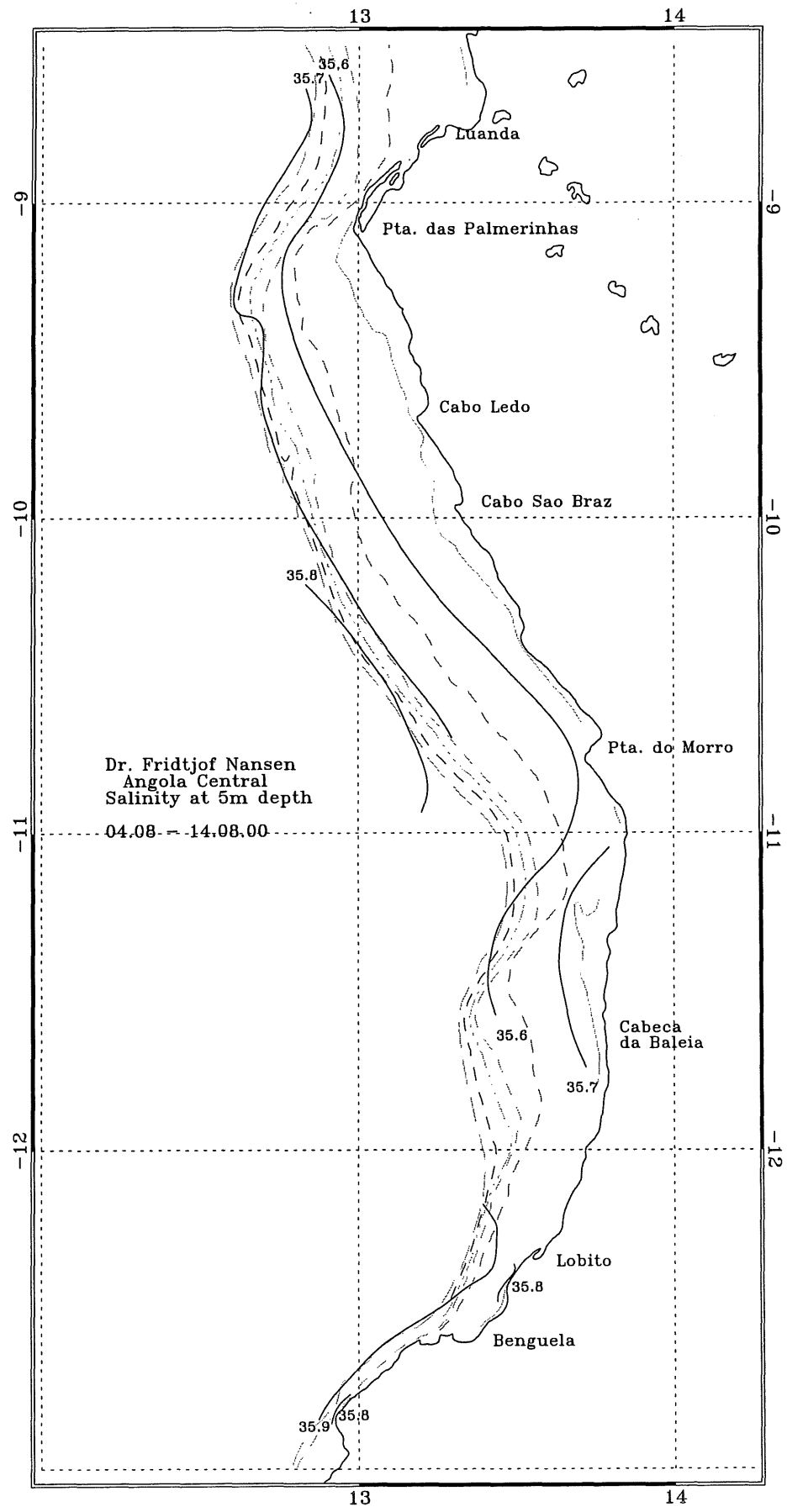

13
14
-9
-10
-11
-12
35.6
35.7
Luanda
Pta. das Palmerinhas
Cabo Ledo
Cabo Sao Braz
35.8
Pta. do Morro
Dr. Fridtjof Nansen
Angola Central
Salinity at 5m depth
04.08 - 14.08.00
35.6
Cabeca
da Baleia
35.7
Lobito
35.8
Benguela
35.9
35.8

Figure 3b. Horizontal distribution of and salinity (psu), Pta das Palmeirinhas – Benguela.

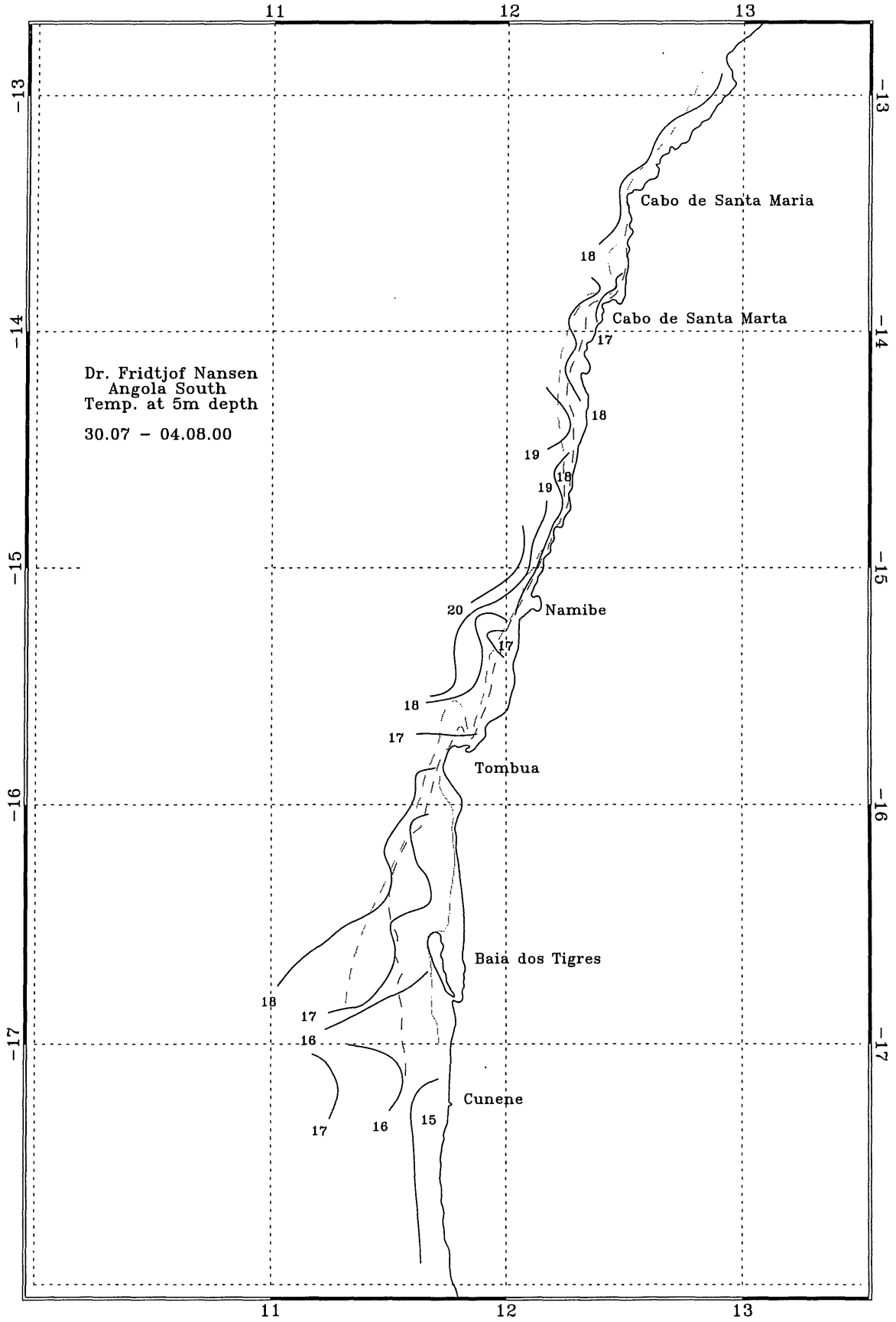


Figure 4a. Horizontal distribution of temperature (°C), Benguela – Cunene.

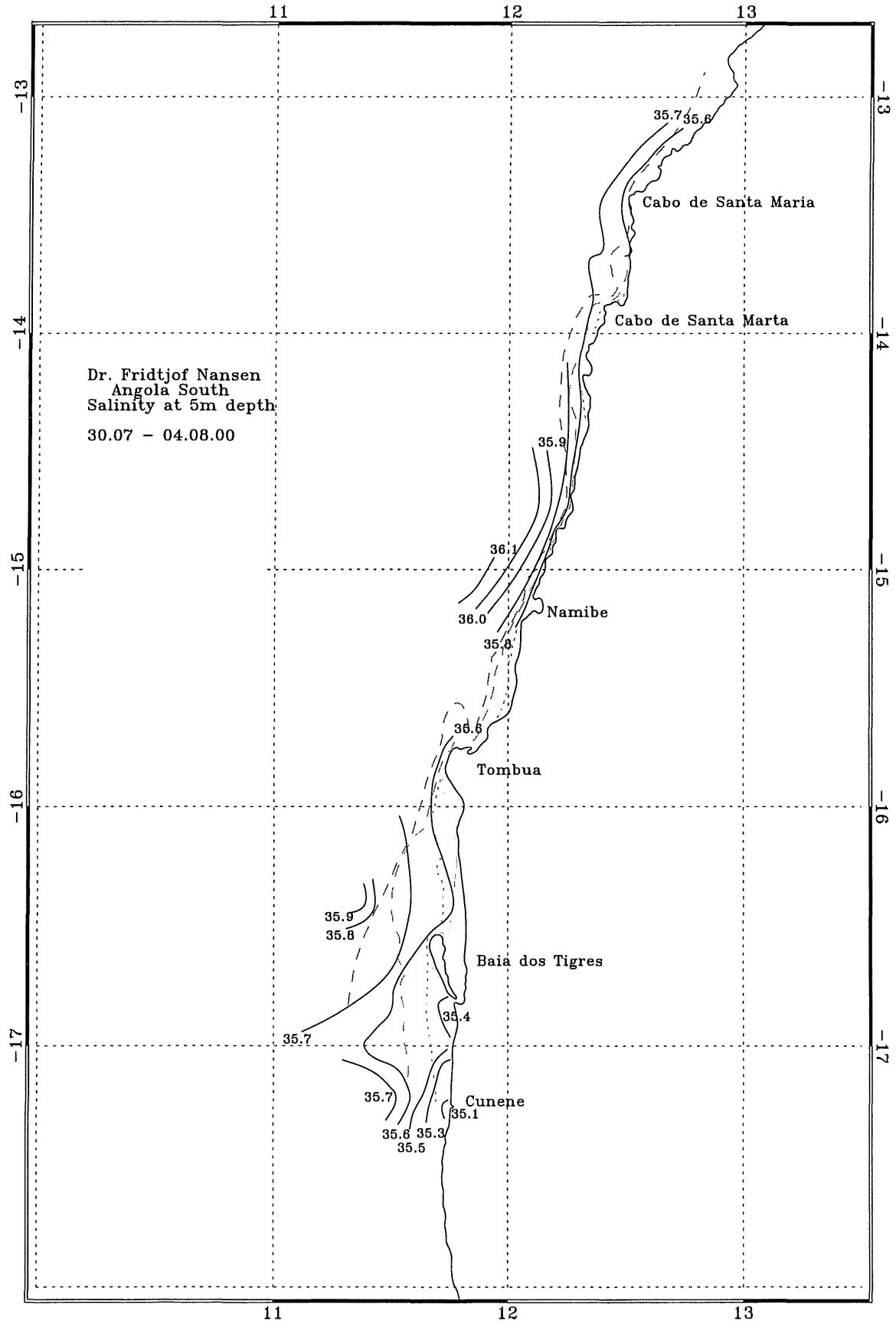


Figure 4b. Horizontal distribution of salinity (psu), Benguela – Cunene.

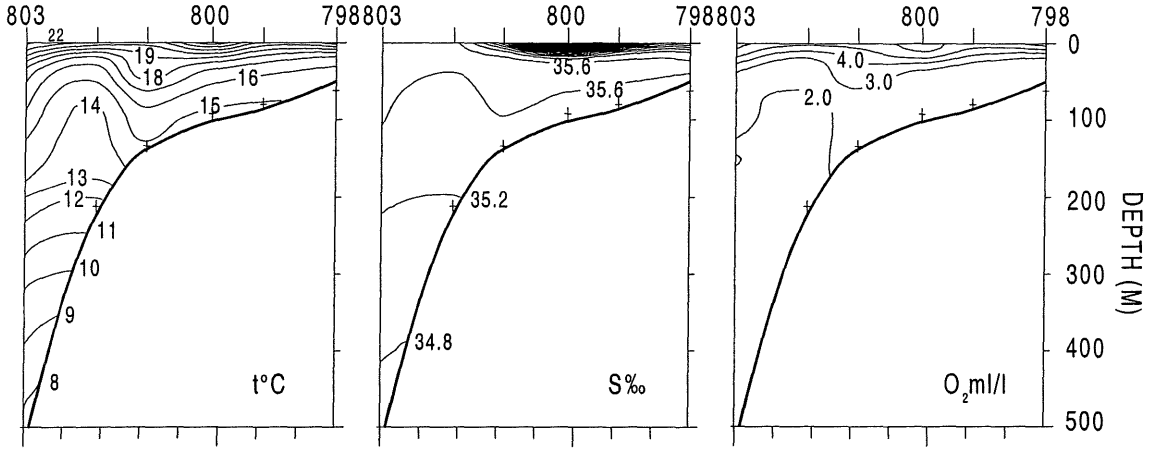
Vertical distribution

The vertical distributions of temperature, salinity and oxygen along the standard sections are shown in figure 5.

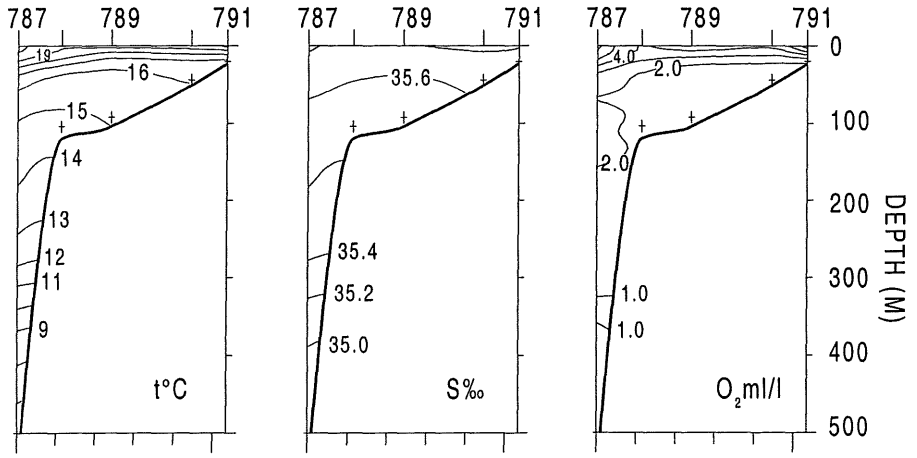
The profile of Ponta da Moita seca shows the presence of low-salinity water (22.3 psu) from the Congo River and the strong stratification in upper layer due the dynamic of the both the Angolan current and the Congo River runoff. As in southern and central regions, oxygen depletion was observed below 40 m depth.

The section of Ponta das Palmerinhas shows a strong stratification in the upper layer, probably due the presence of freshwater coming from Cuanza River. The thermocline was located about 30 m depth. The influence of Cuanza River is also evident from the presence of a thin low-salinity layer (35.4 psu) (station 776). The figures reveal two different water masses: one in the upper layer characterized by mixing process and another below 200 m depth characterized by flat isolines (no mixing processes). At Lobito, the profile, the vertical distribution of temperature and salinity show nearly the same structure as in August 1998; isolines bent toward surface and thermocline located at about 30 m depth. However, oxygen-deficient water dominated from 40 m depth and downwards.

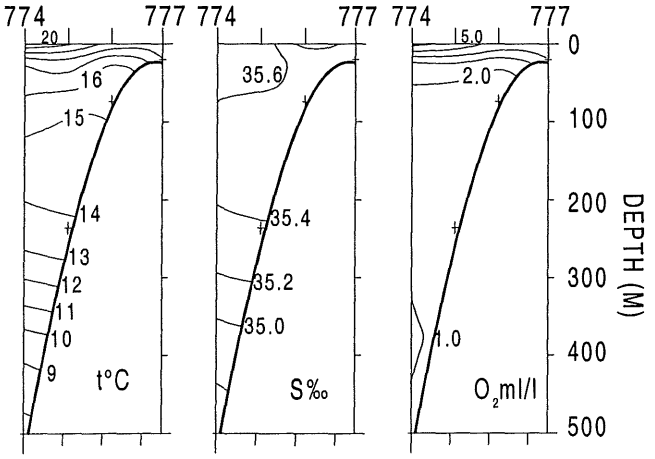
In the hydrographical section at Baía dos Tigres in the southern region, slightly inshore elevated isolines of temperature and salinity indicates light coastal upwelling in shallow waters. Deeper than 200 m the oxygen is lower than 1.0 ml/l, and very low values (< 0.5 ml/l) were recorded around 300-350 m depth. Summarizing, most of the area of the Angolan – Benguela front showed a stratified vertical structure characteristic for weak mixing processes and an almost absent thermocline.



a) Pta da Moita Seca 18.08.2000

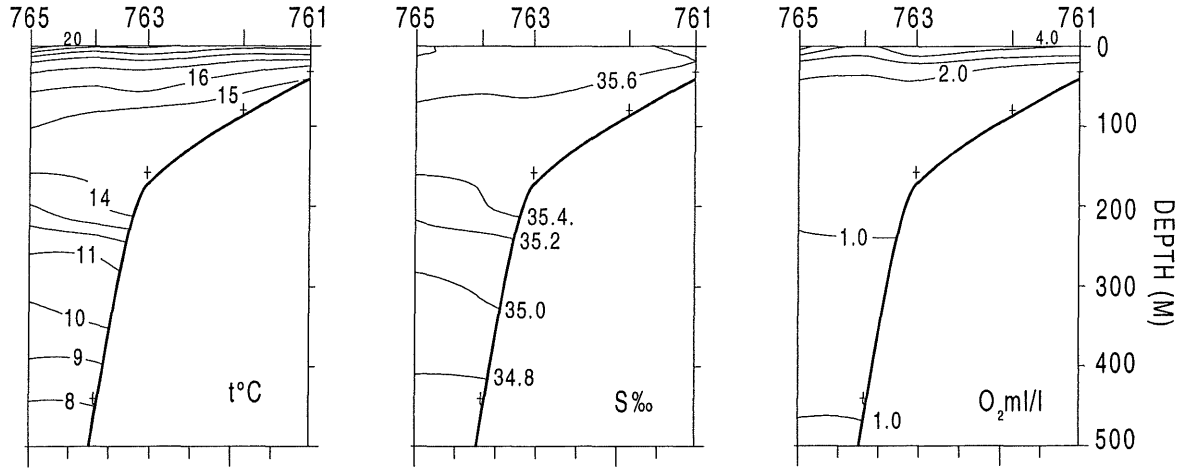


b) Ambriz 15.08.2000

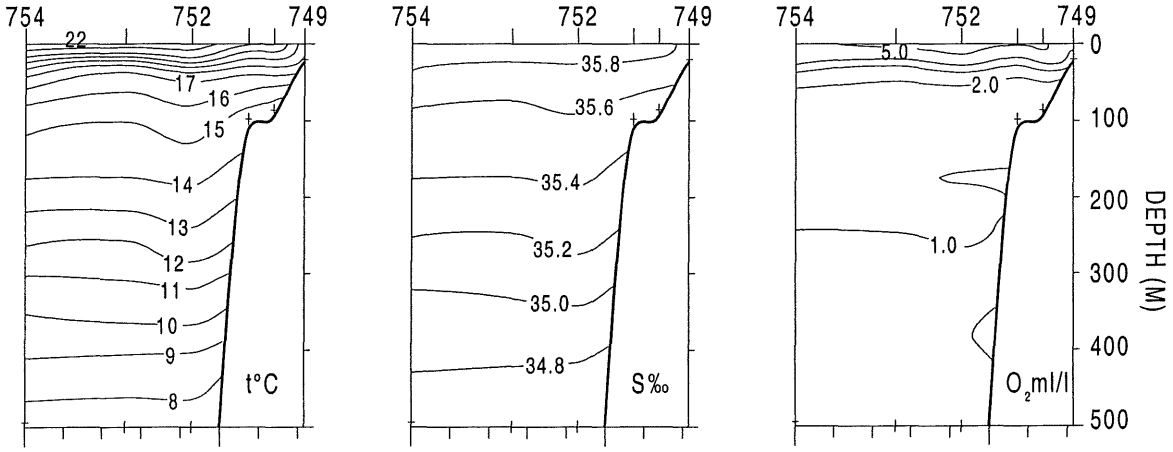


c) Ponta das Palmeirinhas 13.08.2000

Figure 5. Vertical profiles of temperature (°C), salinity (psu) and oxygen (ml/l).

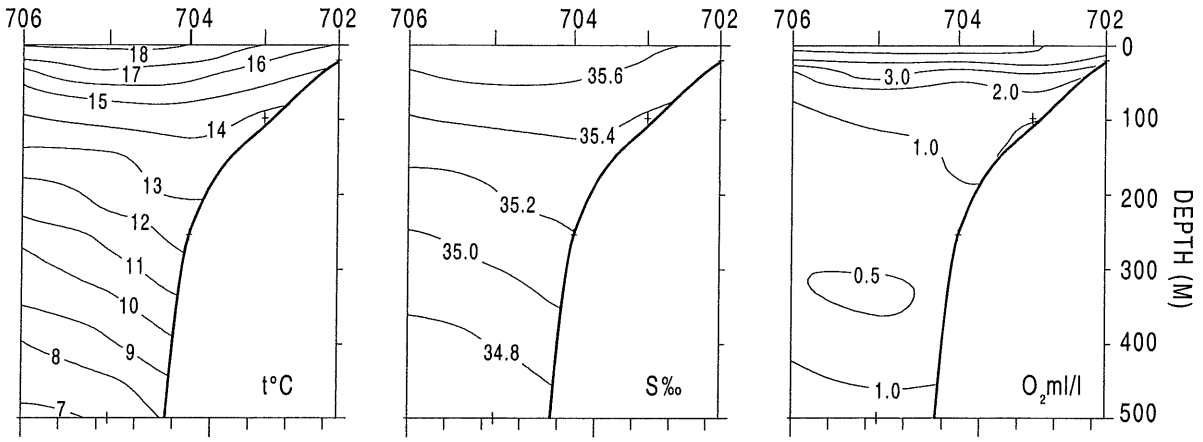


d) Ponta do Morro 09.08.2000



e) Lobito 06.08.2000

Figure 5. Continued.



f) Baía dos Tigres 31.07.2000

Figure 5. Continued.

Wind conditions

The wind conditions along the cruise track are presented in figure 6. Weak to moderate, southern or south-eastern winds prevailed throughout the survey area.

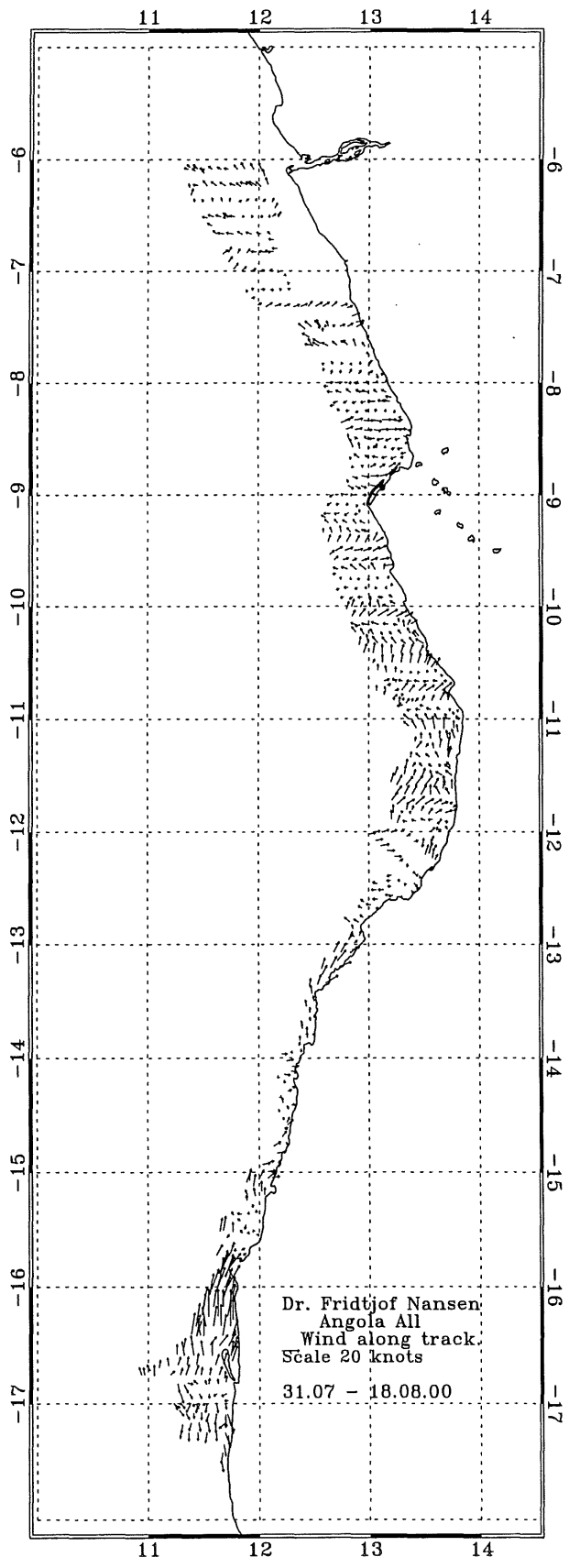


Figure 6. Wind measurements. Congo River to Cunene River.

CHAPTER 4 DISTRIBUTION, COMPOSITION AND BIOMASS ESTIMATES OF PELAGIC FISH

4.1 Congo River - Pta das Palmeirinhas

4.1.1 Sardinella

Both sardinella species *Sardinella maderensis* and *S. aurita* were found in patches throughout the area, the former both inshore and offshore and the latter only offshore (figure 7). Compared to last year, the distribution seemed was more patchy, covering a smaller total area. While the densities last year were generally low, high density spots were found both inshore ($300 < s_A < 1000$, north of Luanda) and offshore ($1000 < s_A < 3000$, south of N'Zeto). Like last year, the shallow waters between N'Zeto and Pta. da Moita Seca could not be covered because of the oil drilling activity. Sardinella was usually observed and caught in the upper water layers, schooling near the surface during daytime and forming loose aggregations during night time, but was sometimes observed to exhibit vertical avoidance down to about 80 m during trawling.

Figure 8 shows the length frequency distribution of S. *maderensis* and S. *aurita*. The S. *maderensis* ranged from 25 cm to 35 cm total length, without any clear modal length. For S. *aurita*, the distribution ranged from 26 to 38 cm.

The biomass of sardinella was estimated at 173 000 tonnes, which is about 30 % higher than last year (135 000 tonnes). From the total, around 88 000 tonnes was S. *madarensis* and 86 000 tonnes S. *aurita*. Figure 9 shows the cumulative distribution of the biomass. For S. *madarensis*, the bulk of the biomass consisted mainly of individuals larger than 32 cm, while most of the S. *aurita* (90 %) was < 35 cm.

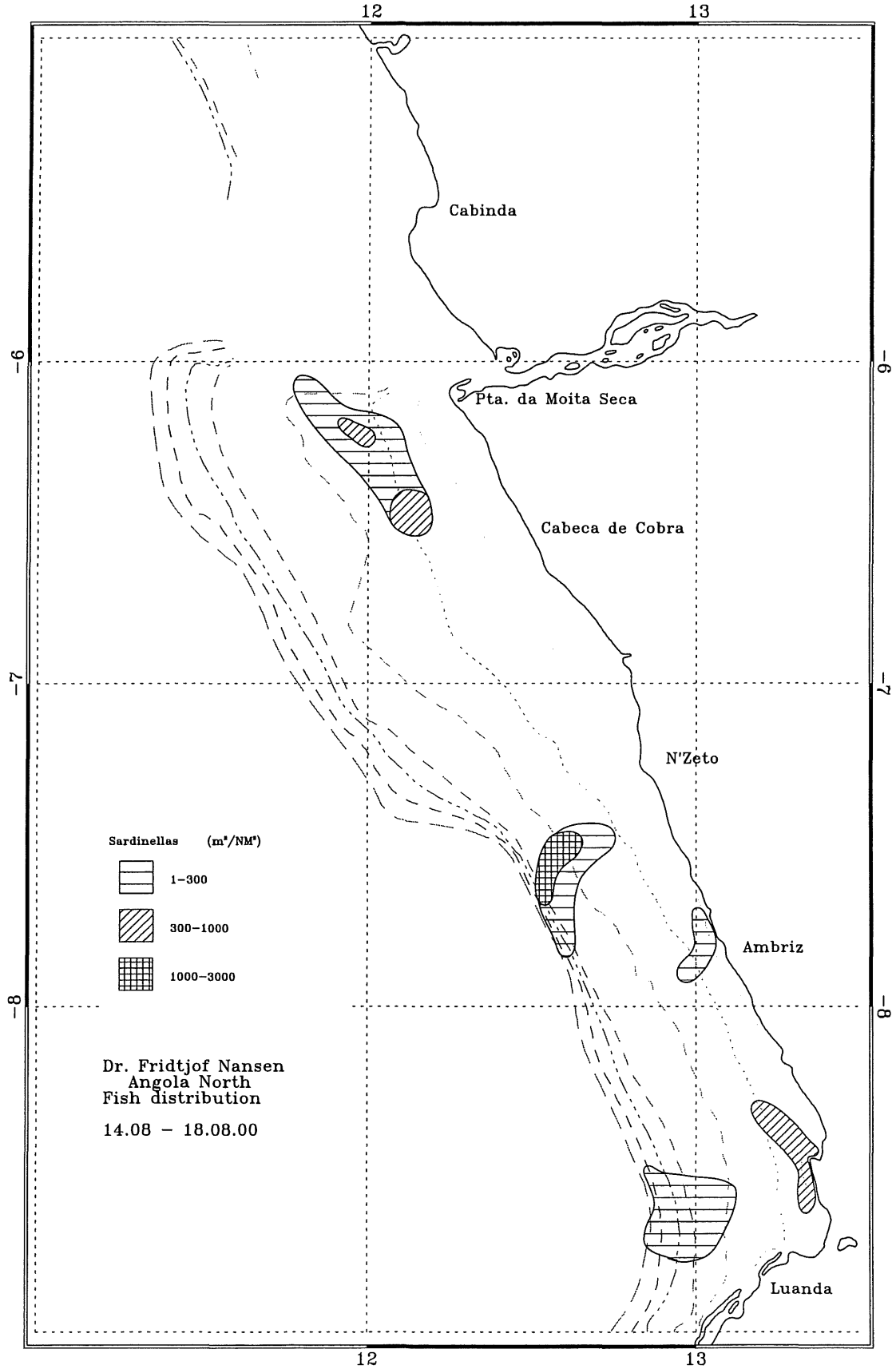
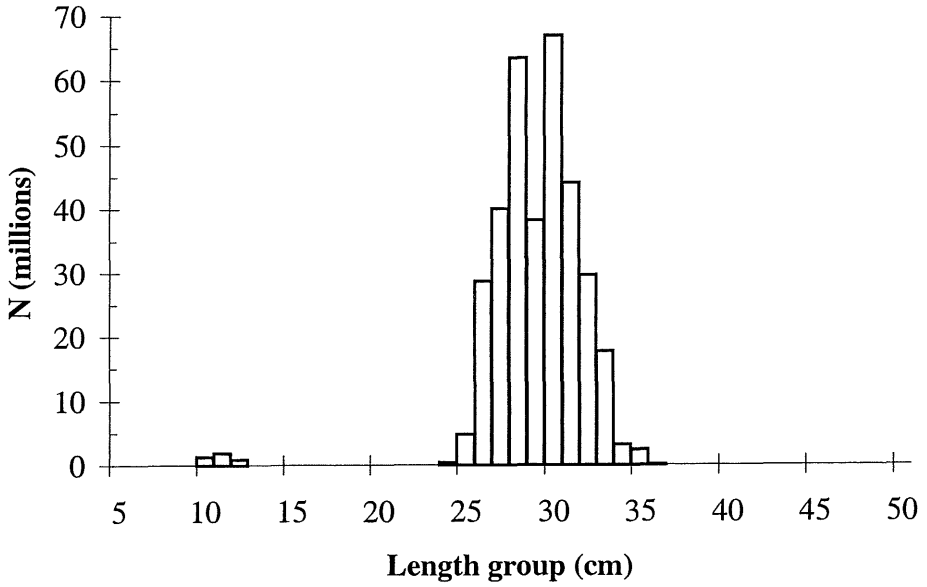
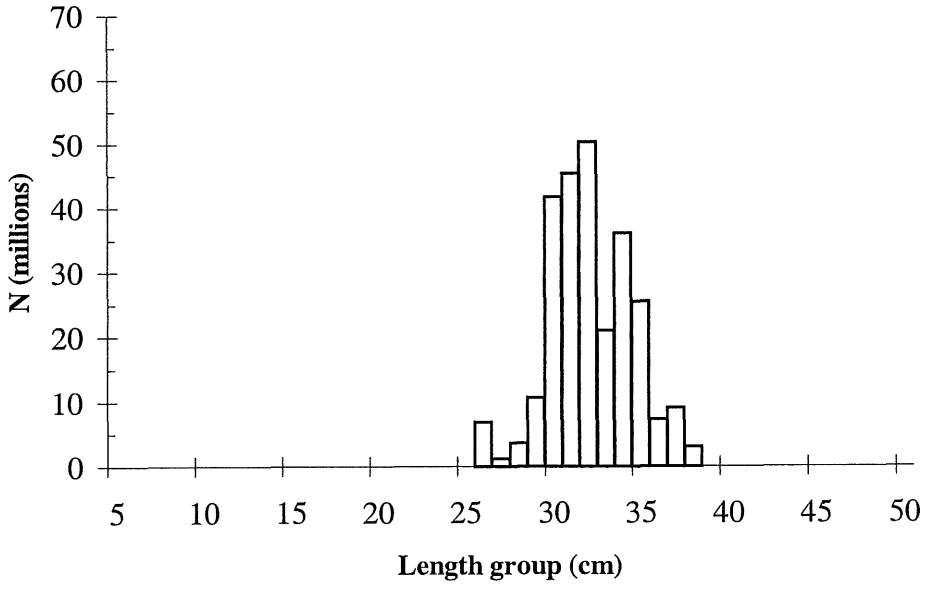


Figure 7. Distribution of *Sardinella* spp.Congo River-Pta das Palmeirinhas.

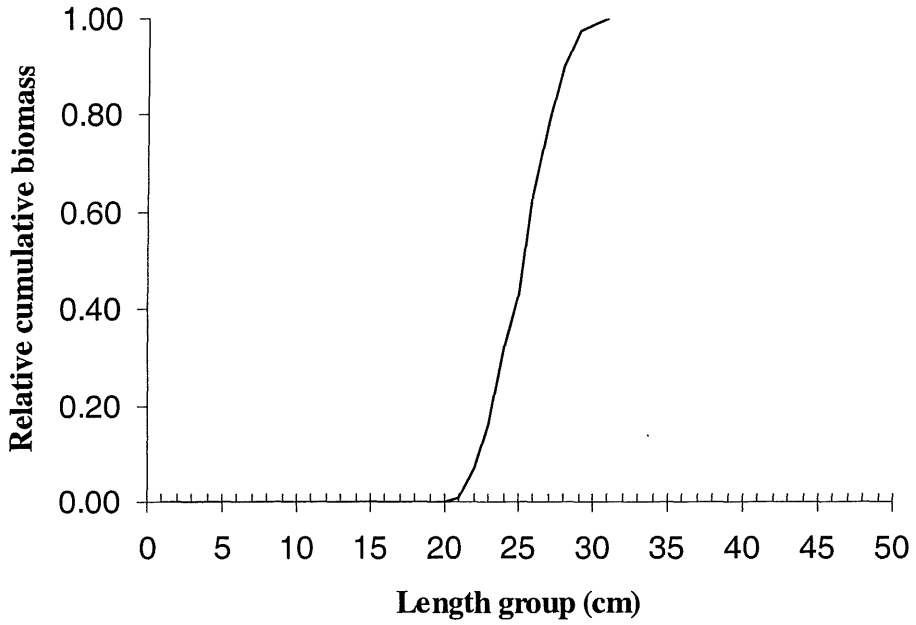


a) *Sardinella maderensis*

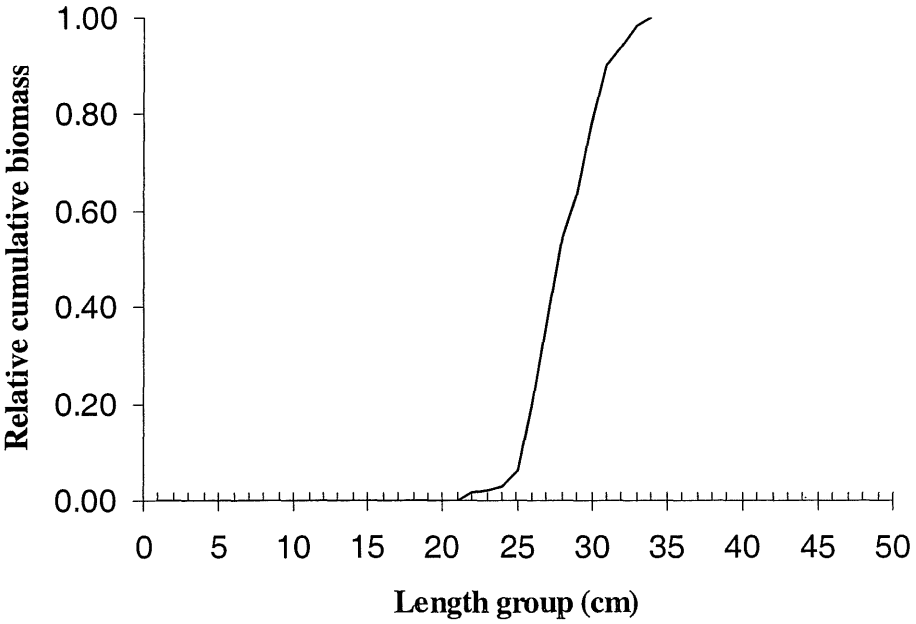


b) *Sardinella aurita*

Figure 8. Total length distribution of flat *Sardinella maderensis* (a) and S. *aurita* (b), Congo River-Pta das Palmeirinhas.



a) *Sardinella madarensis*



b) *Sardinella aurita*

Fig 9. Relative cumulative biomass *Sardinella madarensis* (a) and S. *aurita* (b), Congo River-Pta das Palmeirinhas

4.1.2 Cunene horse mackerel

Figure 10 shows the distribution of horse mackerel for the region. Like usually, only *Trachurus trecae* was found in this region, located in three main patches. Like last year, the densities were generally low (s_A< 300), but one area of intermediate density (300< s_A< 1000) was found inshore, south of Ambriz (8 ° S).

Figure 11 shows the length frequency distribution of horse mackerel for the region. The distribution showed two main groups, one from 15 cm to 25 cm, and one from 30 cm to 45 cm total length. For the larger group, the peak was around 32 cm. Fish between 25 cm and 30 cm were poorly presented in the catches, while length groups between 20 cm and 25 cm were absent last year. Juvenile fish (< 15 cm) were caught only inshore (PT 2411), south of Ambriz.

The estimated biomass of T. *trecae* was about 63 000 tonnes for the northern region, compared to 68 000 tonnes last year. Most of the biomass (about 90 %) was comprised of fish < 35 cm total length (figure 12).

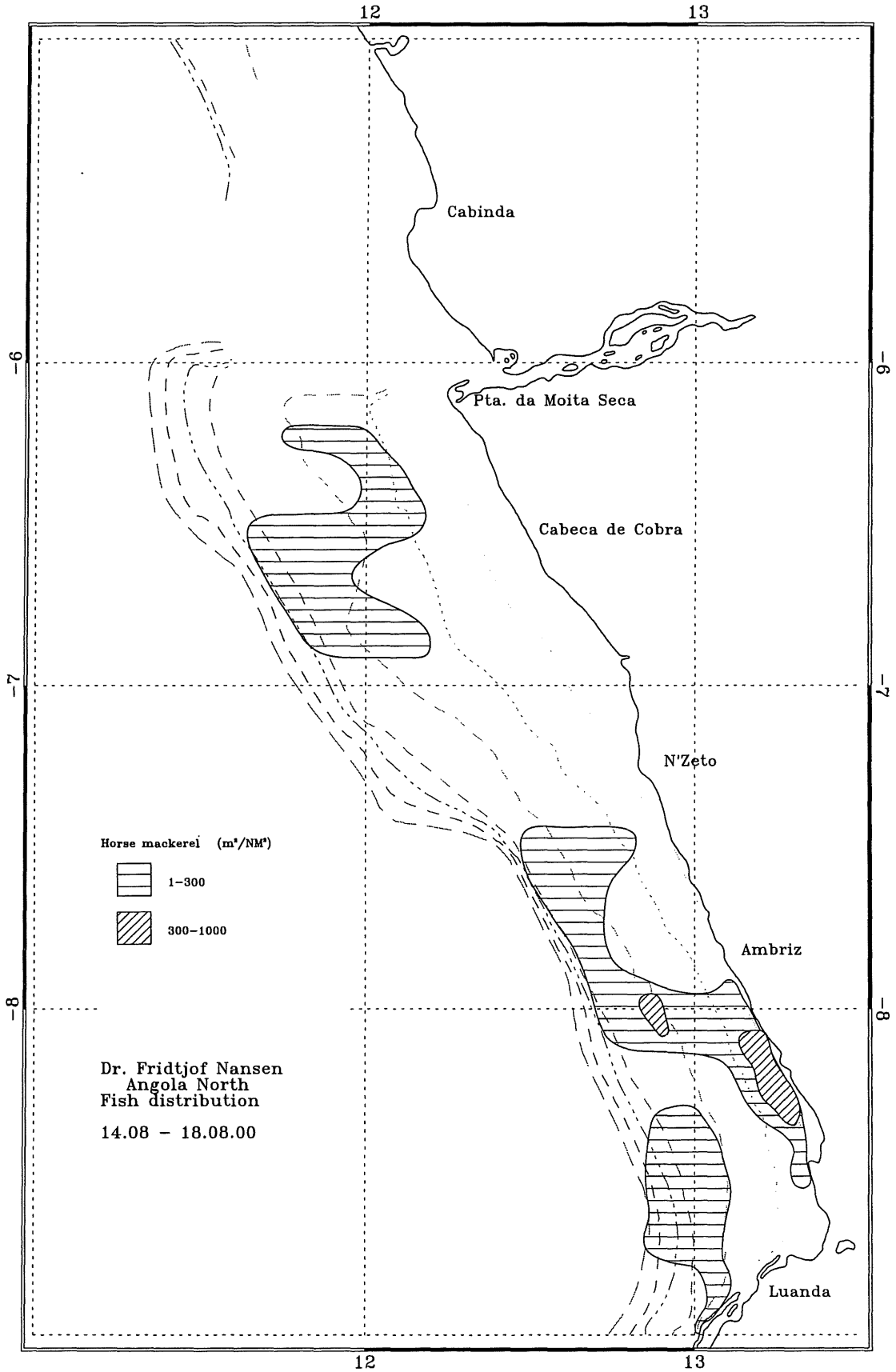


Figure 10. Distribution of Cunene horse mackerel (*Trachurus trecae*), Congo River - Pta das Palmeirinhas

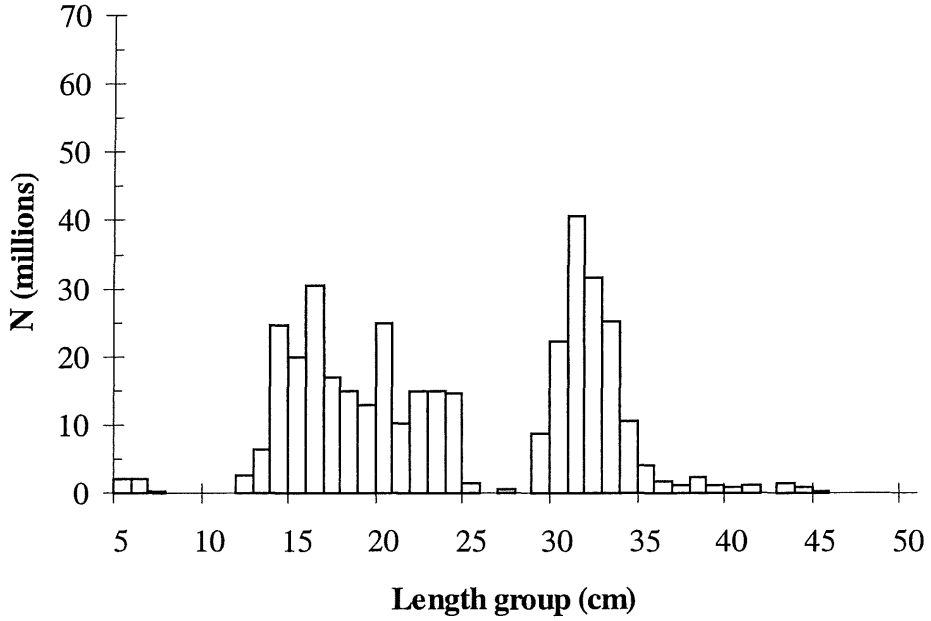


Figure 11. Total length distribution of Cunene horse mackerel (*Trachurus trecae*), Congo River - Pta das Palmeirinhas.

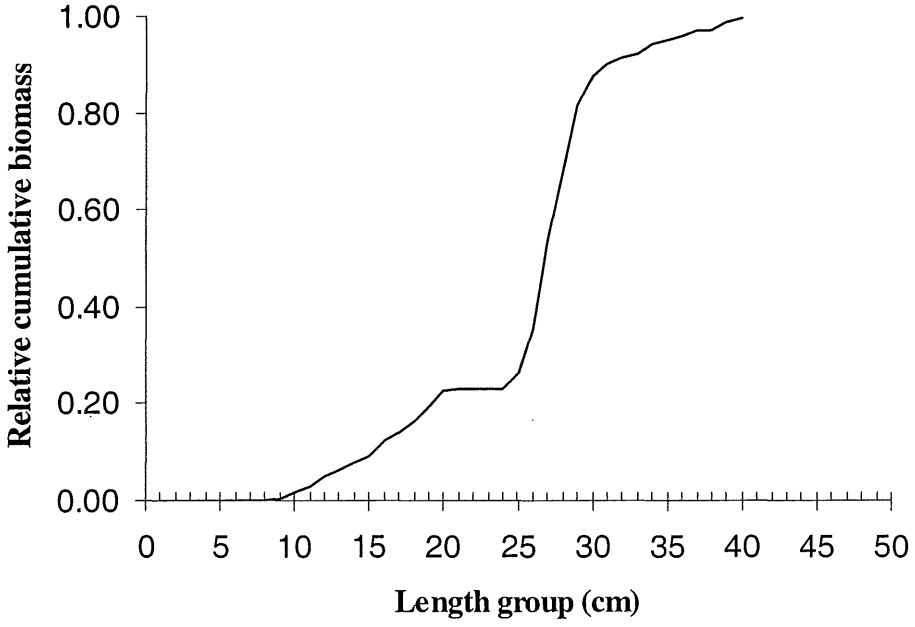


Figure 12. Cumulative percentage biomass by length group, *Trachurus trecae*. Congo River-Pta das Palmeirinhas

4.1.3 Other pelagic species

4.1.3.1 Group1 (i.e. clupeiformes)

Only one species belonging to the other pelagic species group 1, *Ilishia africana*, was caught in the northern region. Consequently, no distribution map or biomass estimate is provided for this group.

4.1.3.2 Group 2 (i.e other carangids)

This category, which includes members of the family Carangidae (other than horse mackerels), species of the family Scombridae, Sphyraenidae and *Trichiurus lepturus*, was widely distributed in the region (figure 13). The scombrids was the dominant species group, followed by hairtail (*Trichurus lepturus*) (Table 2). One of the most common carangid species, *Chloroscombrus chrysurus*, was absent from the catches.

The biomass estimate, based on an average length of 30 cm and a condition factor equal to 0.01, resulted in 68 000 tonnes, which is exactly the same as last year.

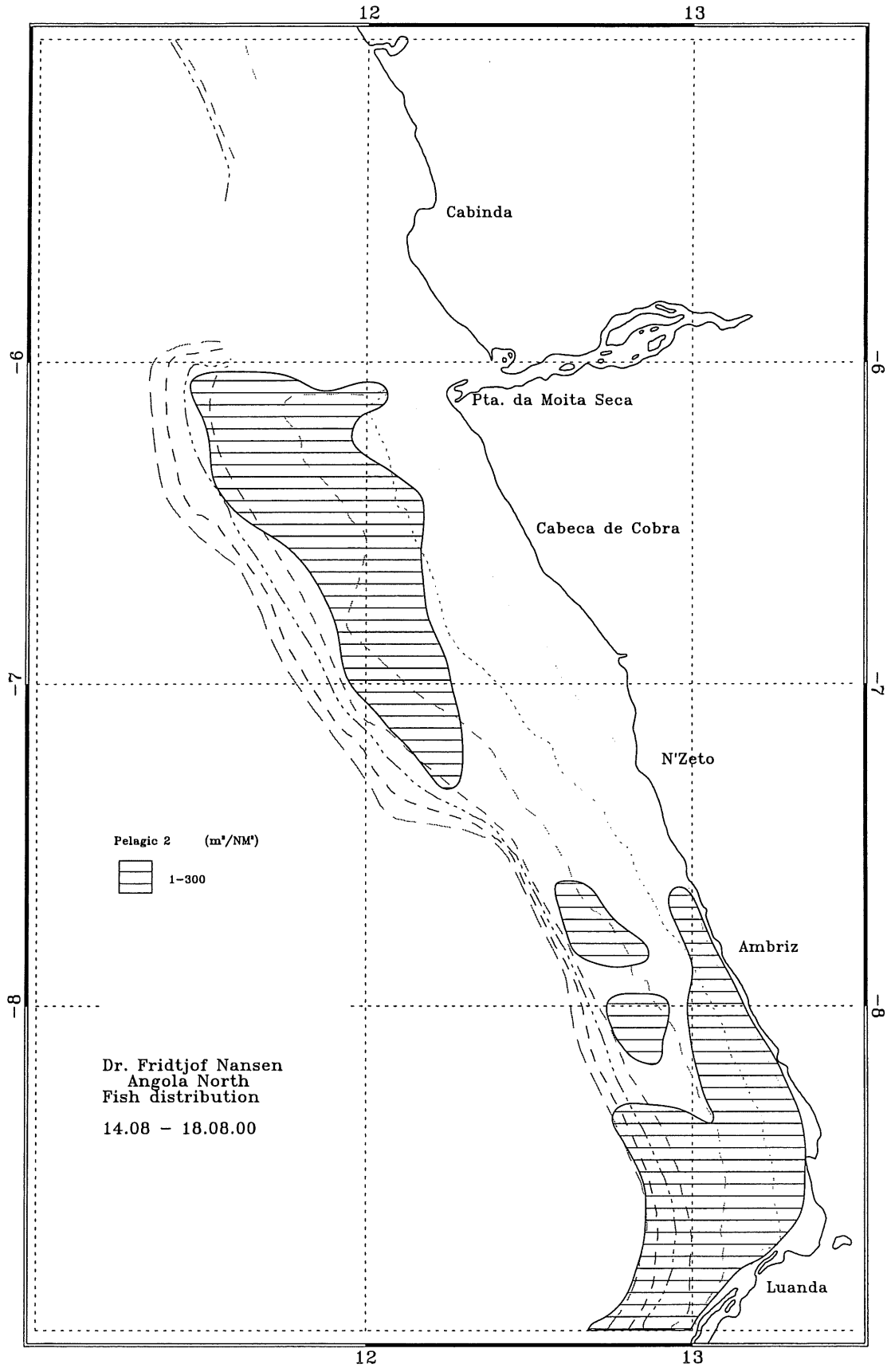


Figure 13. Distribution of other pelagic species, Congo River - Pta das Palmeirinhas.

Table 2. Catch rates (kg/h) of the main groups of pelagic fish. Congo River-Pta das Palmeirinhas

Station	Ilishia sp.	Carngids	Barracudas	Scombrids	Haitail	Other	
2401				18.35		86.19	136.11
2402				19.00		64.92	476.60
2403				1.94		59.88	409.29
2404		48.60				36.29	1790.75
2405				5.24		30.05	123.09
2406		0.76				55.70	546.42
2407		7.58		15.34			2364.56
2408		108.90	19.80	16.10		117.90	7199.10
2409						6.50	231.99
2410		14.59		19.12		41.38	1170.18
2411		3.44		2.29		20.56	967.40
2412	15.23	166.02		7.61		19.41	2830.50
2413	4.58	3.93	1.72	4.42		20.78	502.25
2414		61.20		20.40		842.40	249.60
2415		0.02					0.04
2417		3.60					23.40
2418		14.36				2.77	79.99
2419						61.76	512.00
2420				2807.40		14.08	1257.00
2421		115.36		10.88		5.00	138.24
2422		8.88		5.28			490.02
2423		3.91					0.04
2424							1643.40
2425		36.42		6.99		14.47	442.25
	MEAN	0.79	23.90	0.86	120.25	60.00	943.37

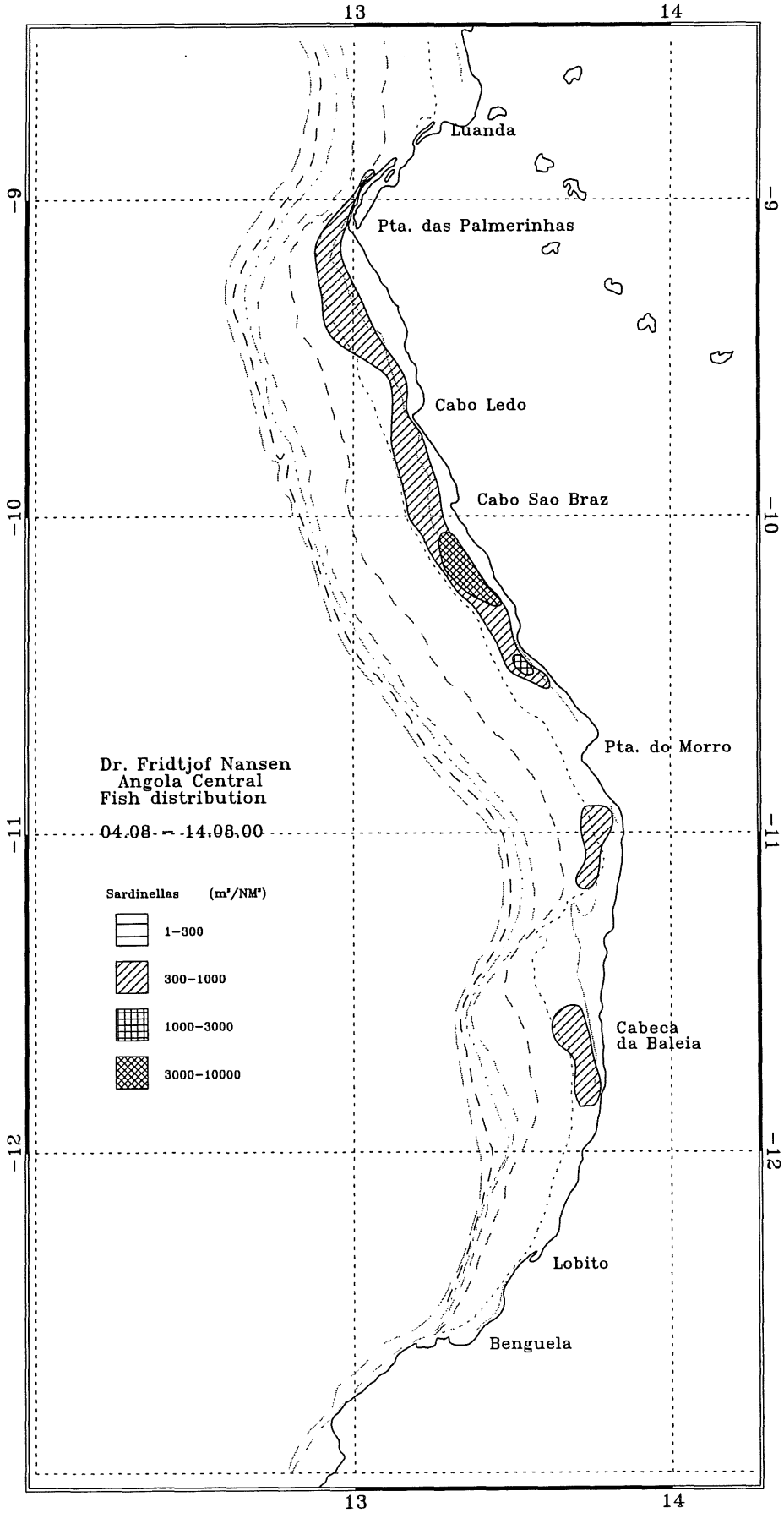
4.2 Luanda-Benguela

4.2.1 Sardinella

The flat sardinella (*Sardinella maderensis*) dominated also in this area. The round sardinella (S. *aurita*) was caught only in two of the hauls, PT 2396 (10 ° 10' S) and PT 2399 (9 ° 24' S). In the first sample, only five individuals were caught. The survey took place in the same period as the winter survey of 1999, but during the present survey, the sardinella seemed to have a more inshore and northward distribution compared to last year. One area of high densities was recorded inshore immediately south of Cabo São Braz (10 ° S) (figure 14). The density level was similar to last year, but the overall distribution area was much smaller.

The size distributions of S. *madarensis* showed that a year class with a mode of 30-33 cm total length dominated throughout the area. However, a cohort with modal length around 24 cm and a juvenile cohort with modal length around 10 cm was recorded south of Ponta das Palmerinhas (9 ° S). The S.*aurita* at Cabo São Braz (10 ° 10' S) was 31-34 cm, while the specimens caught at Ponta das Palmerinhas (9 ° 24' S) averaged around 24 cm. The small size classes are known to occur in very shallow waters that cannot be covered by the vessel, and poor coverage of the distribution area is a probable cause of the low incidence of small sardinella in the catches. Figure 15 shows the total length frequency distribution for this species in this area. Both species of sardinella showed a bimodal length distribution pattern, with peaks around 23-24 cm and 30-31 cm total length. Individuals <33 cm comprised most of the total biomass (about 90 %) of both sardinella species (figure 16).

The biomass estimate resulted in 179 000 tons. The S. *madarensis* comprised 126 000 tonnes of the total, while the S. *aurita* totalled to 23 000 tonnes. The total biomass estimates from last year survey was 228 000 tons, and the results from the present survey thus suggest a reduction of the biomass of about 20 %.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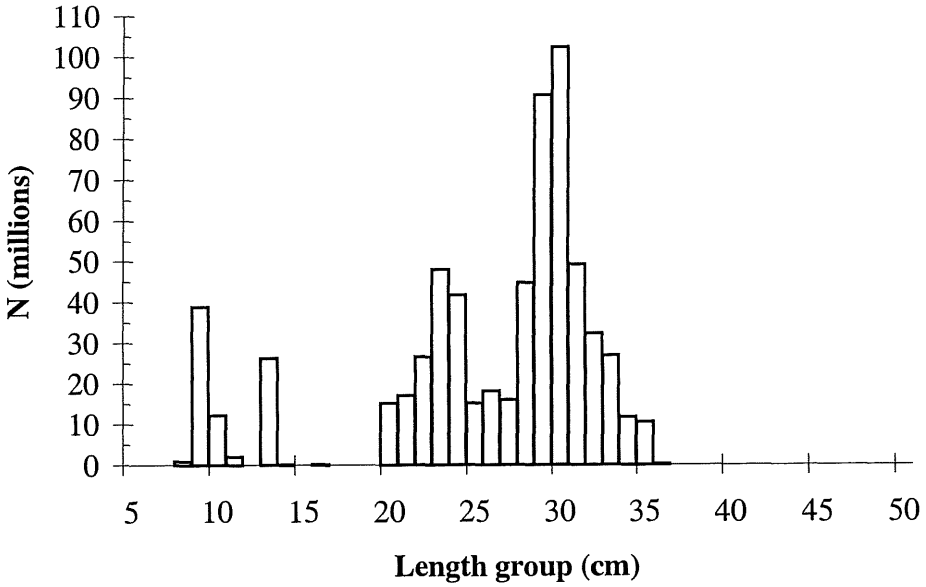
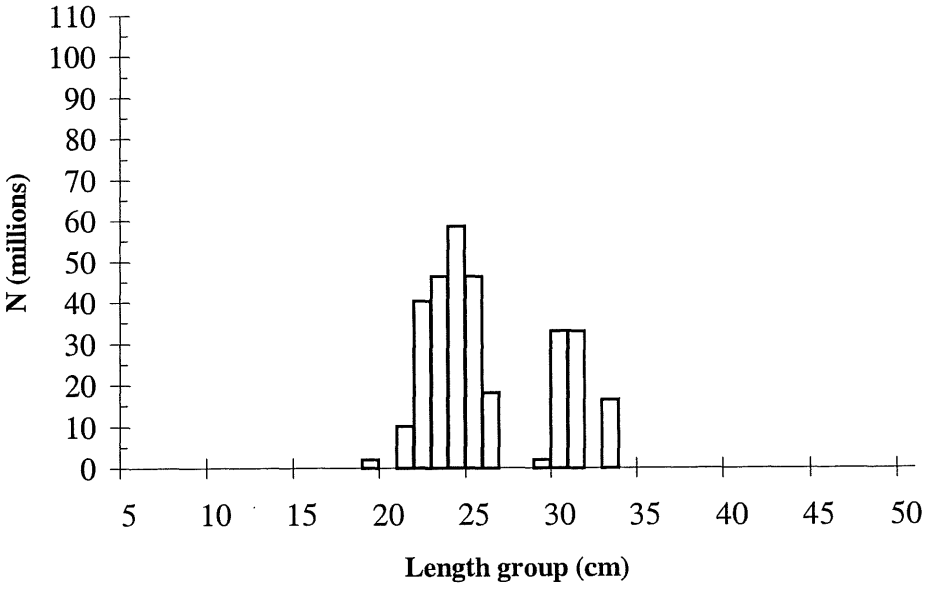
Pta. das Palmerinhas
Cabo Ledo
Cabo Sao Braz
Pta. do Morro
Cabeca
da Baleia
Lobito
Benguela
Dr. Fridtjof Nansen
Angola Central
Fish distribution
04.08 - 14.08.00
Sardinellas (m²/NM²)
1-300
300-1000
1000-3000
3000-10000

Figure 14. Distribution of *Sardinella* spp. Pta das Palmeirinhas - Benguela.

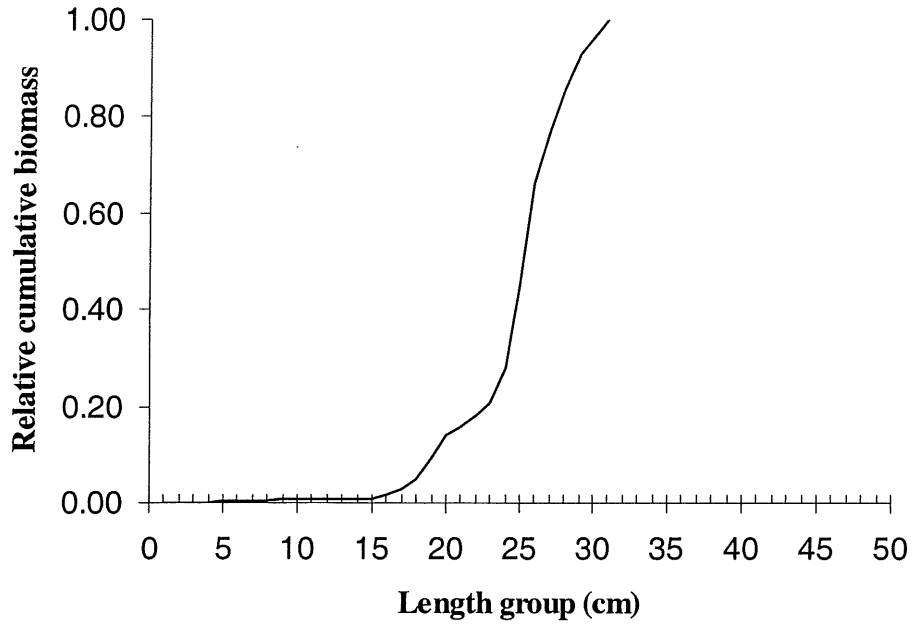


a) *Sardinella maderensis*

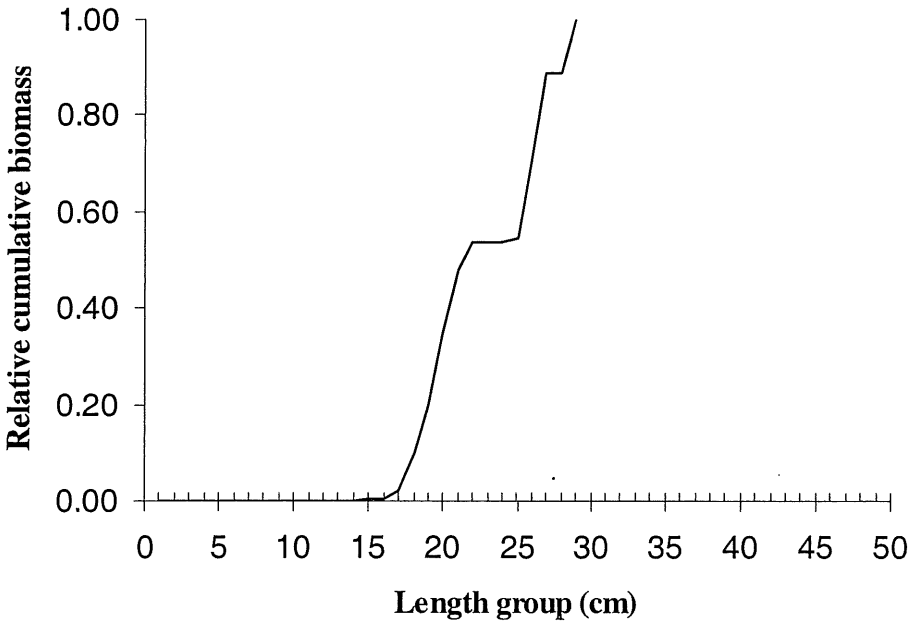


b) *Sardinella aurita*

Figure 15. Total length distribution of *Sardinella maderensis* (a) and S. *aurita* (b). Pta das Palmeirinhas – Benguela



a) *Sardinella maderensis*



a) *Sardinella aurita*

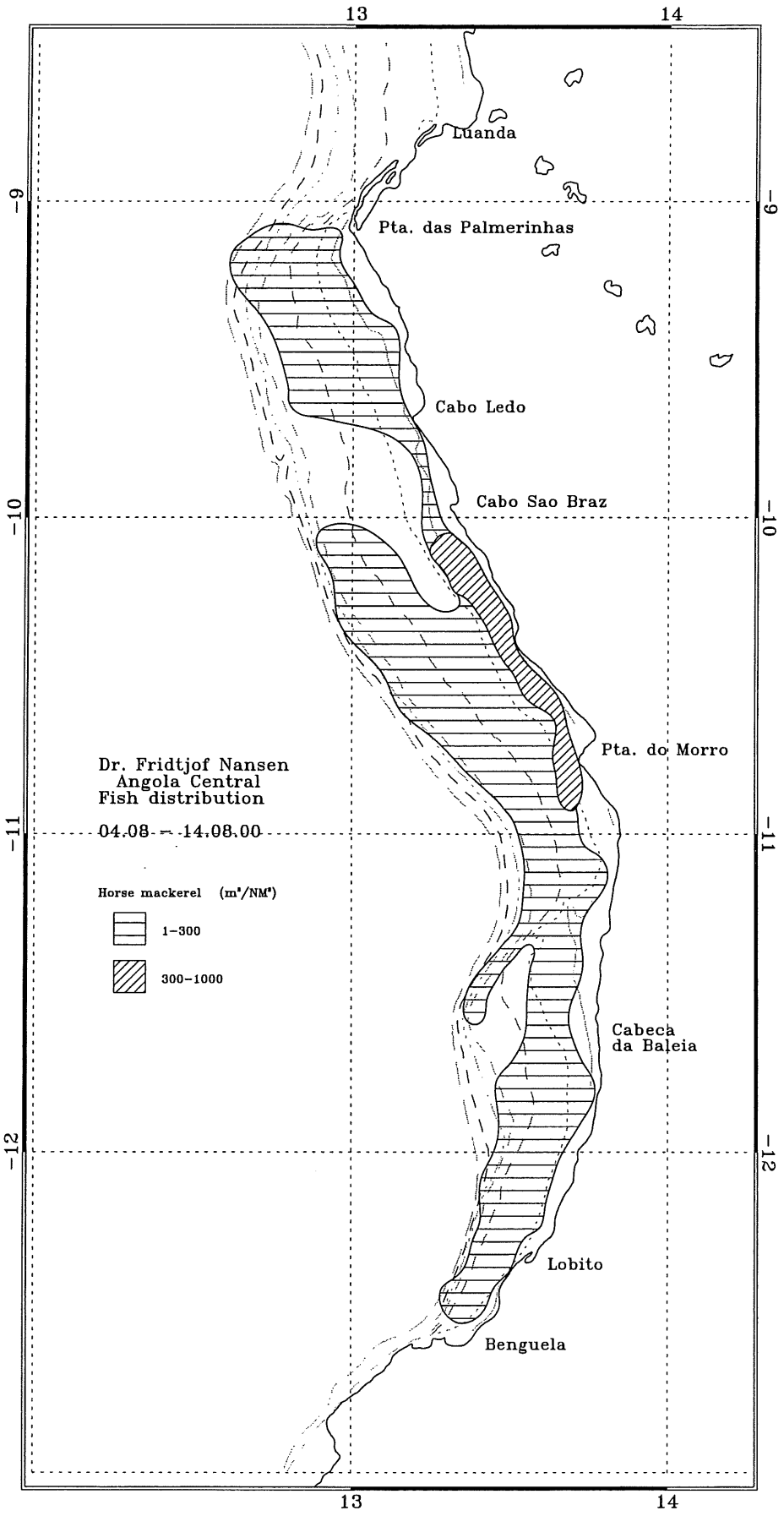
Figure 16. Relative cumulative biomass *Sardinella madarensis* (a) and S. *aurita* (b), Pta. das Palmeirinhas-Benguela.

4.2.2 Horse mackerel

Only the Cunene horse mackerel was encountered in this region. Like last year, it was widely distributed, except between Cabo Ledo and Cabo São Braz, where there only was a moderate inshore distribution. An area of relatively high densities (300 $<s_A<$ 1000 m^2 /NM^2) was located inshore from Cabo São Braz to Ponta do Morro. An offshore component was branching off the main distribution west of Cabeça da Baleia. Juvenile horse mackerel (< 20 cm) was found inshore, south of Cabeça da Baleia and at Benguela.

The biomass of Cunene horse mackerel was estimated at 178 000 tons, about 40 % higher than last year (129 000 tons). This difference may in part or entirely be due to migration from the southern region, where there was a reduction of 25 % compared to last year for this species.

Figure 18 shows the total length frequency distribution of this species. The population has a bimodal distribution pattern, with the main peak around 30-32 cm and a smaller peak around 16-18 cm. The bulk of the biomass (~90 %) consisted of individuals < 35 cm (figure 19).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Cabo Ledo
Cabo Sao Braz
Pta. do Morro
Cabeca
da Baleia
Lobito
Benguela
Dr. Fridtjof Nansen
Angola Central
Fish distribution
04.08 - 14.08.00
Horse mackerel (m²/NM²)
1-300
300-1000

Figure 17. Distribution of horse mackerel (*Trachurus trecae*), Pta das Palmeirinhas – Benguela

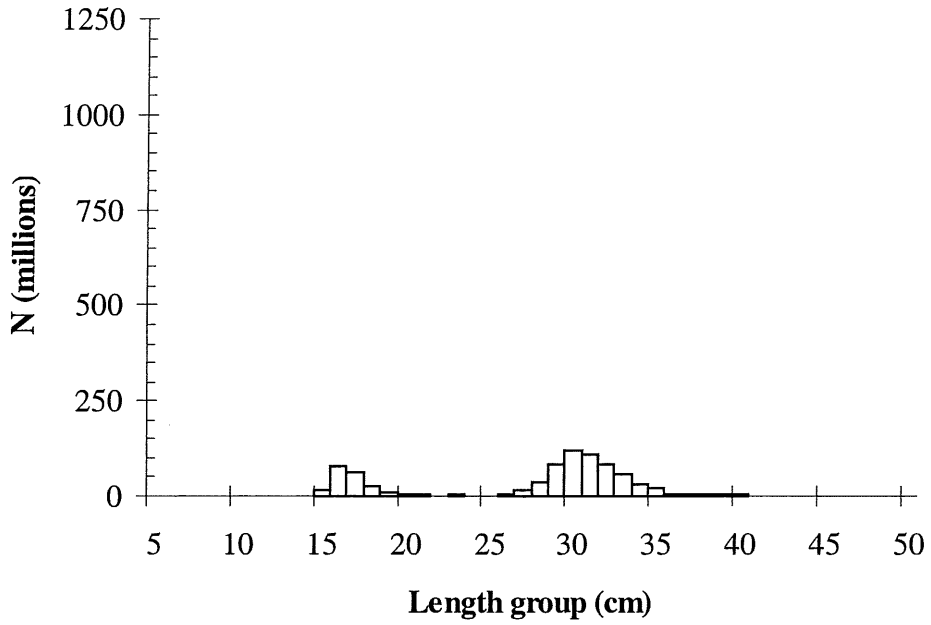


Figure 18. Total length distribution of horse mackerel (*Trachurus trecae*), Pta das Palmeirinhas-Benguela.

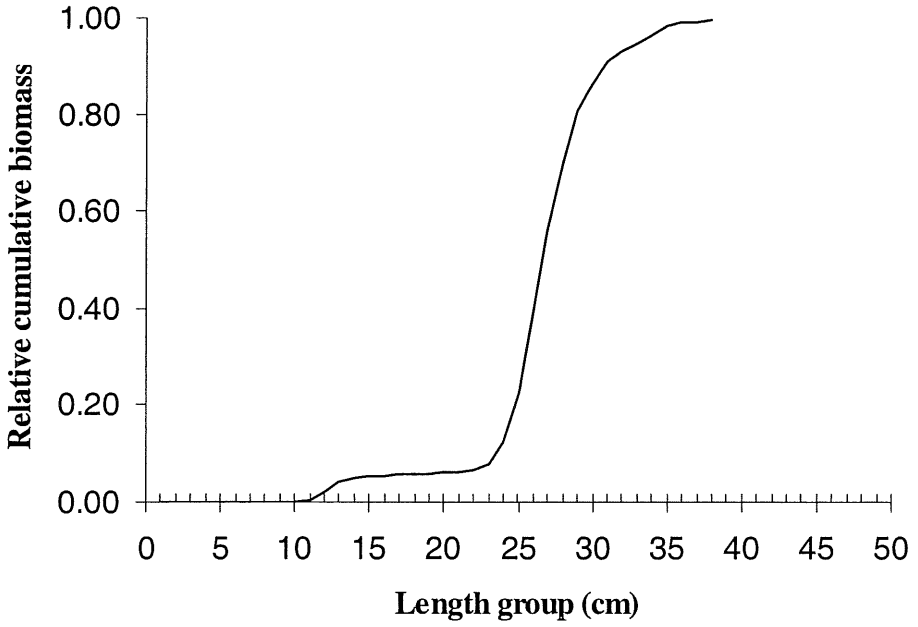


Figure 19. Relative cumulative biomass of horse mackerel (*Trachurus trecae*), Pta das Palmeirinhas-Benguela.

4.2.3 Other pelagic species

An overview of the main groups of other pelagic fish in the central region is given in table 3.

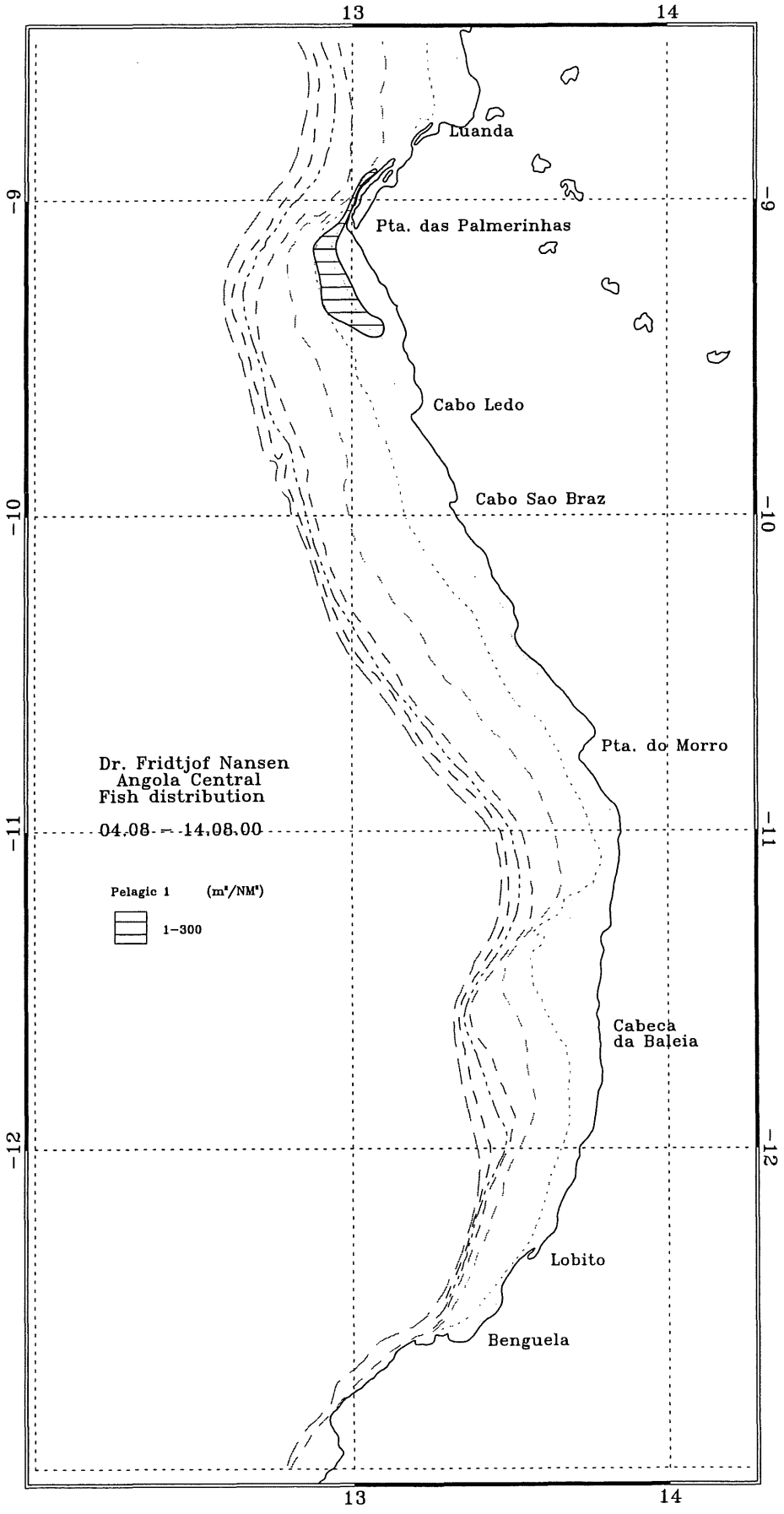
4.2.3.1 Group1 (i.e. clupeiformes)

Pelagic fish type 1 was only recorded in the northernmost part of this region, around and a little bit south of Ponta das Palmerinhas. The recorded densities were low (s_A< 300 m^2/NM^2). The only recorded species were *Ilishia africana* and *Etrumeus whiteheadi*. The biomass estimate, based on an average length of 30 cm and a condition factor equal to 0.01, resulted in about 21 000 tons.

4.2.3.2 Group 2 (i.e. other carangids)

Pelagic fish type 2 was encountered in low-density aggregations scattered throughout the shallow part of the shelf north of Cabeça da Baleia. An offshore component was located off Cabo São Braz. The most common species was hairtail (*Trichurus lepturus*). Other species included *Sarda sarda* and *Scomber japonicus*. No caranigds were caught in the samples, wheras this group was the dominating species last year.

The biomass estimate, based on an average length of 30 cm and a condition factor equal to 0.01, resulted in about 35 000 tonnes. This estimate is well below the one obtained last year (43 000 tonnes) and the one in 1998 (81 000 tons), coinciding with a reduction in the distribution areas.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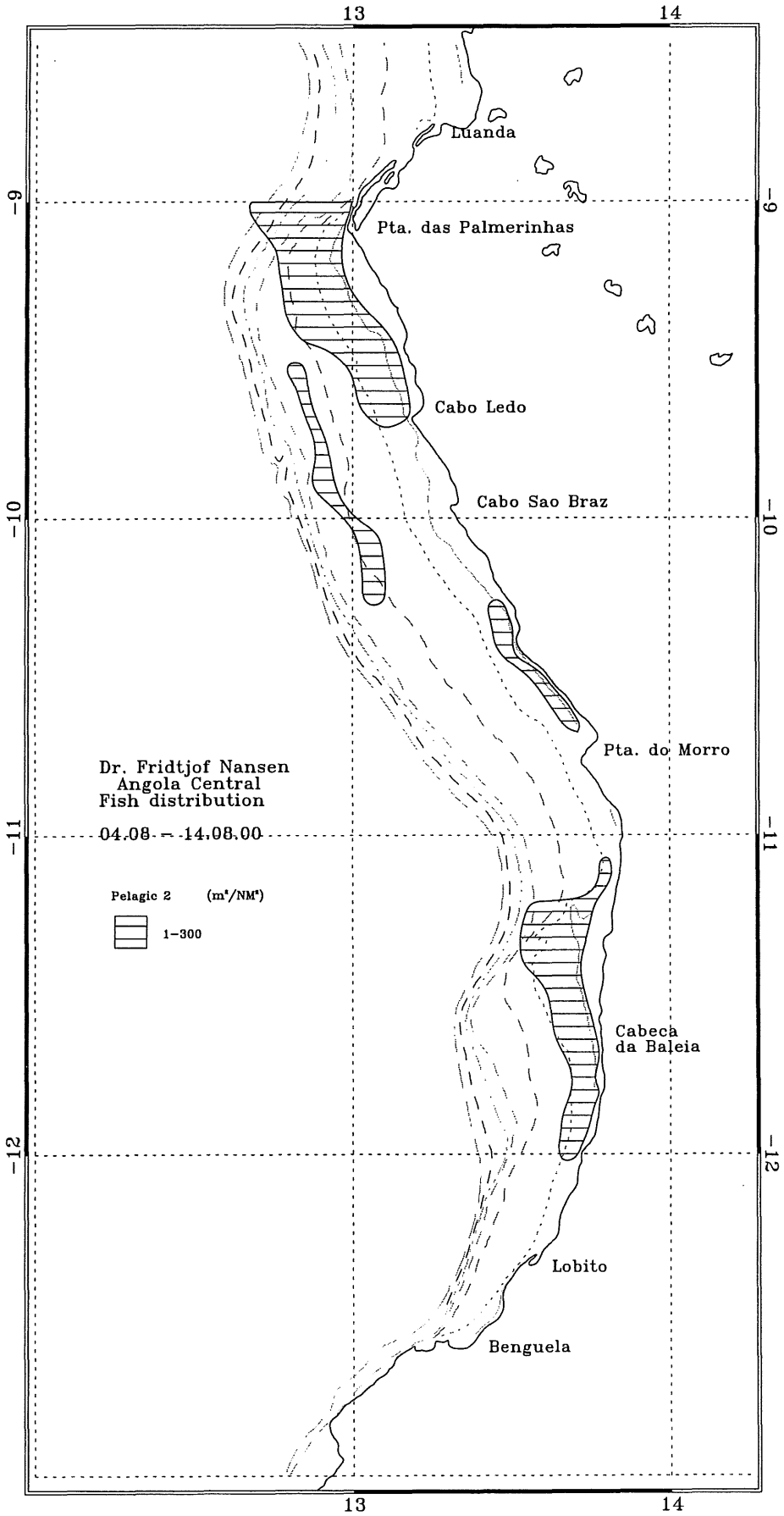
Cabo Ledo
Cabo Sao Braz
Pta. do Morro
Cabeca
da Baleia
Lobito
Benguela
Dr. Fridtjof Nansen
Angola Central
Fish distribution
04.08 - 14.08.00
Pelagic 1 (m²/NM²)
1-300

Figure 20. Distribution of other pelagic species, group 1. Pta das Palmeirinhas – Benguela.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Pta. das Palmerinhas
Cabo Ledo
Cabo Sao Braz
Pta. do Morro
Cabeca
da Baleia
Lobito
Benguela
Dr. Fridtjof Nansen
Angola Central
Fish distribution
04.08 - 14.08.00
Pelagic 2 (m²/NM²)
1-300

Figure 20. Distribution of other pelagic species, group 2. Pta das Palmeirinhas – Benguela.

Table 3. Catch rates (kg/h) of the main groups of pelagic fish, Pta das Palmeirinhas – Benguela.

Station	Ilishia africana	Etrumeus whiteheadi	Hairtail	Scombrids	Other
2369					2337.20
2370				6.53	542.21
2371			5.28		1665.12
2372					855.51
2375					75.09
2376				9.96	36.84
2377					649.54
2378				8.00	214.28
2381			58.47		496.15
2382			11.49		3.65
2383					134.97
2384	207.28		66.34		2033.36
2385			53.46		656.73
2386				26.96	769.85
2387					801.48
2388			20.94		1975.53
2389					31.79
2390					2697.52
2391			37.46		12609.83
2392			0.53		0.23
2393					34754.30
2394			9.43		699.23
2395			53.76		6348.03
2396			1.13		424.72
2397			31.20		11590.12
2398			819.00		20.88
2399		313.8	24.43	0.09	986.32
2400			12.69		9041.25
MEAN			38.89		2889.12

4.3. Benguela - Cunene

4.3.1 Sardinella

No positive identification of sardinella was made in this region.

4.3.2 Horse mackerel

Both species of horse mackerel, the Cape horse mackerel *Trachurus capensis* and the Cunene horse mackerel *T. trecae* were found off southern Angola. The Cape horse mackerel was present throughout the southern region. Close to the Cunene River, it occupied most of the shelf and slope areas, from about 50 m depth to beyond the shelf edge. The transect lines consequently covered depth ranges up to 500 m, but some transects were extended to cover the entire depth range of the horse mackerel distributions, which in some areas reached the 1000 m isobath. The bulk of the biomass was located south of Tombua (~16 ° S), extending southwards to the border at Cunene river (figure 21). Three main areas of high density (s_A>1000) were located; south of Tombua (offshore), inside the Baía dos Tigres (juveniles) and on the mid-shelf around 17 ° S. A local dense area was found south of Cabo de Santa Maria.

Mixed samples of the two species were encountered in both inshore and offshore waters in the southern part of the region (south of Tombua). The inshore samples were dominated by juveniles (8-15 cm) while the offshore samples contained mostly adults (15-25 cm). The length distributions of both species showed the same latitudinal distribution pattern, with the smallest specimens (15-25 cm) in the southern part of the region and the biggest specimens (>25 cm) in the north. The occurrence of *T. capensis* is generally associated with the colder waters of the Benguela current that usually reaches its northernmost extension in this area. This year, it seemed that the frontal area extended further north than usual, causing a greater overlap between the two horse mackerel species.

The biomass estimate for the horse mackerels in the southern region was 335 000 tonnes, compared to 253 000 tons for last year. Divided between the two species, the biomass was 242 000 tonnes for Cape horse mackerel and 92 000 tonnes for Cunene horse mackerel, compared to 128 000 and 124 000 last year, respectively. For Cape horse mackerel, the estimate is thus roughly twice as high as last year, while the Cunene horse mackerel was about 25 % lower compared to last year. In order to evaluate this difference it is necessary to consider the abundance and distribution of these species, and migration in and out of Namibian waters. Consequently, large annual and seasonal fluctuations for these species should be expected due to the position of the Angola-Benguela front. In order to eliminate such fluctuations from the estimates, it is suggested to combine the Namibian and the

Angolan surveys. This may be particularly important during the austral winter (peak in July-August), when the Cape horse mackerel usually is distributed far north. Combining the surveys would also provide indices of the proportions of the species located on either side of the border at the time of the surveys, and over time, valuable information about how the position of the front system affects the spatial dynamics of the horse mackerel stocks could be obtained as well.

Figures 22 a and b show the length frequency distributions of the Cape and Cunene horse mackerels, respectively. The Cape horse mackerel has a main mode around 15 cm, and smaller, more delusive modes around 23 and 30 cm. These larger fish (>20 cm) represented only a small fraction of the total. The Cunene horse mackerel showed two main modes, at 7-8 cm and around 22 cm. The majority of the smallest fish (<10 cm) were found in Baía dos Tigres (station PT 2357). Figures 23 a and b show the cumulative biomass by length. Individuals <32 cm comprise about 90 % of the biomass of Cape horse mackerel, while most of the biomass of Cunene horse mackerel (~90 %) consists of fish <28.

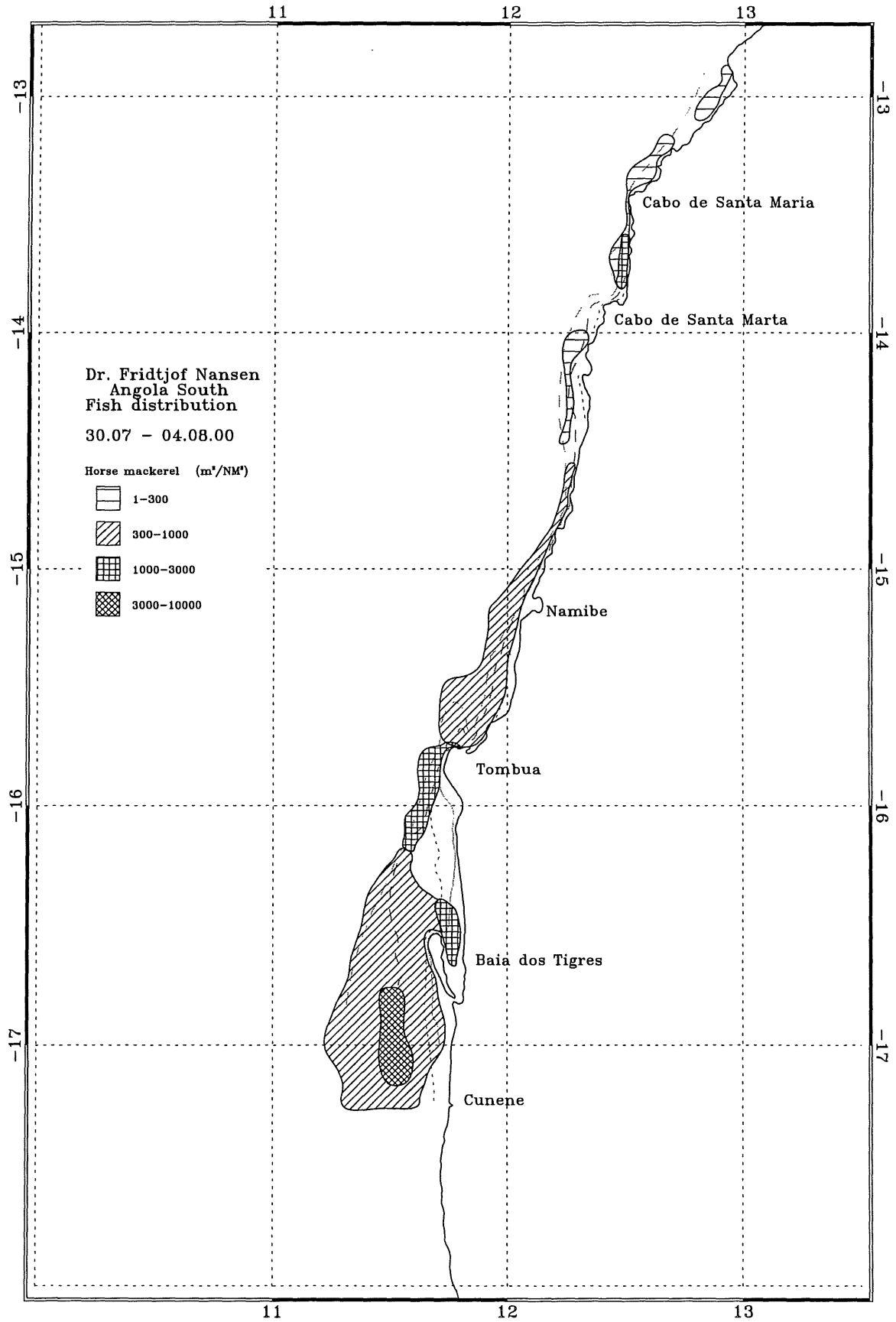
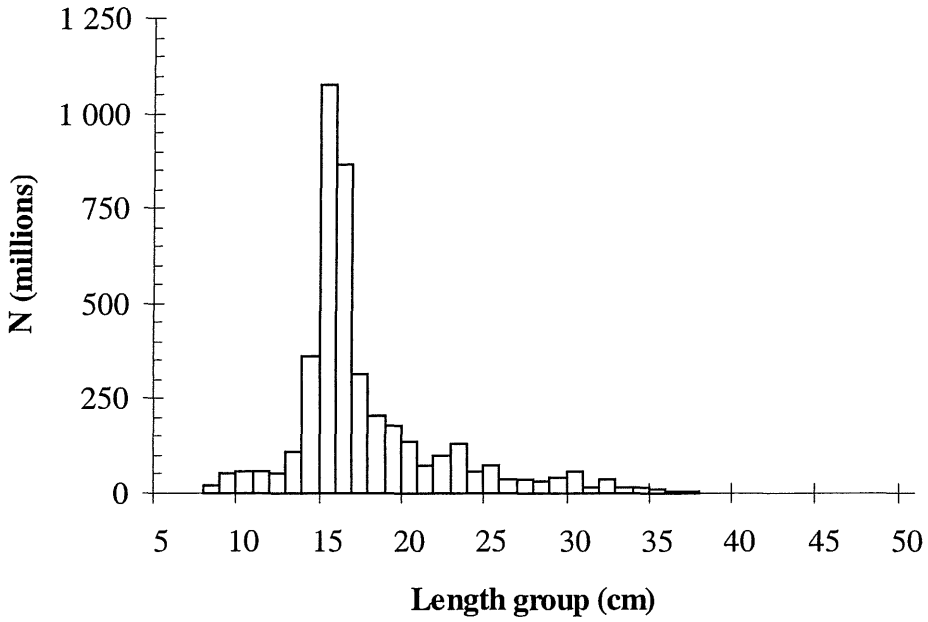
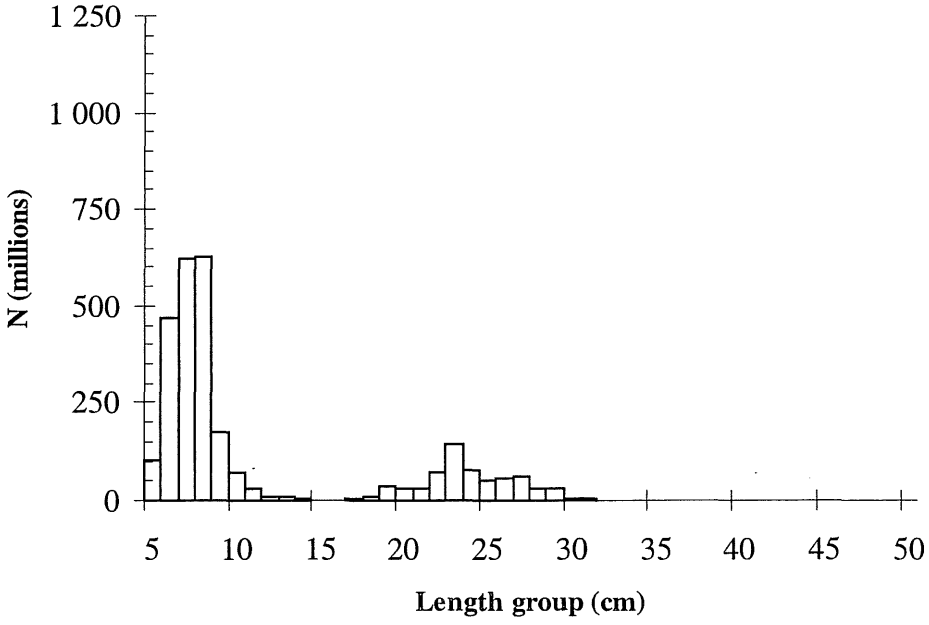


Figure 21. Distribution of horse mackerel. Benguela – Cunene

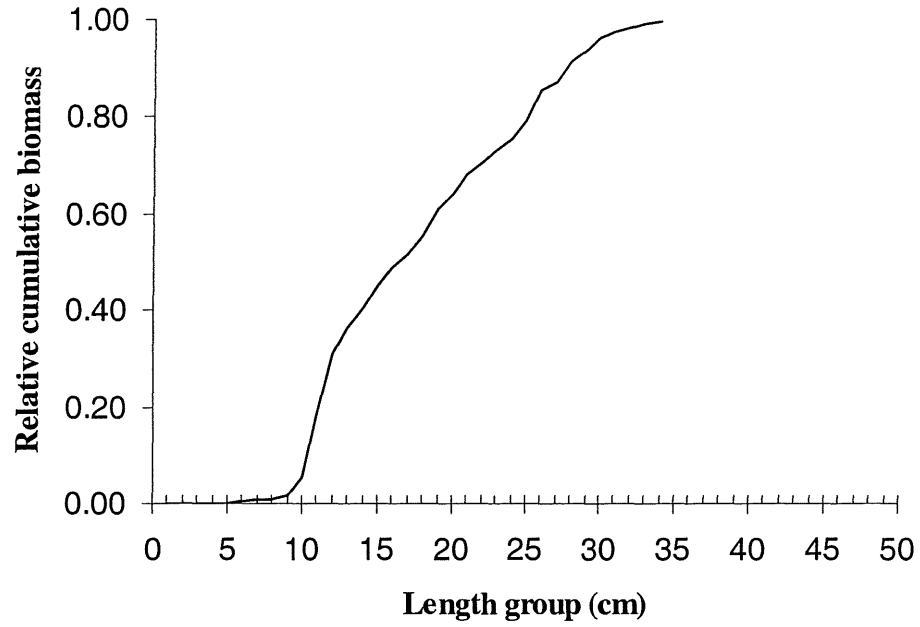


a) *Trachurus capensis*

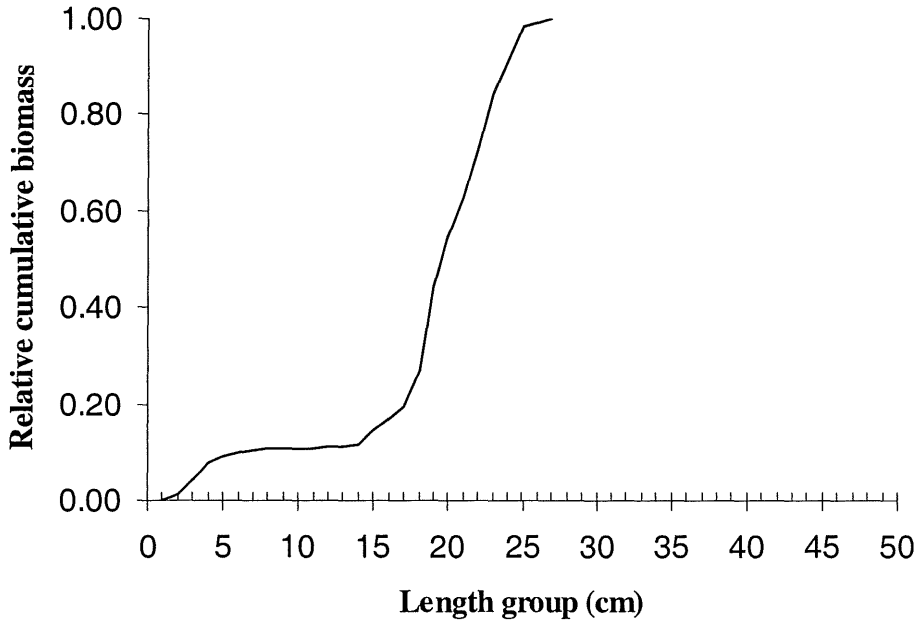


b) *Trachurus trecae*

Figure 22. Total length distribution of *Trachurus capensis* (a) and T. *trecae* (b). Benguela-Tombua.



a) *Trachurus capensis*



b) *Trachurus trecae*

Figure 23. Cumulative percentage biomass by length group for *Trachurus capensis* (a) and *T. trecae* (b).

4.3.3 Other pelagic species

An overview of the main groups of other pelagic fish in the southern region is given in table 4.

4.3.3.1 Group 1 (i.e. clupeiformes)

Pelagic fish type 1 was recorded in one main aggregation in this region, extending from Cunene river (17 ° 15' S) to around 16 ° 55' S, and in two smaller aggregations at Baía dos Tigres and south of Tombua, respectively (figure 24). The acoustic densities were relatively high in the main distribution area (s_A>1000), otherwise low (s_A<300). Round herring (*Etrumeus whiteheadii*) dominated the catches (see table 4). The biomass estimate was about 130 000 tons, based on an average length of 30 cm and a condition factor equal to 0.01.

4.3.3.2 Group 2 (i.e. other carangids)

Pelagic fish type 2 was recorded in two main area in this region, one extending from Cabo de Santa Maria (13 ° 55' S) to around 14 ° 25' S, and one between Namibe (15 ° 20' S) and Tombua (15 ° 40' S) (figure 25). Scattered observations were made between 16 ° 40' S and 17 ° 00' S. The dominant species in this group was hairtail (*Trichurus lepturus*). The acoustic densities were generally low (s_A< 300). The biomass estimate of the two defined regions was about 8 000 tonnes, based on an average length of 30 cm and a condition factor equal to 0.01.

Table 4. Catch rates (kg/h) of the main groups of pelagic fish. Benguela – Cunene river.

Station	Engraulis sp.	Etrumeus sp.	Hairtail	Other
2341	4043.80			
2342	2355.30			
2343	3691.80	178.67		
2344	12352.50	1926.00		
2345		233.20		
2346		9.40		
2347		3.32		
2348		28.26		
2349	2.25	1264.50		
2350		0.23	95.90	
2351	2121.60		49.20	
2352			10353.77	
2353		12.40	19966.06	
2354	236.80	427.20	14.40	1933.65
2355		61.71		690.00
2356			7.75	1769.94
2357				949.20
2358				3425.14
2359				105.74
2360				333.75
2361				
2362				337.10
2363				127.44
2364				61.75
2365				2046.47
2366			30.05	1003.14
2367	0.48			354.72
2368	0.60			14.14
MEAN	**84.27**	**675.12**	**1.86**	**1832.30**

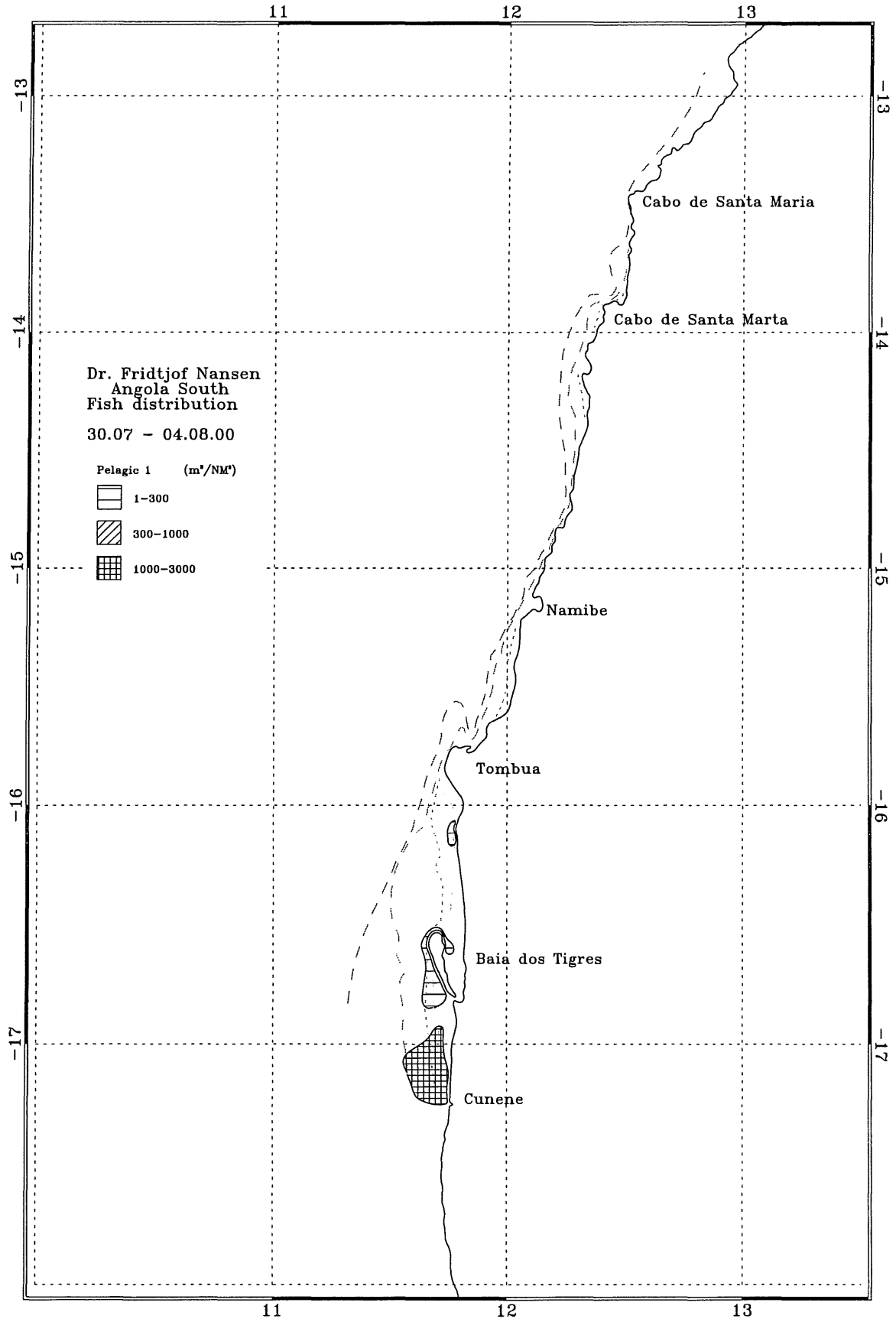


Figure 24. Distribution of other pelagic species group 1. Pta das Palmeirinhas – Benguela

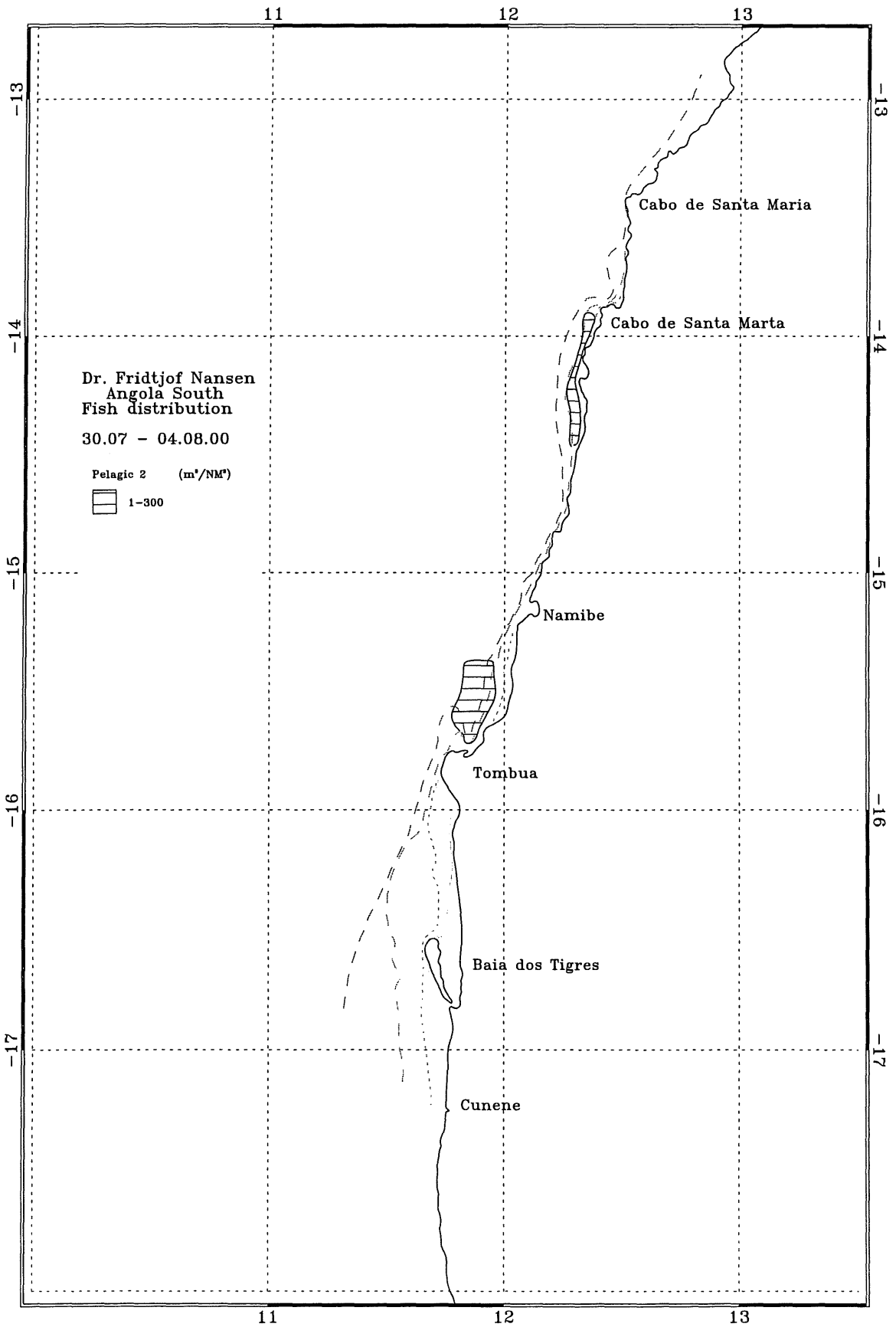


Figure 25. Distribution of other pelagic species group 2. Pta das Palmeirinhas – Benguela

CHAPTER 5 REVIEW OF SURVEY RESULTS AND AVAILABILITY FOR THE FISHERY

5.1 Sardinella and horse mackerel

Tables 4 and 5 show the time series of biomass estimates for the sardinellas and the Cunene horse mackerel, respectively. In both cases, care should be paid in interpreting the time series as the figures are not fully compatible, particularly because of differences in the survey coverage. Apart from the differences indicated below each table, it should be noted that the mid-shelf and inshore areas north of Ambriz have not been covered the last few years because of the oil drilling activity. Additionally, there is no information available on the possible impact of industrial activities on the fish stocks. The total biomass estimate for sardinellas (353 000 tons) is at the same level as last year (363 000 tons) (table 4), but a shift in biomass from the central to the northern region is evident. Similarly, the total biomass of Cunene horse mackerel was estimated at 333 000 tons, which is the same level as last year (321 000 tons), while more of the fish was located in the central region and less in the southern.

Considering the stock levels in the mid '90s, with several survey estimates in excess of 500 000 tons, there has been a gradual descent over time. The strong reduction of S. *aurita*, which was the dominating species in the '80s and last year only a small percentage, was evident from the catches also this year, but the proportion of S. *aurita* of the total estimate is much larger this year (~40 %). This ratio should, however, be interpreted with extreme care, as it arises from the proportion caught in each length group. Relatively few samples of S. *aurita* have been obtained, and the trawl catches may not be representative for the actual ratio between the two species.

Shifting locations of the frontal system may trigger extensive migrations, particularly of the horse mackerels, and this may represent a major source of variability in the estimates. As the hydrographical conditions and the position of the frontal system may vary annually and seasonally, this may also affect the validity of the estimates as relative indices. For the sardinellas, the extremely shallow distribution may represent a substantial methodological problem, as the fish is partly distributed above the transducer level.

Table 4 Biomass estimates of sardinellas by regions and surveys (1 000 tons).

Survey	Cunene-	Palmeiri	Cabinda-	TOTAL

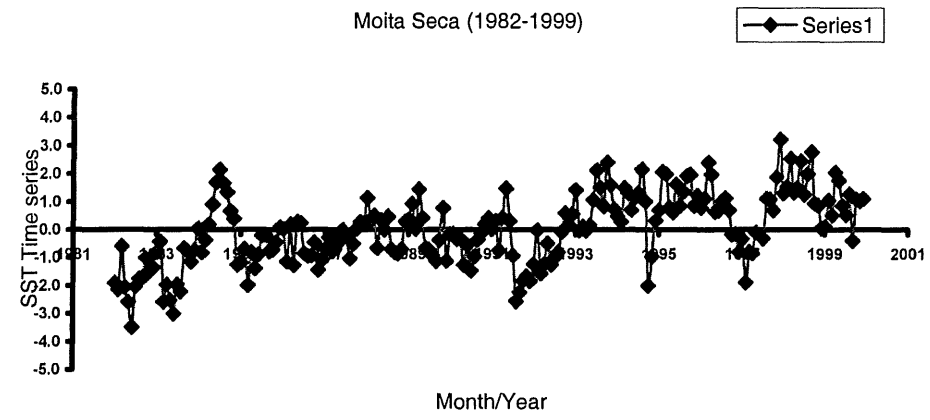
	Benguela	n.-Benguela	Palmeirin.-		
1/85	25	220	80	300	325
2/85	110	190	180	370	480
3/85	0	70	190	260	260
4/85	0	200	110	310	310
1/86	10	140	110	250	260
2/86	10	130	130	260	270
1/89	40	200	60	260	300
2/89	20	40	130	170	190
3/89	40	100	60	160	200
1/91	+	180	120	300	300
2/91	+	68	154	222	222
1/92	+	119	161	280	280
1/94	*	410	100	510	510
2/94	*	245	290	535	535
1/95	*	140	24	164	164
2/95	+	277	297	574	574
1/96	49	175	70	245	294
2/96	+	130	233	363	363
1\97		195	†300	495	495
1/98	75	389	†79	468	543
3/98	+	233	†159	392	392
2/99	0	228	†135	363	363
2/2000	0	179	†174	353	353

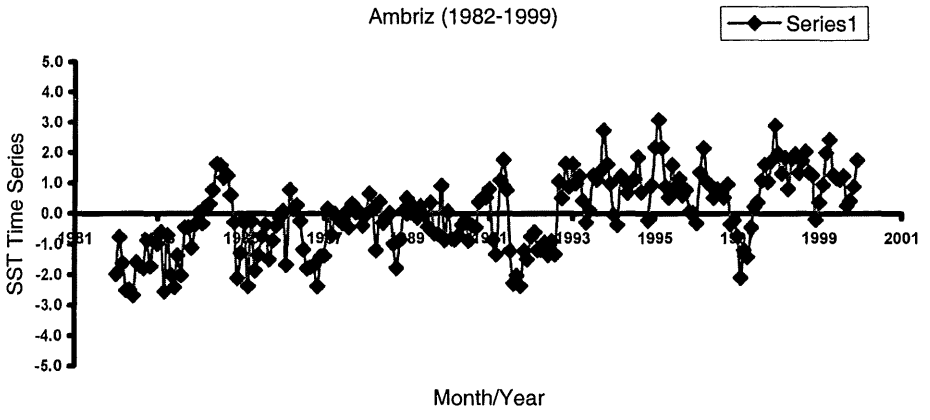
Table 5 Biomass estimates of Cunene horse mackerel by regions and surveys (1 000 tons)

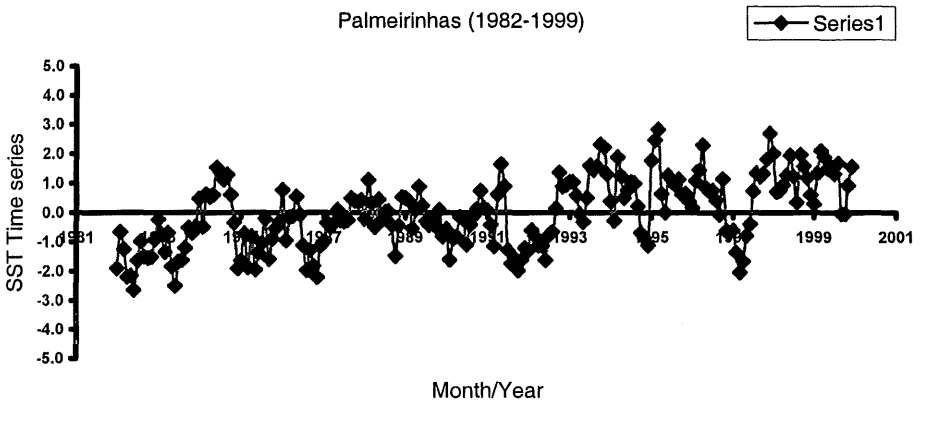
Survey	Cunene-Benguela	Palmeirin.-Benguela	Cabinda-Palmeirin.-		TOTAL
1/85	30	195	40	235	265
3/85	50	90	40	130	180
4/851/	100	125	20	145	245
86	35	55	40	95	130
1/89	170	40	35	75	245
3/89	100	80	20	100	200
1/91	100	70	30	100	200
2/91	98	86	80	166	264
1/92	*	238	1	239	
1/94	*	130	120	250	
2/94	*	*	84	84	
1/95					
2/95	70	160	110	270	340
1/96	286	214	6	220	506
2/96	140	157	63	220	360
1/97	234	55	†138	193	427
1/98	163	58	†18	76	239
3/98	118	112	†37	149	267
2/99	124	129	†68	197	321
2/2000	92	178	†63	241	333

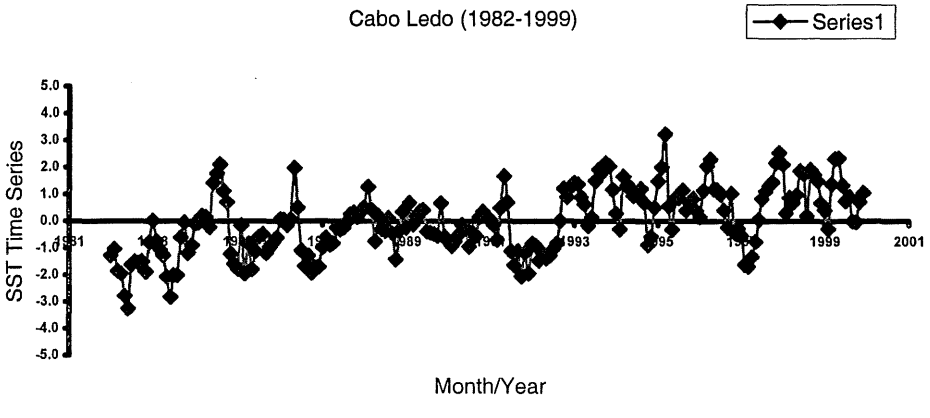
* not surveyed

† surveyed from Congo River- Pta das Palmerinhas


Moita Seca (1982-1999)
Series1
SST Time series
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
-4.0
-5.0
1993
1995
1999
2001
Month/Year


Ambriz (1982-1999)
Series1
SST Time Series
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
-4.0
-5.0
1993
1995
1999
2001
Month/Year


Palmeirinhas (1982-1999)
Series1
SST Time series
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
-4.0
-5.0
1993
1999
2001
Month/Year


Cabo Ledo (1982-1999)
Series1
SST Time Series
5.0
4.0
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1993
1995
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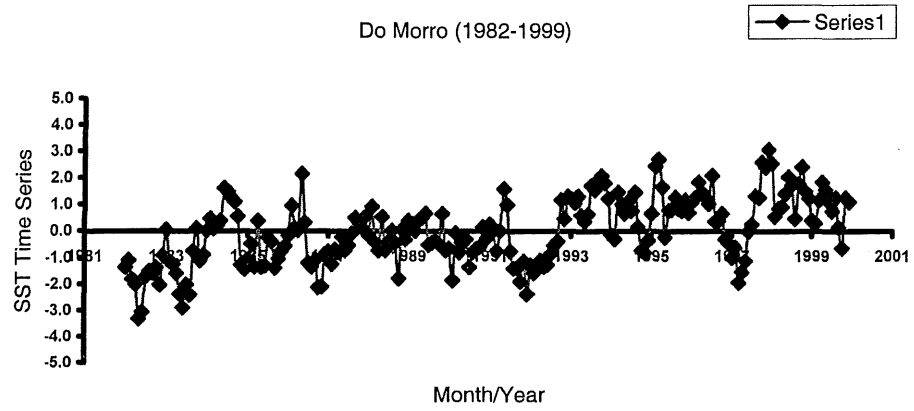
2001
Month/Year


Do Morro (1982-1999)
Series1
SST Time Series
5.0
4.0
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1.0
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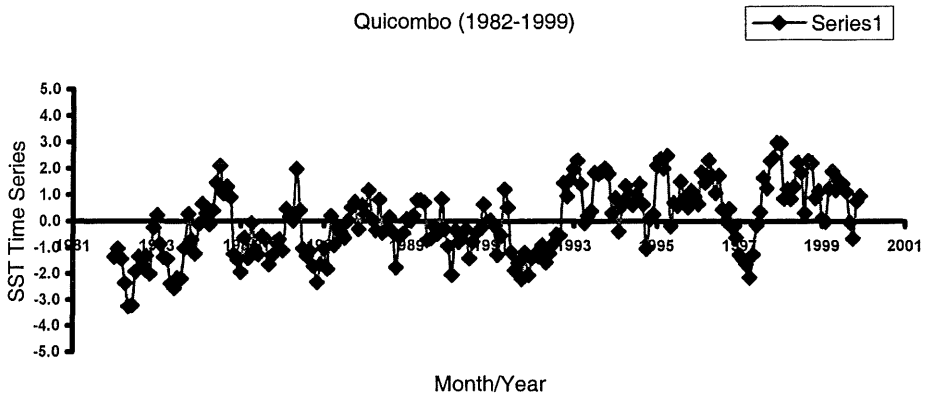
-3.0
-4.0
-5.0
1993
1995
1999
2001
Month/Year


Quicombo (1982-1999)
Series1
SST Time Series
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1993
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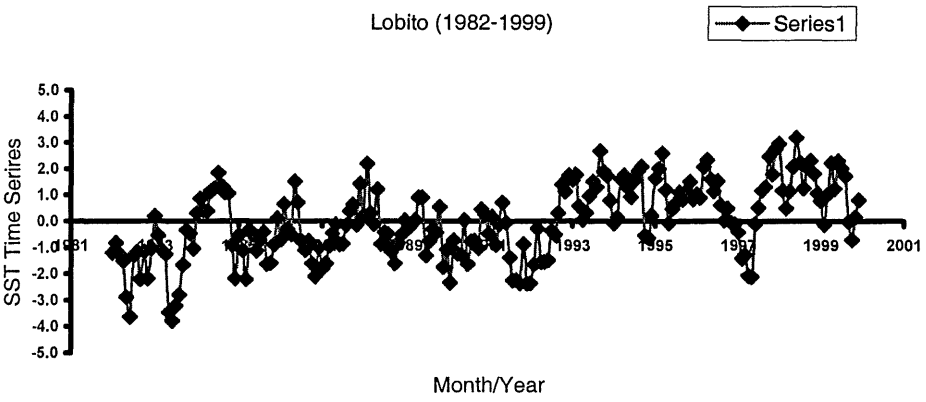
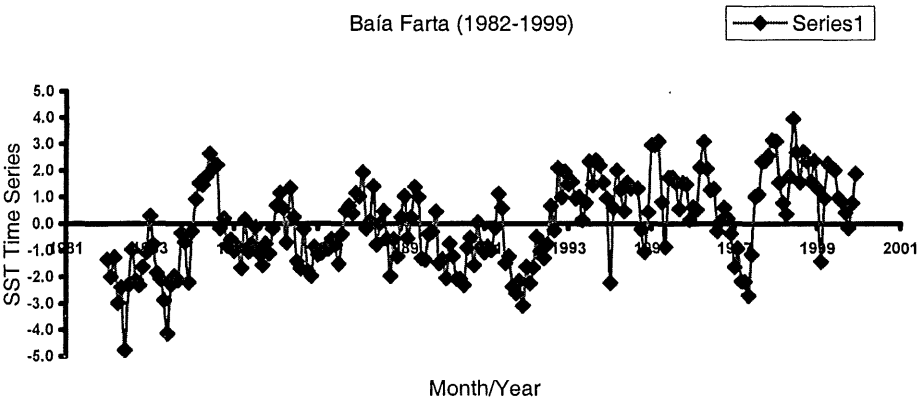
Month/Year


Lobito (1982-1999)
Series1
SST Time Serires
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
-4.0
-5.0
1993
1995
1999
2001
Month/Year


Baía Farta (1982-1999)
Series1
SST Time Series
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3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
-4.0
-5.0
1993
1999
2001
Month/Year