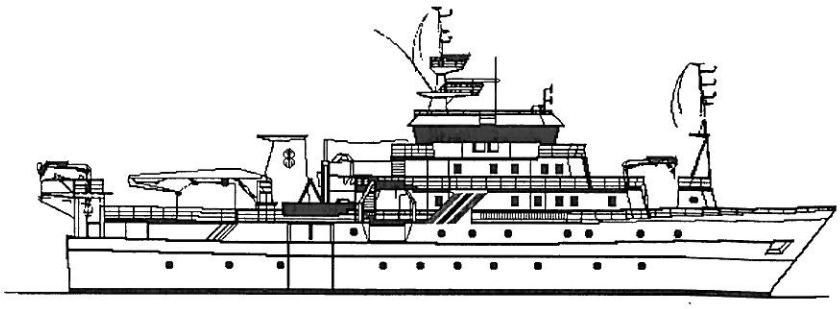


BENEFIT SURVEYS

Recruitment studies on anchovy and sardine

2 - 15 April 2002

National Marine Information and Research Centre
Swakopmund, Namibia

Instituto de Investigação Marinha
Luanda, Angola

Institute of Marine Research
Bergen, Norway

CRUISE REPORTS "DR. FRIDTJOF NANSEN"

BENEFIT SURVEYS

Recruitment studies on anchovy and sardine

2 - 15 April 2002

by

Erling Kåre Stenevik, Kjell Bakkeplass and Berit Endresen

Institute of Marine Research
Bergen
Norway

Rudi Cloete and Anja Kreiner

National Marine Information and Research Centre
Swakopmund
Namibia

Francisco de Almeida

Instituto de Investigação Marinha
Luanda
Angola

Institute of Marine Research
Bergen, 2002

CHAPTER 1 INTRODUCTION

1.1 General objectives

An overall goal of BENEFIT is to improve the knowledge and understanding of the important commercial fish stocks, the environmental conditions and the linkage between environmental processes and growth, distribution and abundance of the stocks.

This survey is part of a project that was initiated based on the results from a horse mackerel recruitment survey from 1st to 17th April 2001. During that survey, in addition to horse mackerel larvae, relatively high concentrations of anchovy larvae were observed in two patches from about 17°S to 22°S. Such high concentrations of anchovy larvae were not observed during the recruitment surveys with R/V *"Dr. Fridtjof Nansen"* during the previous years. The overall objective of the project is to follow up the results from the 2001 cruise and to conduct a comparative study of recruitment mechanisms of anchovy and sardine.

1.2 Specific objectives of the survey

This cruise was the first cruise of this project and was focussed mainly on the larvae of sardine and anchovy. The spatial and vertical distributions of the larvae were mapped. These will be related to the circulation of the water masses and to frontal systems. Samples of anchovy and sardine larvae were preserved in alcohol for later otolith microstructure analyses. Based on these, the birth date distributions and the growth of the larvae will be studied. Growth rates between areas will be compared (particularly in the Angolan front).

1.3 Participation

The scientific members during the cruise were:

From Angola:

Francisco de Almeida and Antònio Barradas.

From Namibia:

Rudi Cloete, Allie Gumbo, Anja Kreiner and Jeremia Titus.

From Norway:

Kjell Bakkeplass, Berit Endresen, Jarle Kristiansen, Tore Mørk and Erling Kåre Stenevik

1.4 Narrative

The vessel left Walvis Bay on the 2nd April at 22h00 and headed for Sandwich Harbour where the survey started on the 3rd April at 04h00. The same survey design as in April 2001 was used for comparative purposes. The survey started with an east-west transect at 23°30'S and continued with a cross section heading northeast. During the first day the vessel experienced some engine problems and had to go to Walvis Bay to get spare parts. Instead of taking the cross section northeast after the second line at 22°45'S, it was decided to steam north and start on the third line from west in order to get closer to Walvis Bay before breaking to collect the spare parts, which were supposed to arrive in the evening on 5 April. One of the crew members had to disembark due to death in the family. At 04h00 on 5th April the vessel headed for Walvis Bay and arrived at 11h00 the same day. Due to strike in Walvis

Bay Port the ship was not allowed to enter the port. In addition, the spare parts would not arrive until Sunday 7th April. It was therefore decided to continue with the survey after the disembarking of the crewmember and the ship headed for the next station (21° 42'S, 13°04'E) at 14h00. The survey continued with transects moving northwards. The distances between the transects were 40 –50 nautical miles. Transects from southwest to northeast were made between the east-west transects. Stations were normally taken every 20 nautical miles and every 15 nautical miles in the near shore region. CTD and Multinet plankton sampler were used on all stations. Methot plankton trawls were taken occasionally and only during nighttime. An ADCP was run throughout the survey. In the morning of the 10th April the wind increased and at the offshore station on the 17°20'S line the weather was too bad to continue northeast to the next station. The course was set northwards and one station was skipped. During the morning the wind calmed enough to do the next station and the survey was continued. After finishing the main part of the survey at the Tombua line at 15°50'S the vessel headed towards Namibe to sample the environmental monitoring line at 15°09'S starting at the inshore station at 12°09'E. On this line the Bongo net was used instead of the Multinet. The last station on the Namibe line was done on 12th April at 17h00. The vessel then steamed back to Walvis Bay and reached Walvis Bay harbour on 14th April at 13h00. During the survey a total of 76 CTD stations, 67 Multinet stations, 15 Methot stations and 7 Bongo stations were conducted. The work on the survey report continued onboard until 16th April.

CHAPTER 2 MATERIAL AND METHODS

2.1 Physical measurements

The survey started on 3rd April 2002 at 04h00 off Sandwich Harbour (23°30'S) and the Namibian coast was covered northwards into Angola up to Namibe (15°09'S). The distance between transects was 40-50 nautical miles. Between the east-west transects cross sections from southwest to northeast with two or three stations on these sections were sampled. Stations were taken every 20 nautical miles and in the near shore regions every 15 nautical miles (Figure 1).

2.1.1 Wind data

Wind speed and direction were measured continuously underway by the Aanderaa weather station and analysed and plotted using Microsoft Excel.

2.1.2 Hydrography

A Seabird 911 CTD was deployed to collect data on temperature, salinity and oxygen between the surface and 10 m off the bottom at every station. If bottom depth was greater than 500 m, the CTD was lowered to 500 m for the deepest measurement. Water bottles for samples for calibration of the oxygen sensors were fired at the bottom (or 500 m at deeper stations), the surface and the thermocline of the profile. At deep stations an additional water sample was taken. Oxygen samples were analysed within six hours using the standard Winkler method. The result yielded a very tight regression ($y = 0.9332x + 0.1978$, $R^2 = 0.9917$, Figure 2).

2.2 Plankton sampling

2.2.1 Multinet plankton sampler

Eggs, larvae and zooplankton were sampled with a Multinet plankton sampler from Hydrobios. The plankton sampler has 5 nets with a mesh size of 405 micrometers. The opening of the plankton sampler is 0.5 x 0.5 m. A flow meter was mounted in the opening of each net. A Scanmar depth recorder with acoustic transmission to the vessel was mounted on top of the Multinet. The depth intervals were 0-25 m, 25-50 m, 50-100 m, 100-150 m and 150-200 m. When bottom depth was less than 200 m, the deepest net sampled from 10 or 20 m above the bottom to the nearest 50 m depth interval (e.g. from 180 to 150 m depth).

2.2.2 Methot fish larvae sampler

The Methot fish larvae sampler that was fabricated at Globe Engineering in Walvis Bay was used during the first part of the survey. The equipment was produced in stainless steel according to the description of Methot (1986). The opening of the sampler is 2.24 x 2.24 m. The mesh size of the inner nets is 7 mm. The Methot sampler was deployed from the stern gate using a 12 mm cable on one of the trawl net winches. The Methot sampler was only used during night time due to well known problems with avoidance when using the sampler during daytime. A Scanmar depth sensor was mounted on top of the frame, and depth was monitored on the bridge during tows. The sampler was towed horizontally at discrete depth at 40 m and 20 m. During one of the stations the Methot frame collapsed due to bad weather and could not be used anymore that night. The following day, the frame was repaired and the Methot

stations continued. During the night on 9th April, the Methot frame collapsed again and due to continued bad weather during the rest of the survey it was decided not to sample with the Methot net and therefore no Methot hauls were taken north of 18°N.

2.2.3 Processing of ichthyoplankton and early juvenile fish samples

After removing the cups from the Multinet the samples were poured into measuring cylinders to determine the volume of the sample by displacement. The samples were transferred into petri dishes and examined with a stereomicroscope. All fish larvae and fish eggs were removed from the sample while the major zooplankton species were recorded. The fish larvae were identified using the key of Olivar and Fortuño (1991). All fish larvae were counted and the standard length of key species was measured before they were preserved in 96% alcohol. Fish eggs were identified, counted, staged and the diameter measured.

Juvenile fish collected from the Methot net were identified, counted and standard lengths were measured.

2.3 Buoyancy measurements of fish eggs and larvae

The onboard equipment from Martin Instrument Co. Ltd. (MIC) was used to measure specific gravity of fish eggs and newly hatched larvae. The equipment consists of three glass cylinders, 50 mm internal diameter and 700 mm high, submersed in a temperature-controlled transparent water container. The temperature was kept constant at 15°C by a ship-mounted cooling unit. A linear salinity gradient was set up in each column by filling the column from two conical flasks, each filled with 830 ml salt water solution connected by a plastic tube at the bottom, one with low-salinity and the other with high-salinity. The two solutions were made from natural seawater. The filling of each column took about 25 min.

The salinity gradients in two of the three columns were prepared before departure on 2nd April when the vessel was still in harbour in Walvis Bay. The columns have to be filled in calm conditions as too much motion of the vessel will cause errors in the filling procedure due to unwanted mixing between the two flasks. Seawater from the Swakopmund Aquarium was used to prepare the salinity solutions for the density gradient columns. The water was filtered through a 90 micron mesh. The low salinity solution was prepared by adding 0.45 l of distilled water to 2.0 l of seawater. The high salinity solution was made by adding 17 g of sodium chloride to 2.5 l of seawater.

The columns were calibrated by inserting glass floats with specific gravities, $\Delta\rho$, ranging from about 1.021 to 1.027 g/cm^3, into each column. Table 1 shows the Id. number and the exact specific gravities, at 11.5°C and 15°C for each float. The absolute specific gravity of the floats was given with an accuracy of +/- 0.0002 g/cm^3.

The fish eggs to be measured were inserted into the columns with a pipette just below the surface and were allowed to settle before the first measurement of the vertical position in the column was taken. Only wild caught eggs were used. Neutral buoyancy of the eggs was expressed in salinity units by calculating the salinity gradient in the column from the absolute densities of the floats and from the temperature in the columns.

Table 1: Exact specific gravities, Δρ, at 11.5°C and 15°C for glass floats.

Column II			**Column III**		
Id. No	**Δρ at**		**Id. No**	**Δρ at**	
	11.5°C	**15.0°C**		**11.5°C**	**15.0°C**
23742	1.0210	1.0202			
23745	1.0228	1.0228	22633	1.0218	1.0217
20377	1.0248	1.0247	20380	1.0241	1.0240
20372	1.0262	1.0261	20374	1.0256	1.0255
20358	1.0281	1.0280	20362	1.0276	1.0275

CHAPTER 3 RESULTS

3.1 Physical measurements

3.1.1 Wind

Figure 3 shows the daily mean wind speed, the daily maximum and minimum wind speed as well as the daily average wind direction. For the first week wind speed average was fairly low (<20 knots). On 9th and 10th April wind speed increased and the average wind speed was around 30 knots with the maximum speed reaching 38 knots. On 11th April the wind calmed down and calm conditions were experienced during the final days of the survey. The wind direction during the survey period was relatively constant, varying between 154 and 195 degrees (south east to south west) with a mean direction of 173 degrees

3.1.2 Hydrography

3.1.2.1 Temperature

Horizontal distributions of temperature at 10, 35, 50 and 100 m depth are shown in Figures 4 a-h. The temperature distributions displayed the typical upwelling features of the region with lowest temperatures inshore and increasing offshore. Upwelling occurred around Cape Frio and Palgrave Point. However, cool inshore temperatures were measured up to Namibe indicating some upwelling along most of the coastline. At Namibe (15°09'S) the temperatures at 10 m in the inshore stations were 21°C, increasing to 26°C at the offshore stations. At 10 m depth no temperature gradient from south to north was observed in Namibian waters and at the Cunene River inshore temperatures were around 17°C, the same as at Walvis Bay. At greater depths the temperature gradient from south to north was pronounced with temperatures in the south being 2 to 4°C cooler than at the Cunene River. At 22°00'S surface temperatures of more than 19°C were measured. At 35 m, however, temperatures on this line were cooler than north and south of the line. At 50 and 100 m no difference in temperature from the surrounding areas were observed.

3.1.2.2 Salinity

Horizontal distributions of salinity at 10, 35, 50 and 100 m depth are shown in Figure 5 a-h. Salinity at 10, 35 and 50 m depth increased from 35.2 in the south (around 23°S) to 35,6 north of Rocky Point (19°S). Off Palgrave Point (20°30'S) just outside the 200 m isobath the intrusion of high salinity water masses (35.8) was observed at 50 m and 100 m. Between Tombua and Namibe, there was an east-west gradient in salinity. The salinity was 35.6 at the inshore stations decreasing to 35.0 at the most offshore stations.

3.1.2.3 Oxygen

Horizontal distributions of oxygen at 10, 50 and bottom depth are shown in Figure 6 a-f. Dissolved oxygen at 10 and 50 m show an increase from inshore to offshore and a decrease from south to north. At 10 m low dissolved oxygen concentrations (less than 2 ml/l) were observed at the two upwelling areas at Cape Frio and Palgrave Point, while oxygen concentrations inshore between 22°S and 23°S were above 6 ml/l. Bottom oxygen showed an

elongated band of low oxygen (less than 2 ml/l) between 23°S and 19°S inshore of the 200 m isobath typical for this time of the year.

3.2 Plankton sampling

3.2.1 Horizontal distribution and species composition

The Methot net was used from Walvis Bay to just north of Cape Frio. Thereafter the net could not be used due to rough weather. The Methot net catches fish larvae that are too big to be caught by the Multinet. The average length caught was 27 mm for horse mackerel, 24 mm for sardine and 23 mm for anchovy. Horse mackerel catches ranged between 5 and 130 mm while sardine and anchovy were between 10 and 40 mm (Figure 7 a-c).

Since the volume filtered in the Methot net samples was unknown, the actual number of fish larvae caught in these samples was used to draw the distribution maps. These Figures display only the presence of fish larvae and not the density. Anchovy larvae were found at three main locations, off Swakopmund, at 20°S and the highest concentration off Cape Frio (18°30'S). The highest number of sardine larvae was found in the area between Walvis Bay and Swakopmund. Only a few sardine larvae were found further north. Horse mackerel larvae were abundant in the area from Dune Point (20°00'S) to Cape Frio (18°00'S). A high number of gobies were found on several stations from Walvis Bay to Cape Frio, while sole larvae were abundant at inshore stations around Cape Frio. Blenniidae species were also present at the Cape Frio stations (Figure 8).

The Multinet samples showed that horse mackerel eggs were widely distributed ranging from Palgrave Point to Tombua. The main concentrations were found slightly offshore, just south and north of Cape Frio and at Tombua. The eggs found in southern Angola most probably belonged to *Trachurus trecae* (Sundby et al., 2001). The highest number of sardine eggs was found at Ambrose Bay (21°00'S) and a few more at Dune Point and Rocky Point (Figure 9). No anchovy eggs were found during the survey.

The larval catches of the Multinet (Figure 10) compared well with the results of the Methot net. Horse mackerel (*Trachurus* sp.) larvae were the most numerous species in the Multinet catches. They were distributed from Palgrave Point (20°30'S) to Tombua (16°00'S) but were most abundant around Cape Frio. The larvae of *T. capensis* and *T. trecae* are very difficult to distinguish but most likely some of the larvae at the northern stations were *T. trecae* (Sundby et al., 2001).

The Multinet catches show that anchovy larvae were abundant from Dune Point (20°00'S) to around Cape Frio (18°00'S). A patch of anchovy larvae was also found at the inshore stations of the Namibe line (15°10'S) (Figure 9). Only a few sardine larvae were present in the Multinet catches and they were mostly distributed from Dune Point to the Cunene River (17°15'S), with a small patch found off Walvis Bay (Figure 10).

Blenniidae species were also abundant and displayed the same distribution pattern as the anchovy. In Angolan waters, *Sardinella aurita* larvae were found at Baía dos Tigres, Tombua and the highest concentration at Namibe.

3.2.2 Vertical distribution

3.2.2.1 Anchovy

No anchovy eggs were found during this survey. This confirms the results from the survey conducted during the same time period last year. The vertical distribution of the anchovy larvae showed that most of the larvae were found above 50 m (Figure 11). The only exception from this was on one station during the night where one larva was found in the 150-200 m depth interval. On the daytime stations, the fraction of anchovy larvae in the 0-25 m depth interval was 56%, decreasing to 15% on the night-time stations.

3.2.2.2 Sardine

A total of 114 sardine eggs were found on three stations during the survey. Most of the eggs (105) were found on one station. All of the eggs on this survey were found in the upper 25 m. Since only 22 sardine larvae were caught in the Multinet, the vertical distribution data are difficult to interpret. However, the data showed that a relatively high fraction of the larvae was found deeper during the nigh-time hauls (Figure 12). In addition, the larvae were more dispersed during the night in accordance with the results from 2001.

3.2.2.3 Horse mackerel

Like in 2001, most of the horse mackerel eggs were found deeper than 25 m (Figure 13). However, in 2001 the highest fraction of eggs were found as deep as the 100-150 m interval. During this survey, the highest fraction was observed in the 25-50 m interval while only a small fraction was found deeper than 100 m. There were apparent day/night differences in vertical distribution of the horse mackerel larvae (Figure 14). The fraction of larvae in the upper 25 m was 83% during daytime while it was reduced to 11 % during the night.

3.3 Buoyancy of eggs and larvae

Only wild caught eggs were used for buoyancy measurements during this survey. On station 19, 105 sardine eggs were caught in the Multinet in the 0-25 m depth interval. 14 of these were inserted into the density gradient column (column III) at 09:00 on 6th April. At 13:00 the same day, the position of the eggs was measured for the first time. Only two of the eggs were still alive. Later the same day, only one egg had survived and this egg survived until hatching. The buoyancy of this egg was measured 8 times (Figure 15). The egg had neutral buoyancy at 33.11 salinity units on the first measurement. Then it got heavier on the two next measurements and neutral buoyancy was at 34.40 on the third measurement. It then got lighter again and then heavier until hatching when it was neutrally buoyant at 35.36 salinity units. The hatching process was incomplete as the larvae died while hatching.

On station 41, 84 horse mackerel eggs were caught in the Multinet. Of these, 24 were inserted in column II at 18:25 on 8th April. The position of these eggs was first measured the same day

at 19:30. At that time 23 of the eggs were still alive. They were observed until 10th April when most of them had hatched and recordings of larval buoyancy were also made (Figure 16). The mean neutral buoyancy was at 34.53 salinity units on the first measurement. This is higher than what was measured in 2001. However, some of the eggs were observed sinking and most likely some of them were dying. When these eggs were removed from the data, the mean neutral buoyancy was at 34.06 salinity units. On the next measurement the eggs were heavier and then they got lighter approaching hatching. The newly hatched larvae had mean neutral buoyancy at 33.26 salinity units. The larvae got heavier as the yolk sac was utilised and on the last measurement they had neutral buoyancy at 36.68 salinity units. At that point 8 larvae were still alive.

CHAPTER 4 DISCUSSION AND CONCLUSIONS

The water temperatures observed during the survey period were distinctly cooler than during the same time period in 2001 and were comparable to temperatures measured during April 1999. The warm waters of the front were observed as far north as at Namibe (15°09'S), although high salinities northwards from Rocky Point (19°00'S) suggest different water masses in the northern part of Namibia. The salinities measured also were also very similar to those measured in April 1999.

The upwelling cells at Cape Frio and Palgrave Point were active during the survey period as can be seen by the cool low oxygenated waters measured at 10m depth in these areas.

The increase in salinity towards the north is characteristic for the system as the tropical waters in Angola have a higher salinity than the freshly upwelled waters of the Benguela system. It is, however, expected that the temperature gradient follows the same trend as the high salinities are usually an indication of southwards movement of Angolan warm water masses. The less saline water that was observed in the surface at the offshore stations between Tombua and Namibe is most likely water from the Congo River, which appears in this area after the raining season.

The temperature gradient from south to north in Namibian waters, was not very pronounced in the surface waters which was possibly a result of high wind stress experienced during the survey period in the northern area and hence surface mixing. In the deeper layers (35 m and 50 m depth) the temperatures showed a steady increase from the south to the north as expected.

A high salinity subsurface eddy was observed around 20°30'S at 50 and 100 m depth. This eddy could, however, not been seen on the horizontal temperature distribution at the same depths. Similar eddies were observed during April 1999 (R/V Poseidon cruise) around 20°30'S at 50m depth.

The observed concentrations of fish eggs and larvae were generally much lower than what was observed during the same period in 2001 (Sundby et al., 2001). An exception was sardine eggs, which on the present survey were found in relatively high concentrations at the inner station on the 21°11 S line. Like in 2001, no anchovy eggs were found this year and this confirms that spawning of anchovy seems to be low in April. Horse mackerel eggs were on the present survey observed in a relatively wide area from 16°S to 20°30S. Highest concentrations (300 eggs/10m^2) were observed near Cape Frio while the highest concentrations last year were observed near Baia dos Tigros. The horse mackerel eggs had similar distribution compared to 2001 although the concentrations were much lower than last year when more than 4000 eggs/10m^2 were observed on one station.

In April 2001, anchovy larvae were found on 39 stations. The larvae were distributed in two patches, one from the Cunene to about 18°30 S and the second from 19°S to about 21°S. In

both of these patches the highest concentrations were more than 700 larvae/10 m^2. During the present survey, anchovy larvae were found at only 13 stations mostly between 18°S and 20°S and also some larvae on the most inshore station at the Namibe line. The highest concentration this year (225 larvae/10m^2) was observed near Cape Frio. Sardine larvae were this year observed on 8 stations mostly located between 17°S and 20°S. However like last year a small concentration of sardine larvae were observed in the Walvis Bay area. Concentrations of sardine larvae were also lower this year compared to 2001. Like for anchovy and sardine, horse mackerel larvae were also found in much smaller concentrations this year compared to 2001. In addition, the distribution did not extend as far south as last year.

There appears to be some correlation between upwelling and presence of fish larvae caught in the Methot net, as is evident by the high number of larvae present at the Cape Frio stations. However this is less evident at Palgrave Point where upwelling was also observed.

The mean neutral buoyancy of the horse mackerel eggs that were measured on this survey ranged around 34 salinity units. This is somewhat heavier than what has been measured on the previous surveys (Sundby et al., 2001). The reason for this difference is not clear, but bacteria growth was observed in both the columns and although this did not seem to induce mortality on the eggs, it may have affected the buoyancy of the eggs. Furthermore, the larvae were heavier than what has been measured earlier and this may also be caused by the bacteria. It is known that larvae in poor condition have problems with regulating their density (Sclafani et al., 1993) and the larvae in this experiment got heavier as their yolk sac was utilised and no food was available. Also, as the larvae hatch their increased mobility makes measurements of density unreliable unless the larvae are anaesthetized.

The vertical distribution data confirms the general pattern that has been described from previous surveys in the region (Sundby *et al.*, 2001) although some differences were observed. The results from this year were based on a relatively low number of larvae and should therefore be interpreted with caution. However, the larvae seemed to have a diel vertical migration pattern with the larvae being deeper and more dispersed during night time than during the day. During the day still a large fraction of the larvae were found deeper than 25 m, which means that they are below the offshore moving Ekman layer and will be retained in inshore nursery areas.

In conclusion, water temperatures were cooler than during April 2001 with the Angola Benguela Front being far north (north of 15°09'S). Upwelling occurred at Cape Frio and Palgrave Point and also to a lesser degree along most of the coastline north to Namibe. Wind speeds of more than 30 knots in northern Namibia and southern Angola resulted in surface mixing and hence cool surface temperatures.

Fewer larvae were found in the Multinet compared to the results of last year's survey, which was conducted at the exact same dates. However, the catches of the Methot net contained relatively large anchovy and sardine larvae, which were too big to be caught by the Multinet. This suggested that spawning of these species might have taken place earlier this year than last year. In addition, the distribution of the larvae did not extend as far south as last year for

most species. According to the results of the Multinet horse mackerel was the most abundant species followed by anchovy while sardine larvae were scarce.

5 ACKNOWLEDGEMENTS

Thanks are extended to Allie Gumbo and Antònio Barradas who participated in working up the plankton samples and to Jeremia Titus who was responsible for the oxygen titrations. Tore Mørk and Jarle Kristiansen were responsible for running the instruments. A special thanks to the officers and crew of the R/V *"Dr. Fritjof Nansen"* for making everything work smooth, sometimes under difficult weather conditions.

6 REFERENCES

METHOT, R.D.1986. Frame trawl for sampling pelagic juvenile fish. CalCOFI Rep. Vol. XXVII: 267-278.

OLIVAR, M-P and FORTUNO, J.M. 1991. Guide to Ichthyoplankton of the Southeast Atlantic (Benguela Current Region). *Sci. Mar.* 55: 1-383.

SCLAFANI, M., TAGGART, C.T. and THOMPSON, K.R. 1993. Condition, buoyancy and the distribution of larval fish: implications for vertical migration and retention. *J. Plankton Res.*, 15(4): 413-435.

STENEVIK, E.K., SUNDBY, S and CLOETE, R. 2001 Buoyancy and vertical distribution of sardine (*Sardinops sagax*) eggs and larvae and its influence on transport of the offspring in the Northern Benguela ecosystem. In: *A decade of Namibian Fisheries Science*. A.I.L Payne, S.C. Pillar, and R.J.M. Crawford (eds). *S. Afr. J. mar. Sci.* **23**, pp. 85-97.

SUNDBY, S., STENEVIK, E.K., ENDRESEN, B., CLOETE, R., CURRIE, B., NOLI-PEARD, K., DE ALMEIDA, F. and ANTONIO, M.A. 2002. Recruitment and reproduction study on horse mackerel and anchovy, 1 – 17 April 2001. Cruise Reports of "Dr. Fridtjof Nansen". BENEFIT Surveys No. 1/2001. Institute of Marine Research, Bergen.

7 FIGURES

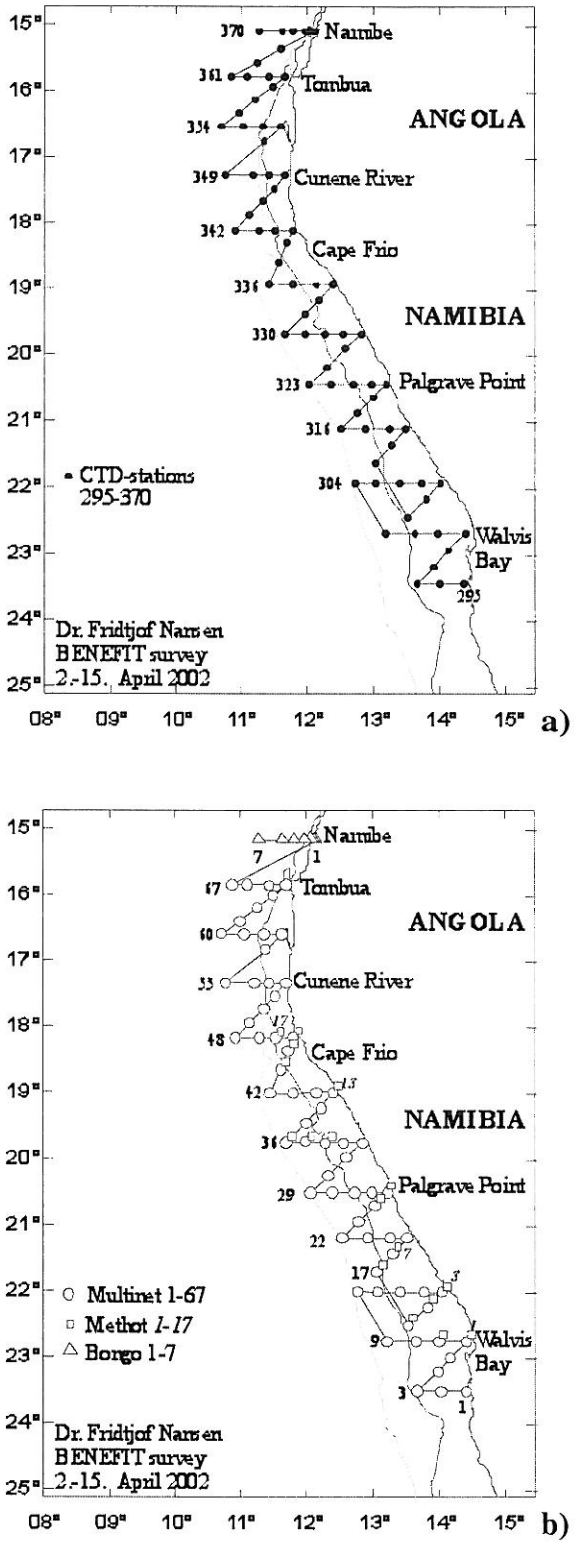


Figure 1: Cruise track of the RV *"Dr. Fritjof Nansen"* with a) CTD stations and b) plankton stations during the survey from 2nd to 14th April 2002.

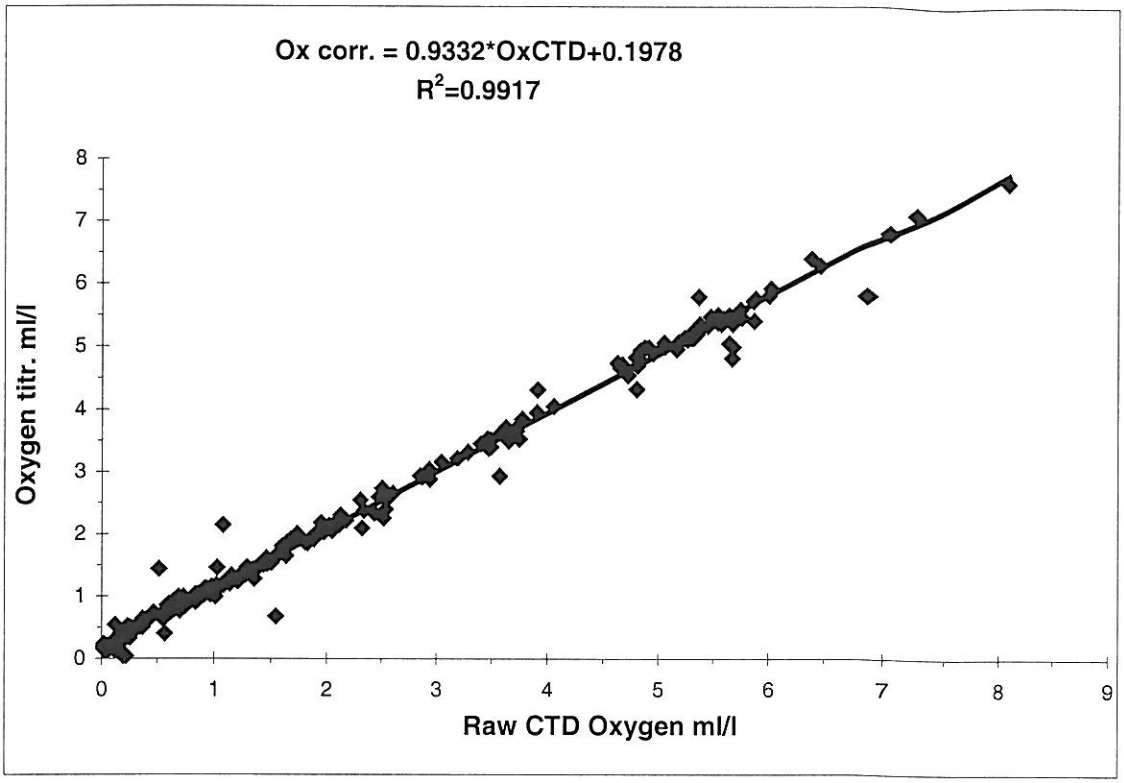


Figure 2: Correlation between oxygen concentrations measured by the CTD sensor and titrated water samples (n = 240).

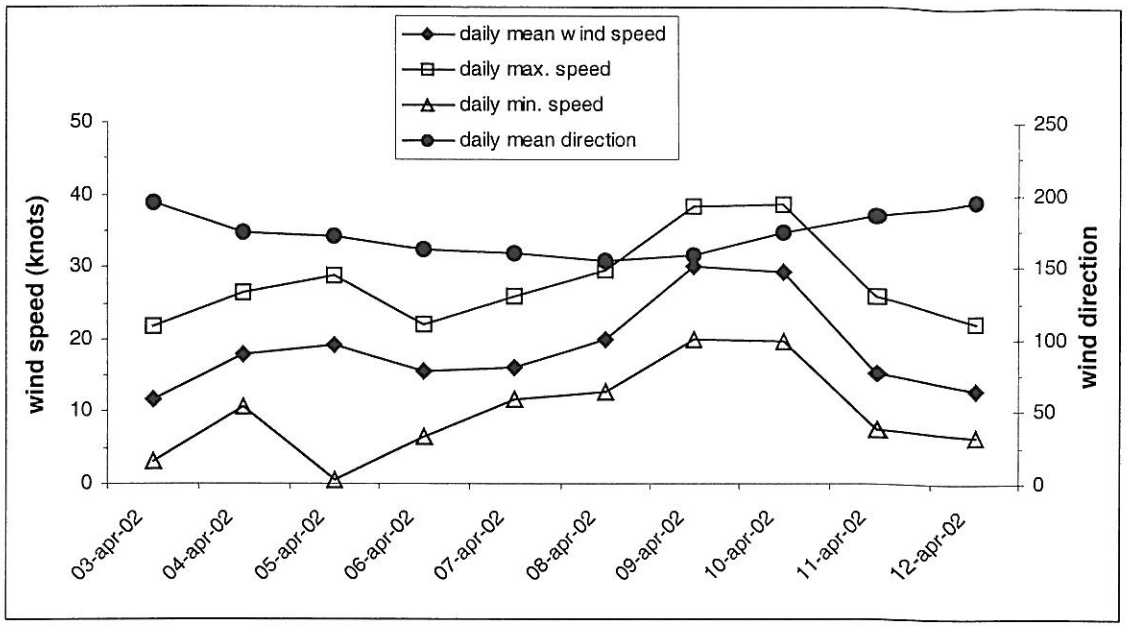


Figure 3: Daily mean, maximum and minimum wind speed and mean wind direction during the survey period.

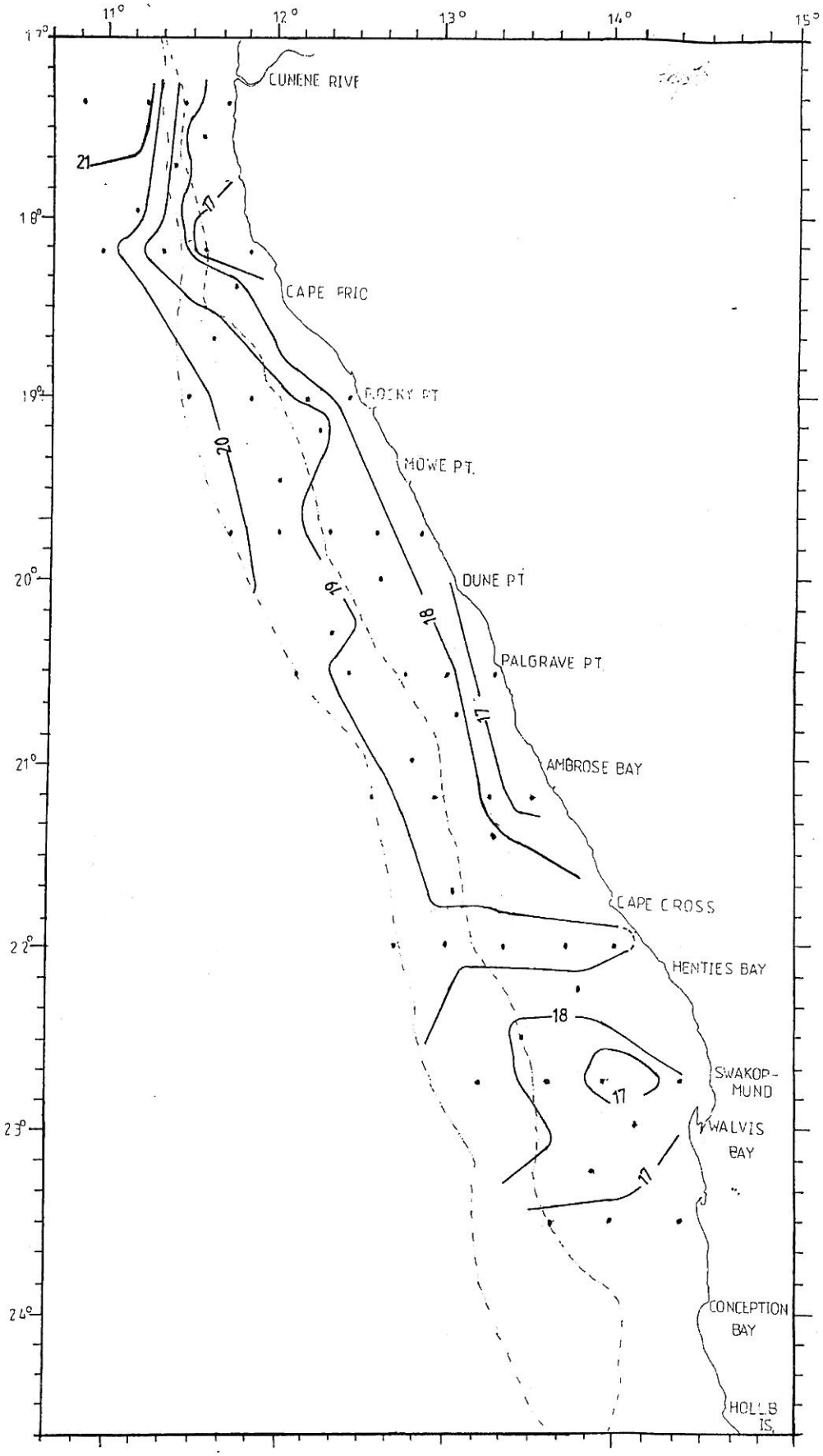


Figure 4a : Horizontal temperature distributions at 10 m depth in northern Namibia.

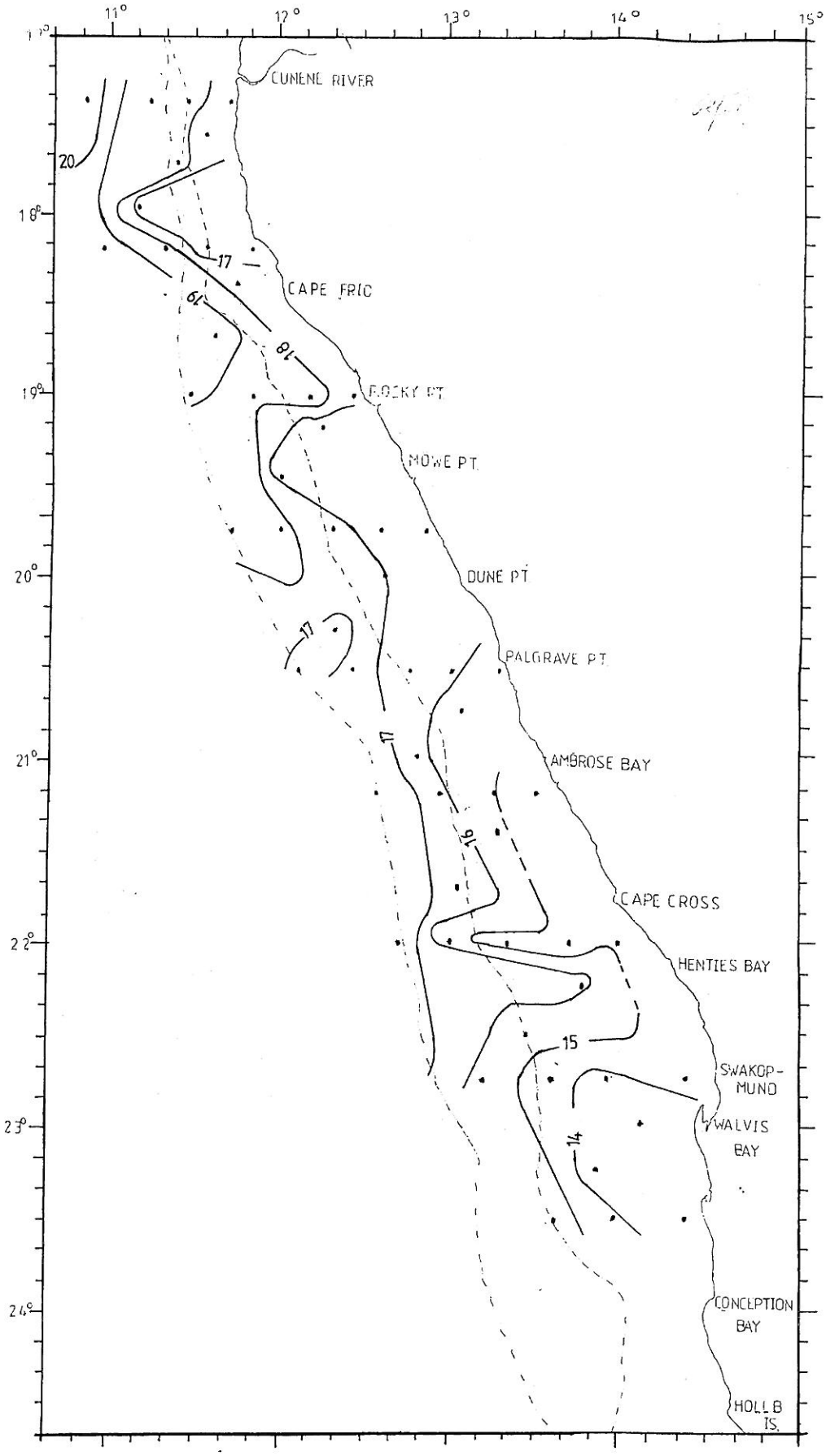


Figure 4b : Horizontal temperature distributions at 35 m depth in northern Namibia.

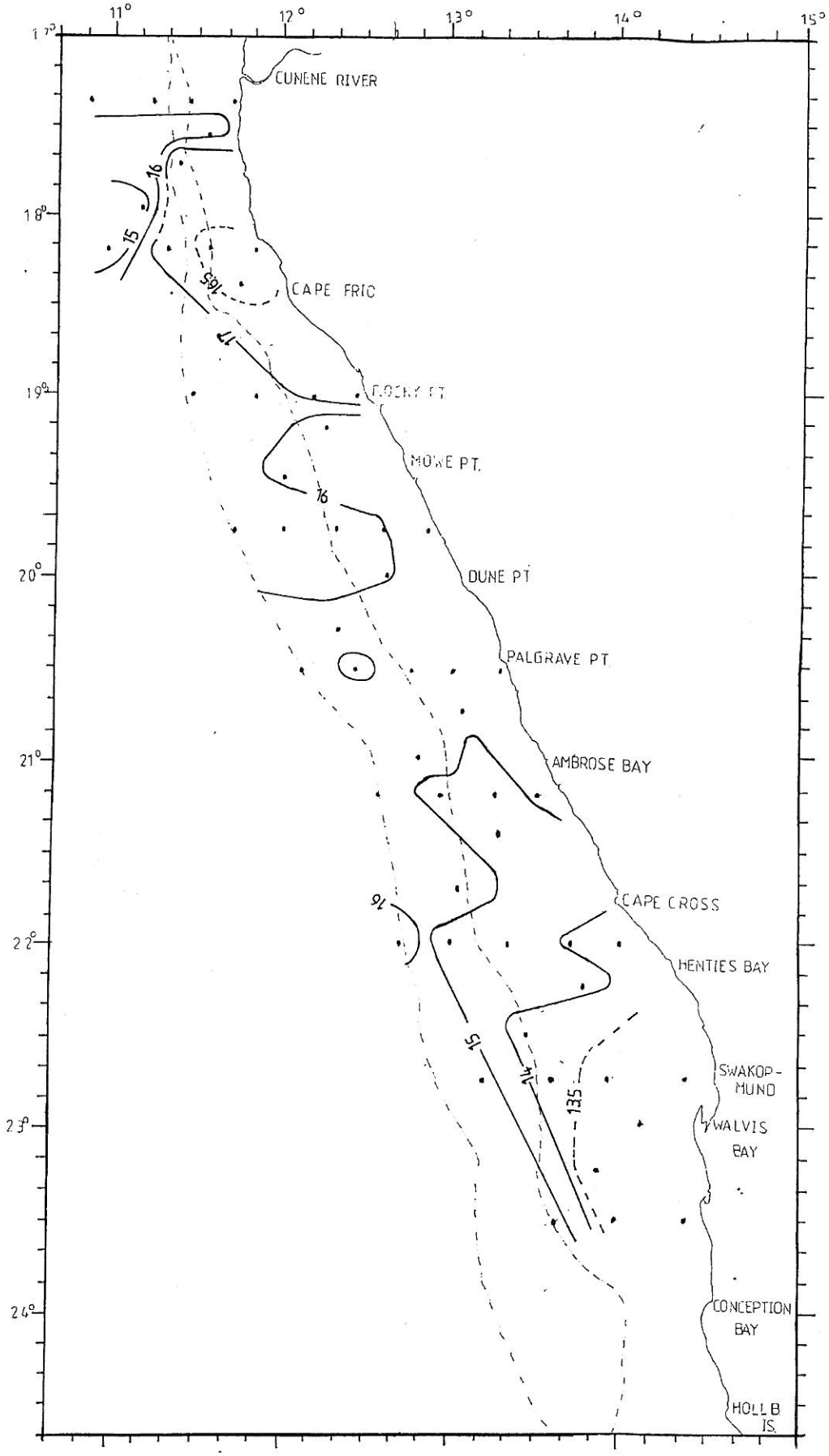


Figure 4c : Horizontal temperature distributions at 50 m depth in northern Namibia.

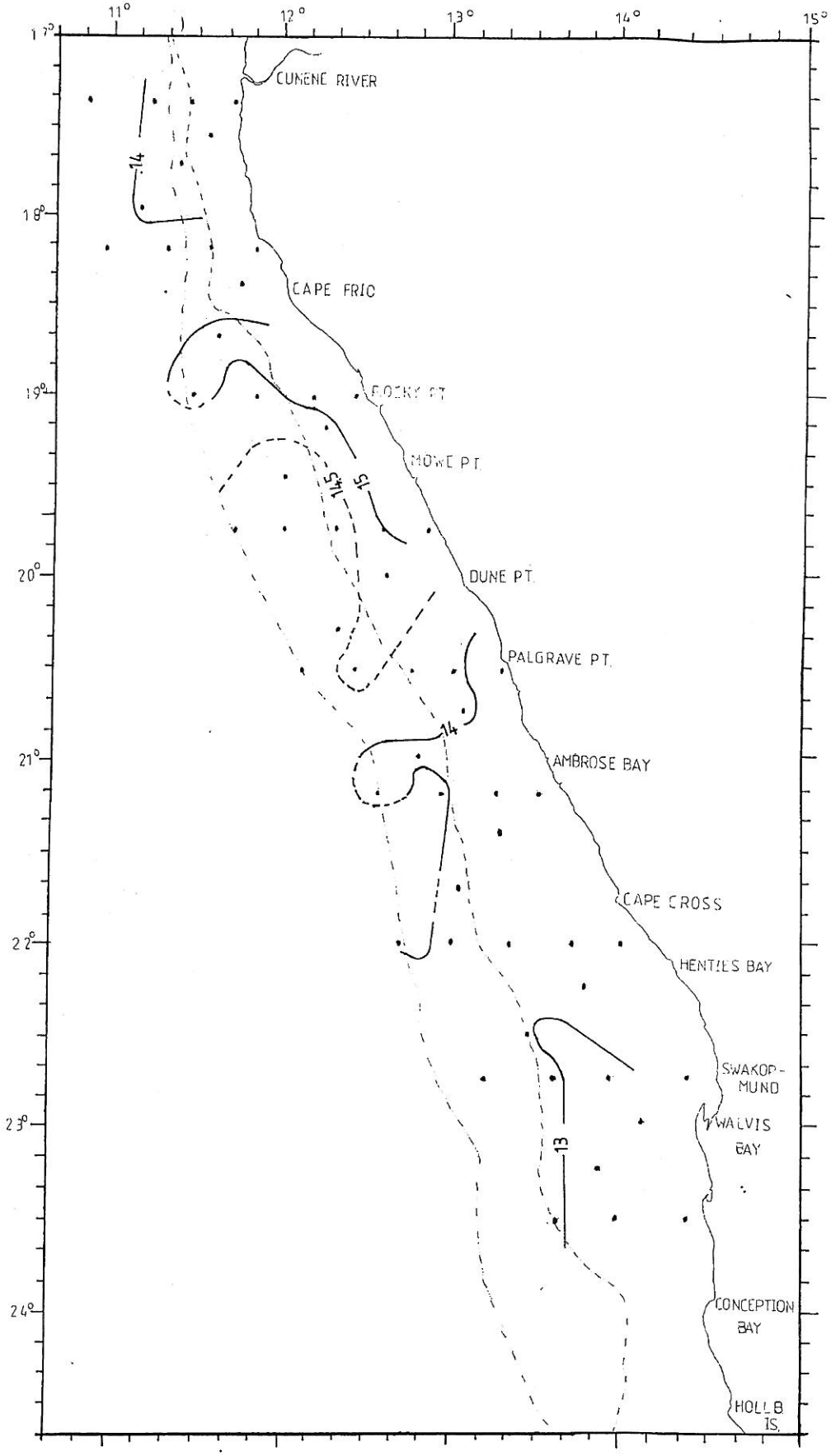


Figure 4d : Horizontal temperature distributions at 100 m depth in northern Namibia.

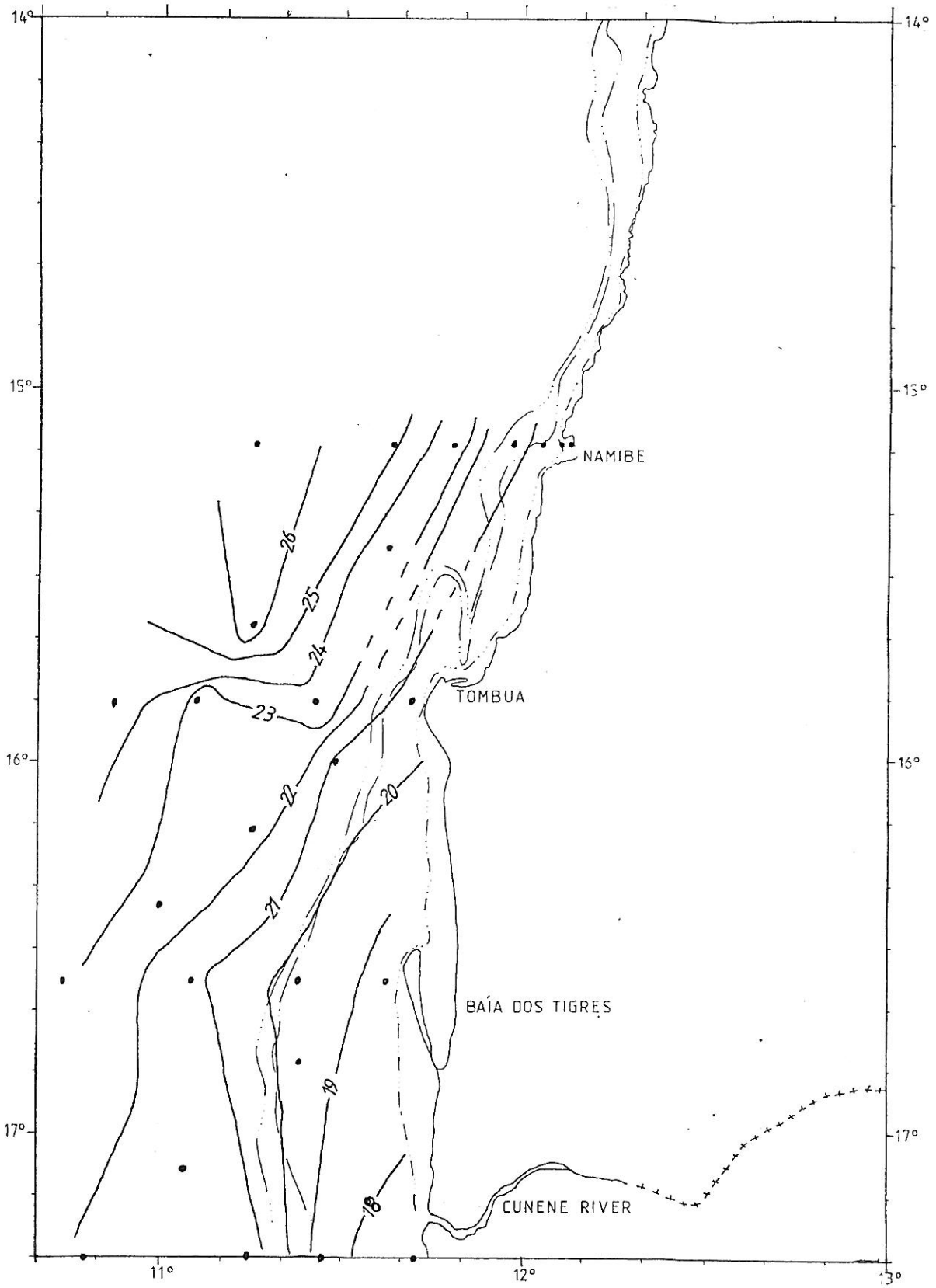


Figure 4e : Horizontal temperature distributions at 10 m depth in southern Angola.

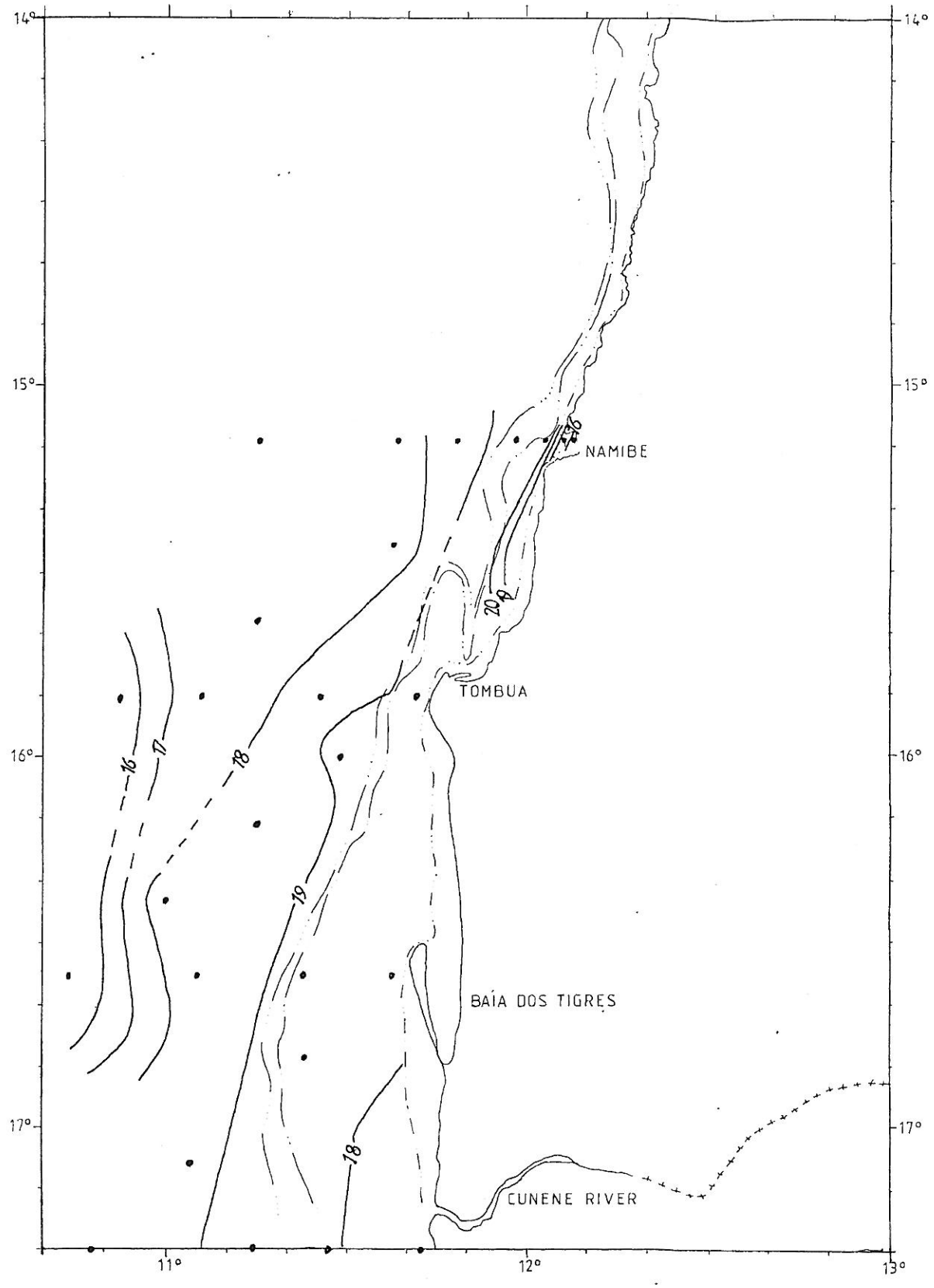


Figure 4f : Horizontal temperature distributions at 35 m depth in southern Angola.

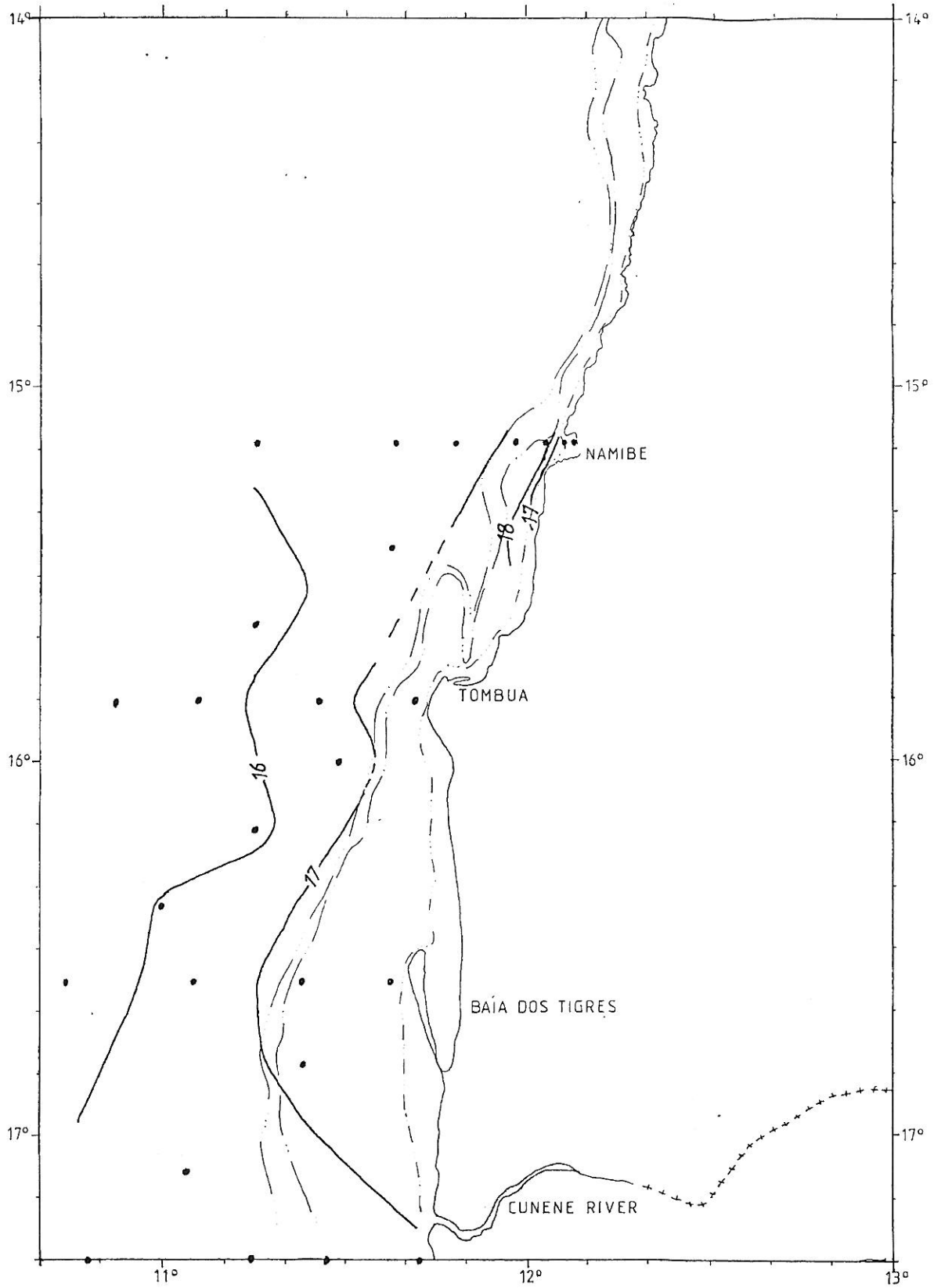


Figure 4g : Horizontal temperature distributions at 50 m depth in southern Angola.

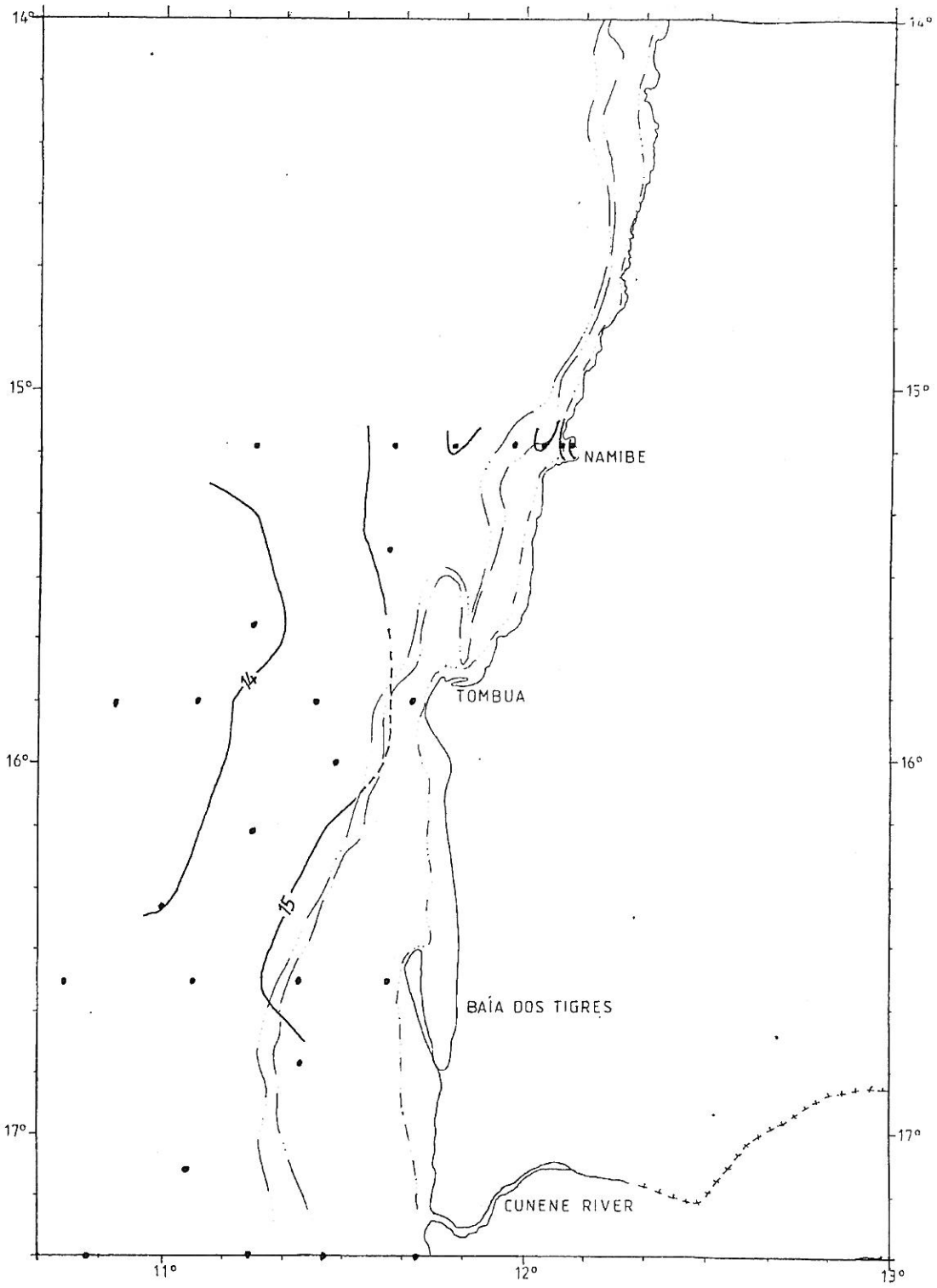


Figure 4h : Horizontal temperature distributions at 100 m depth in southern Angola.

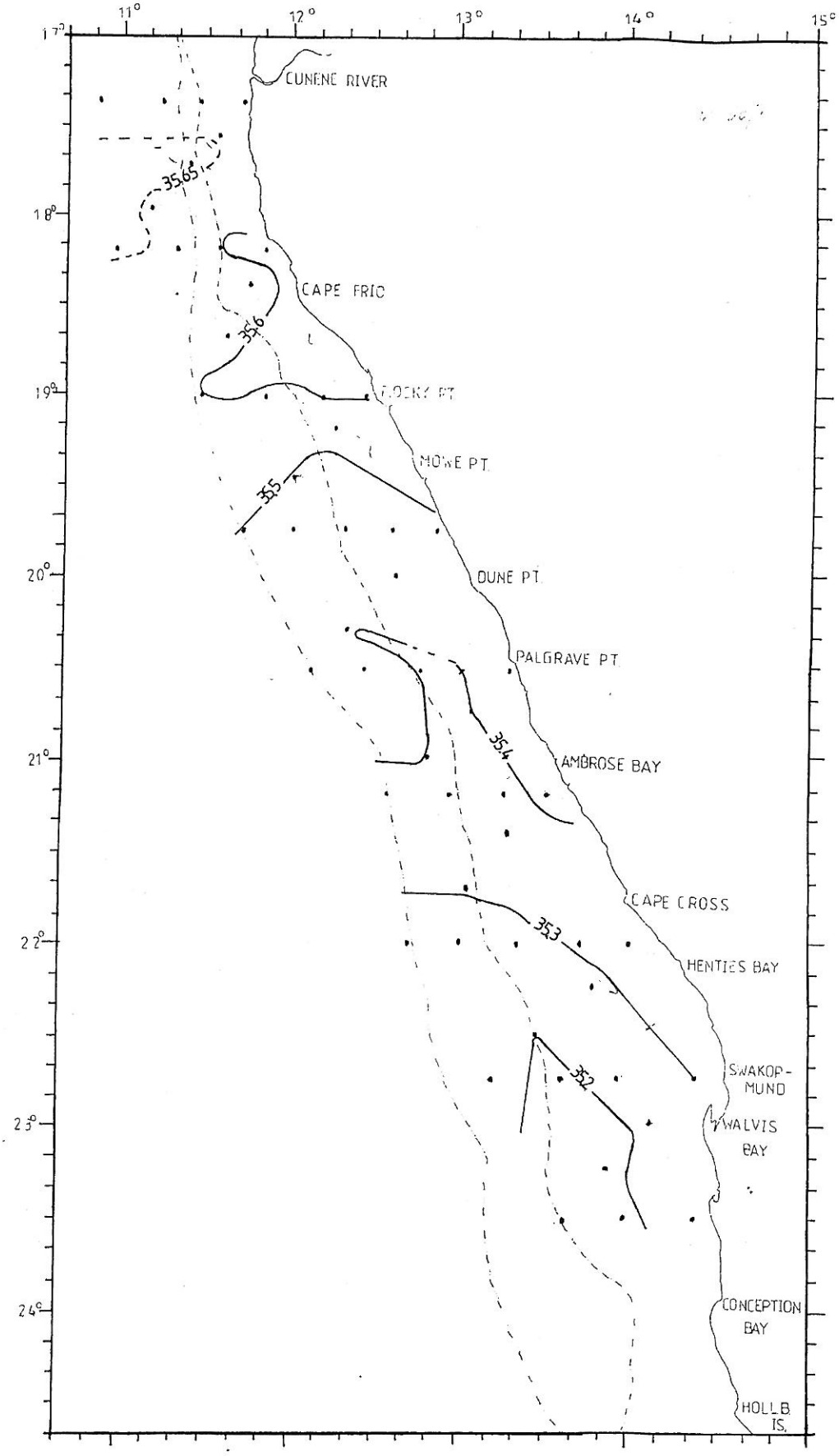


Figure 5a : Horizontal salinity distributions at 10 m depth in northern Namibia.

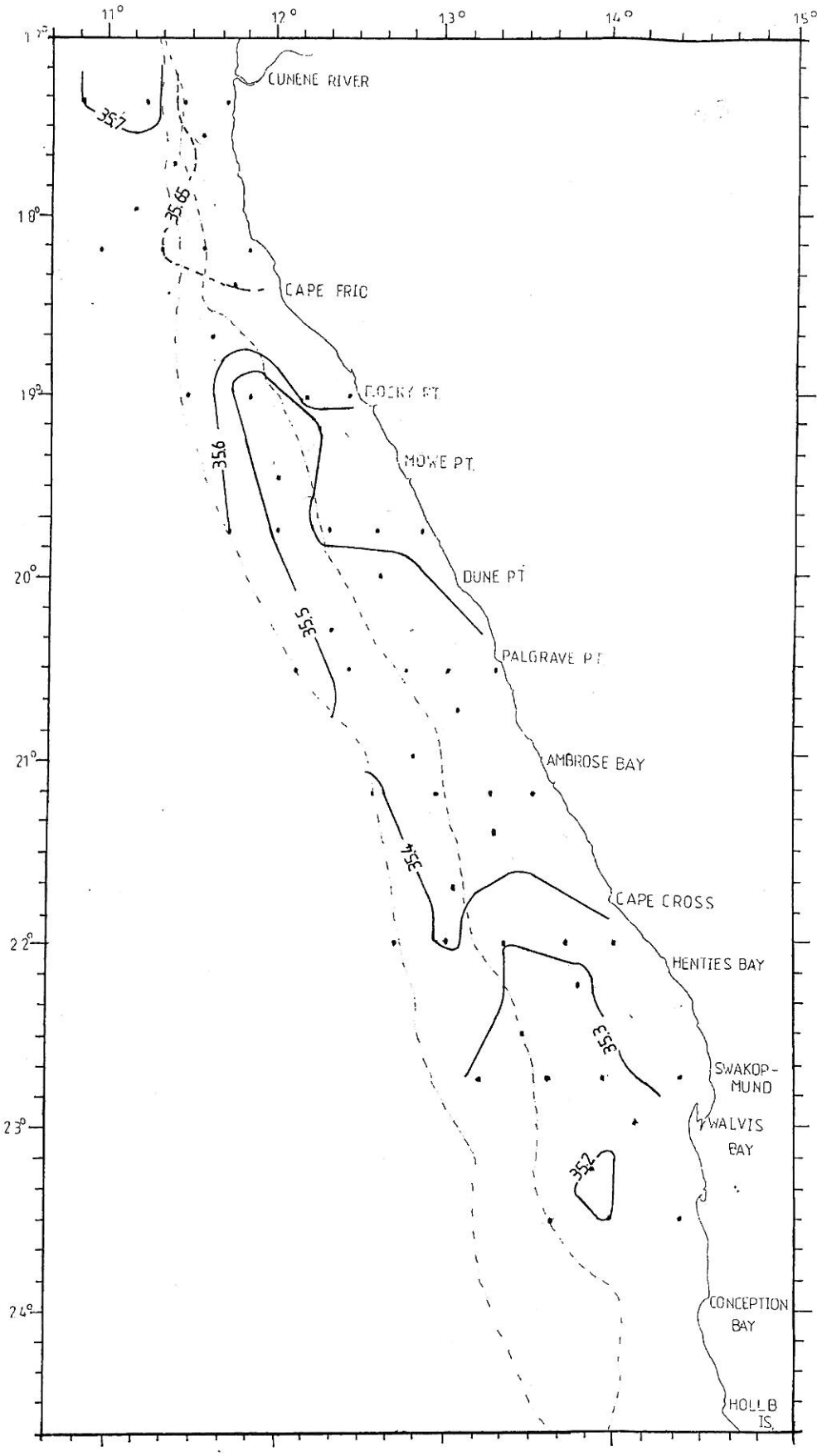


Figure 5b : Horizontal salinity distributions at 35 m depth in northern Namibia.

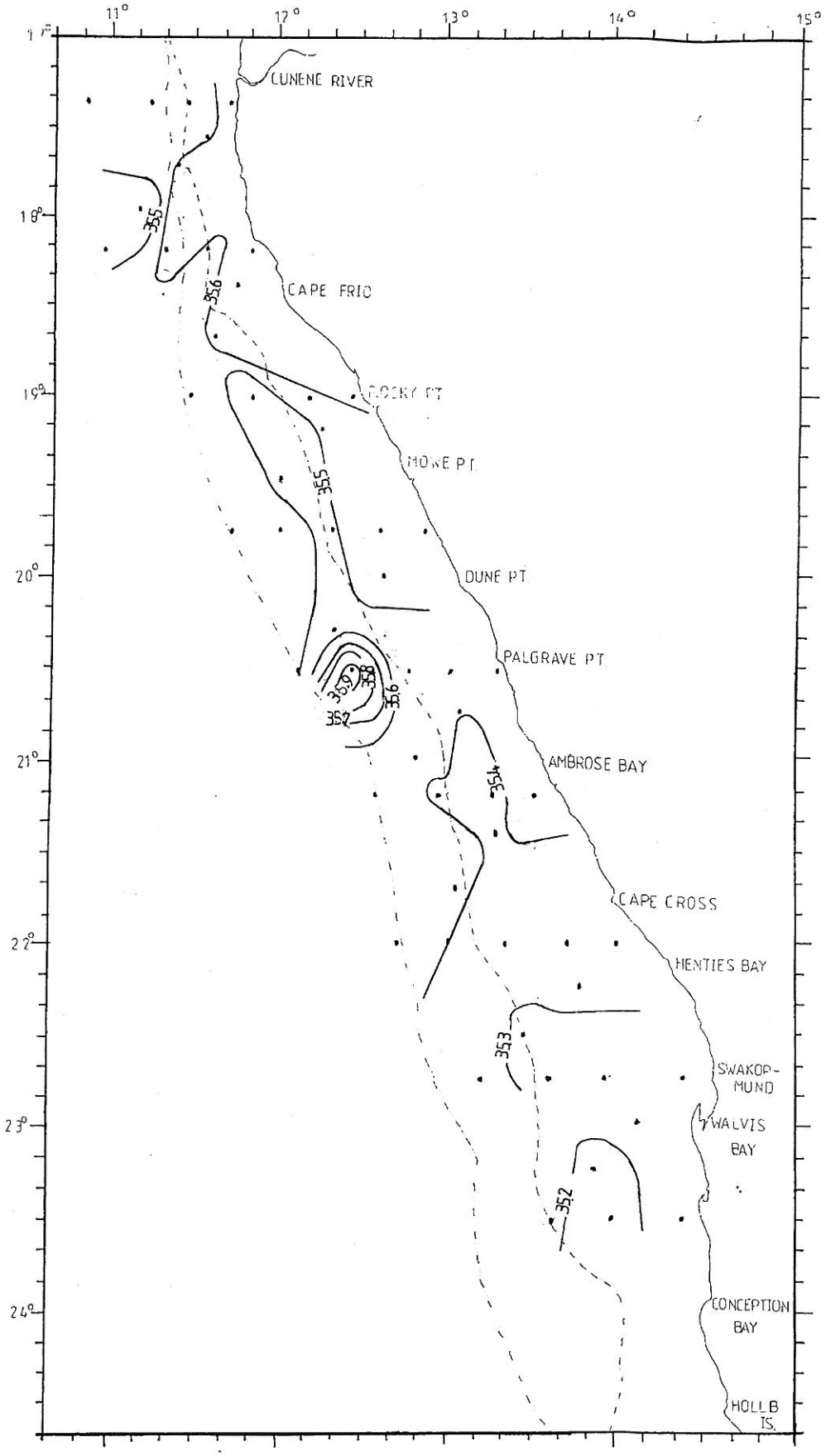


Figure 5c : Horizontal salinity distributions at 50 m depth in northern Namibia.

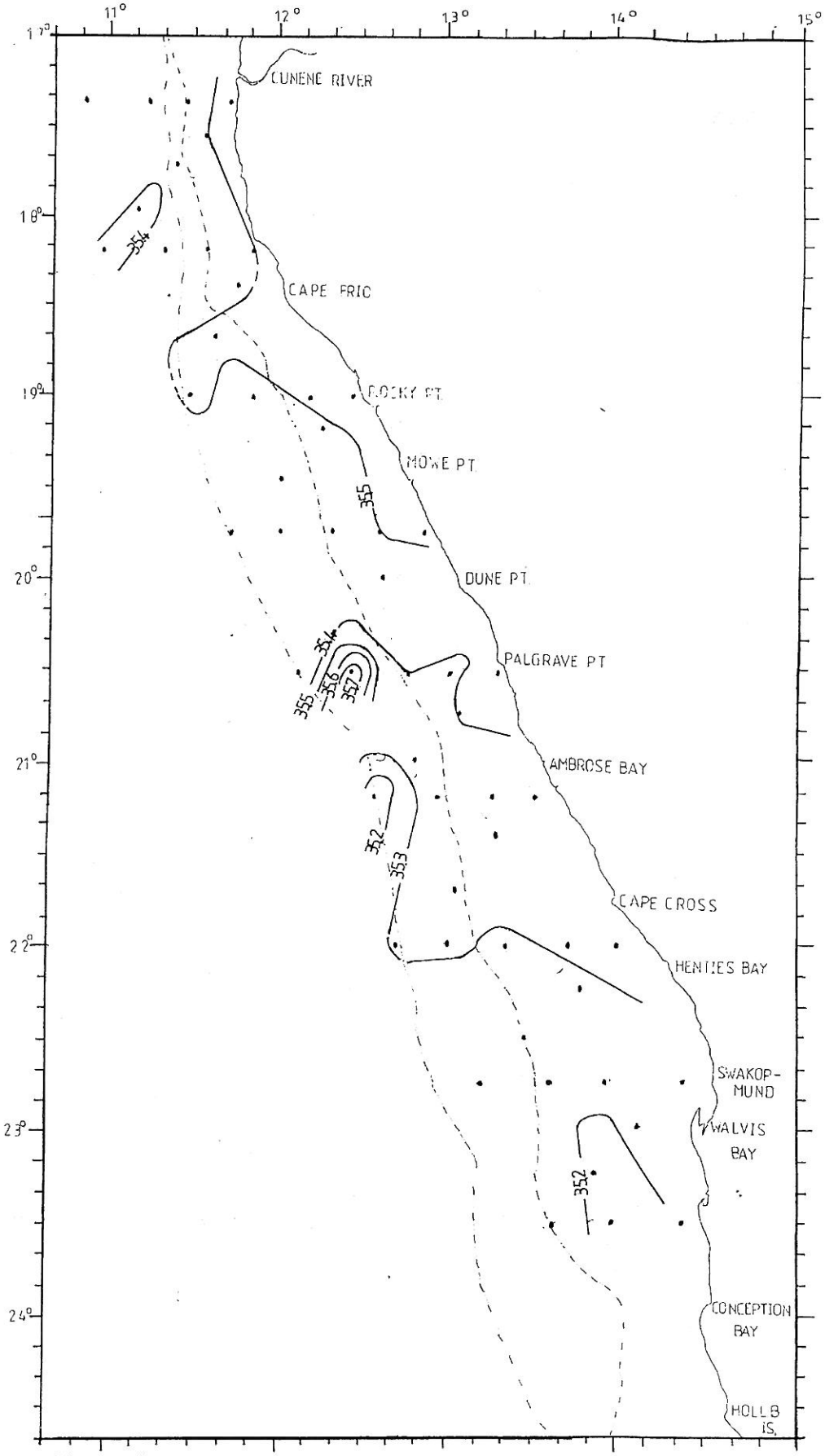


Figure 5d : Horizontal salinity distributions at 100 m depth in northern Namibia.

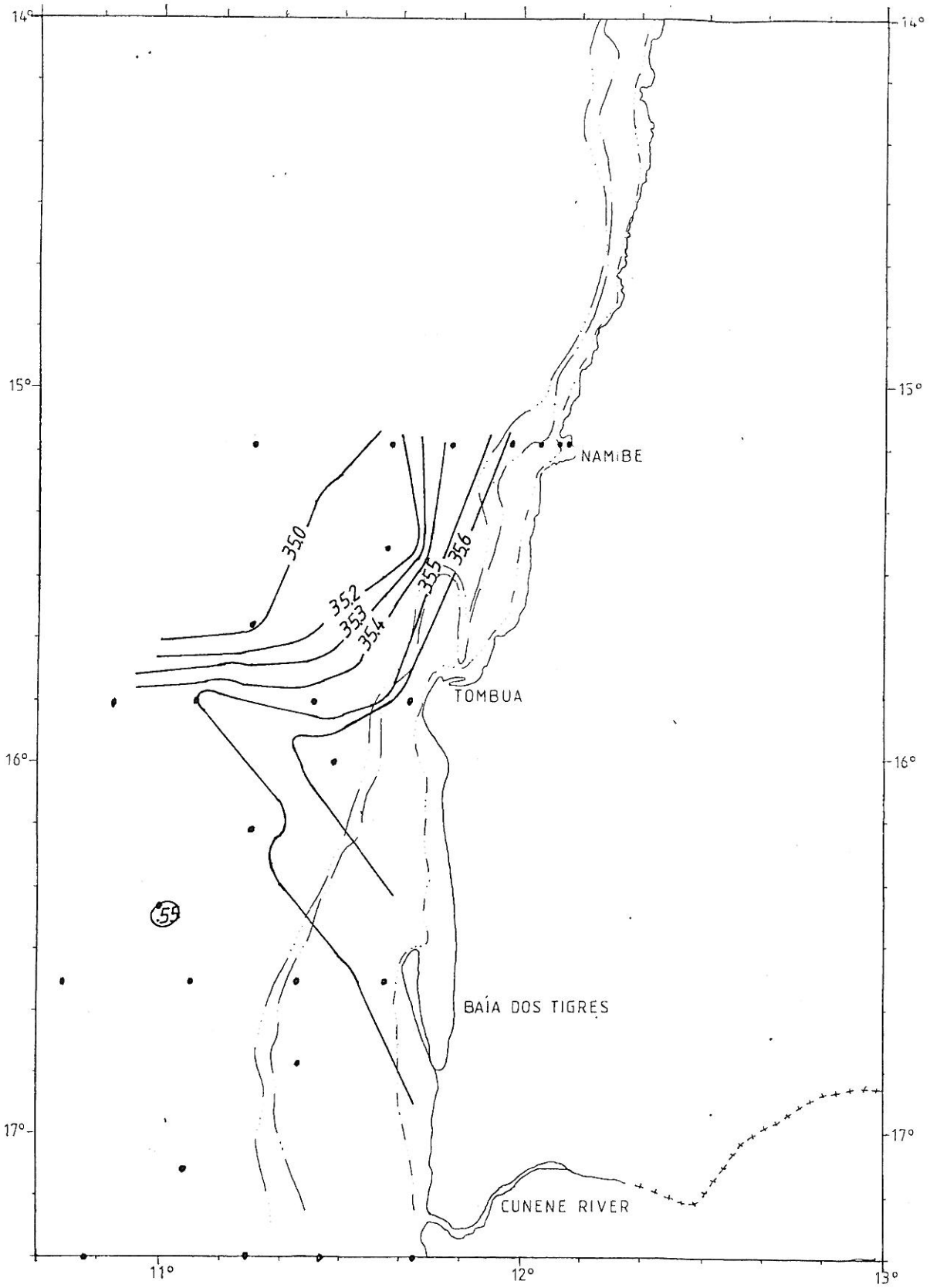


Figure 5e : Horizontal salinity distributions at 10 m depth in southern Angola.

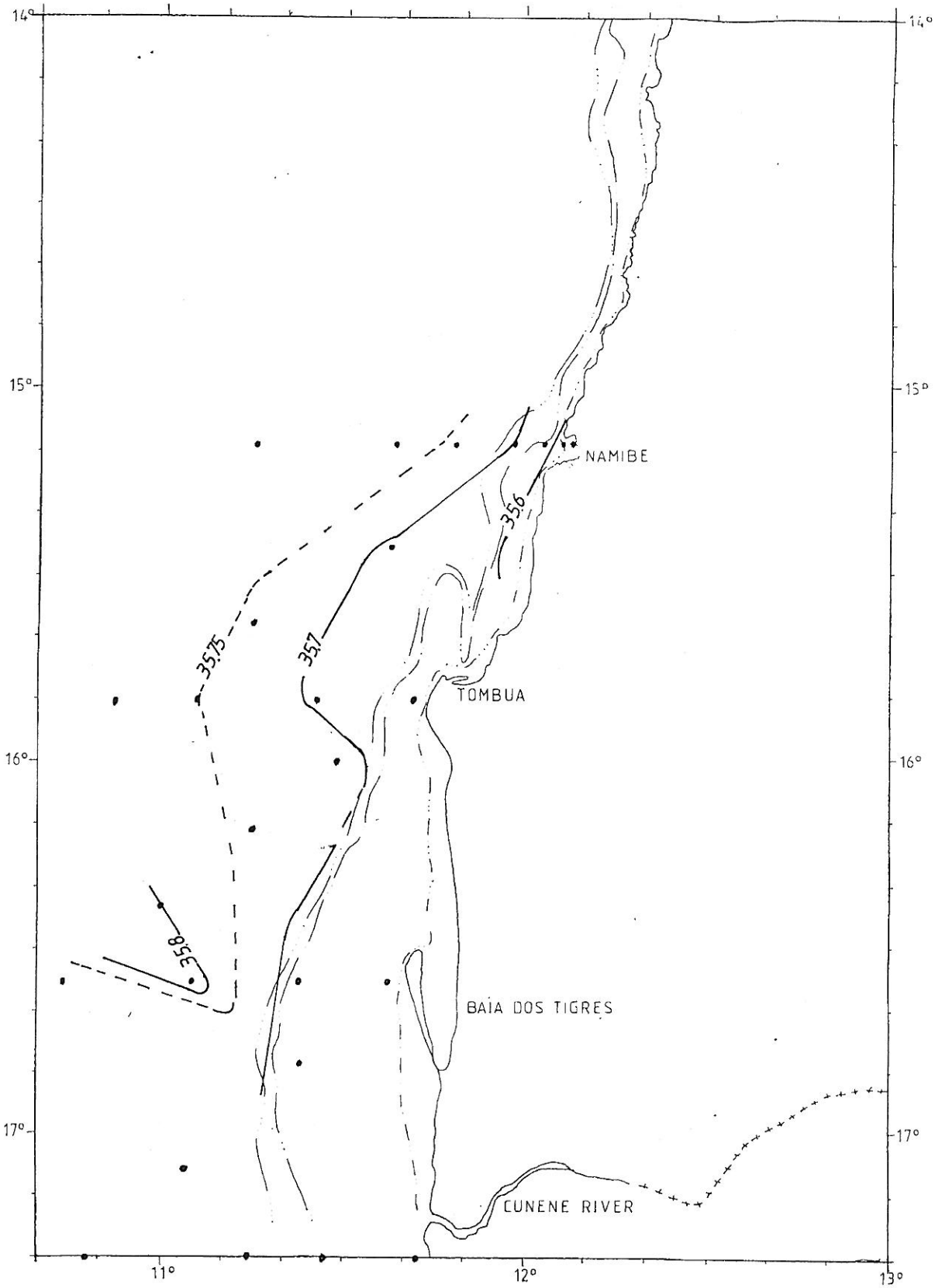


Figure 5f : Horizontal salinity distributions at 35 m depth in southern Angola.

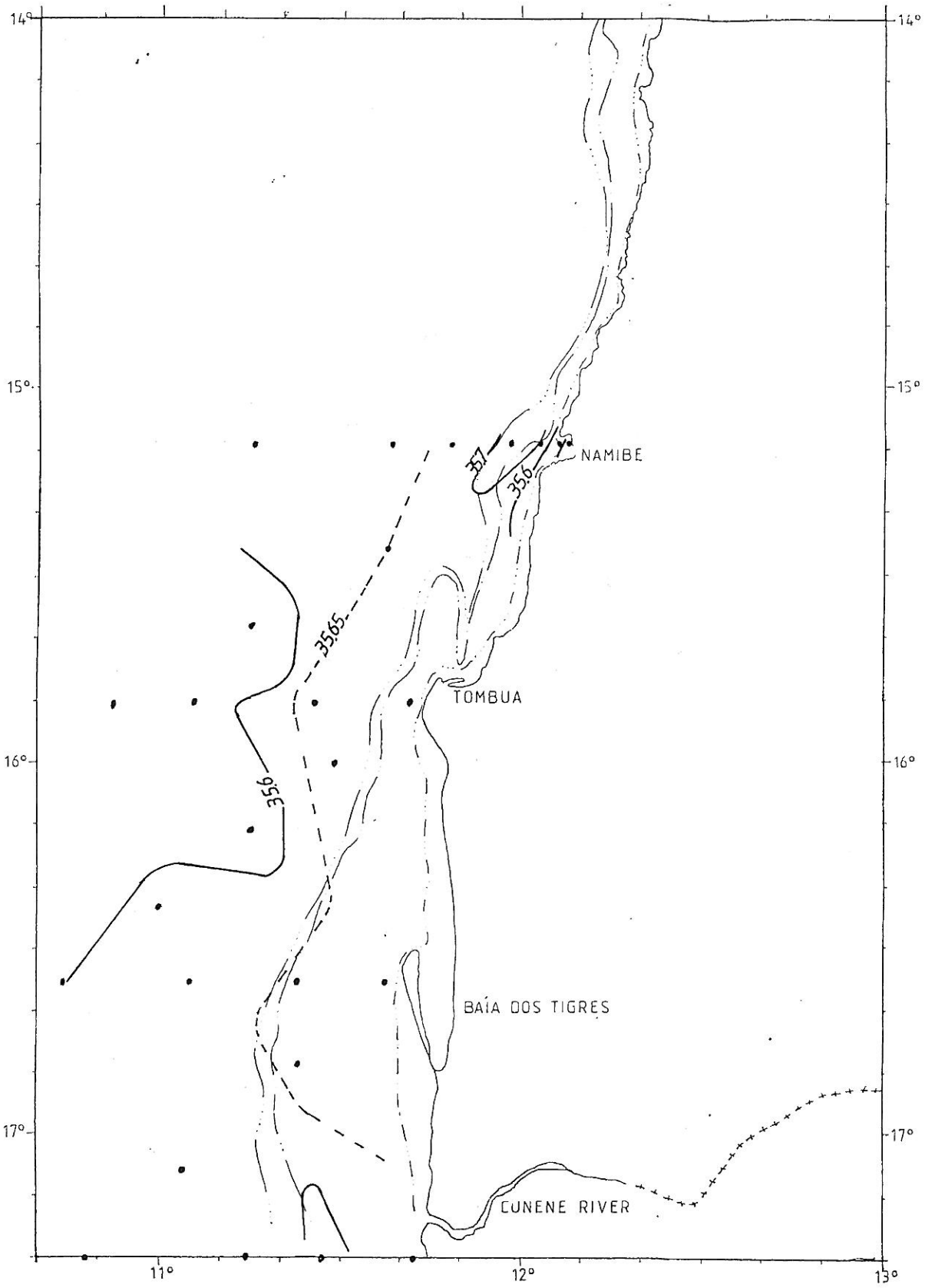


Figure 5g : Horizontal salinity distributions at 50 m depth in southern Angola.

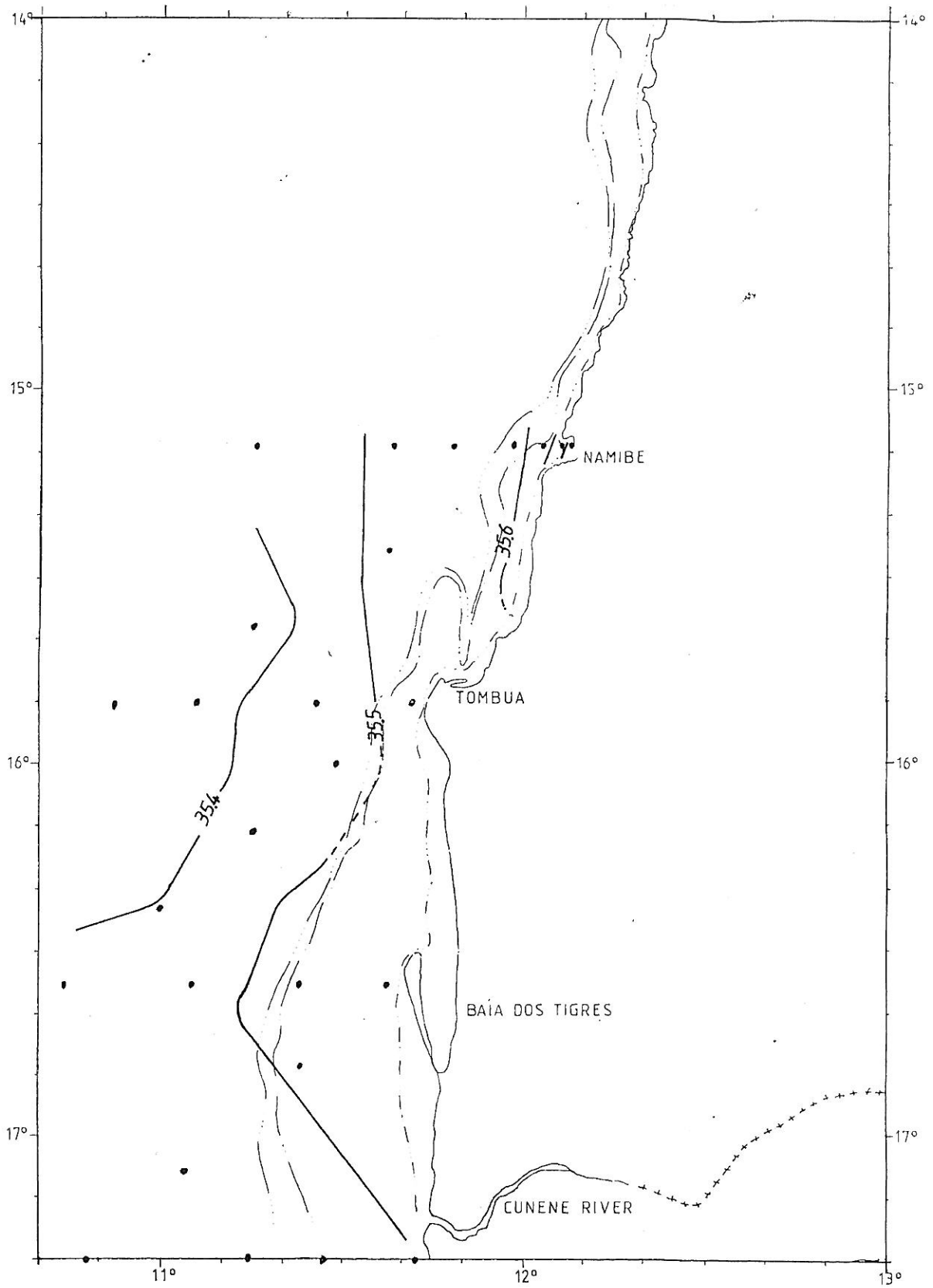


Figure 5h : Horizontal salinity distributions at 100 m depth in southern Angola.

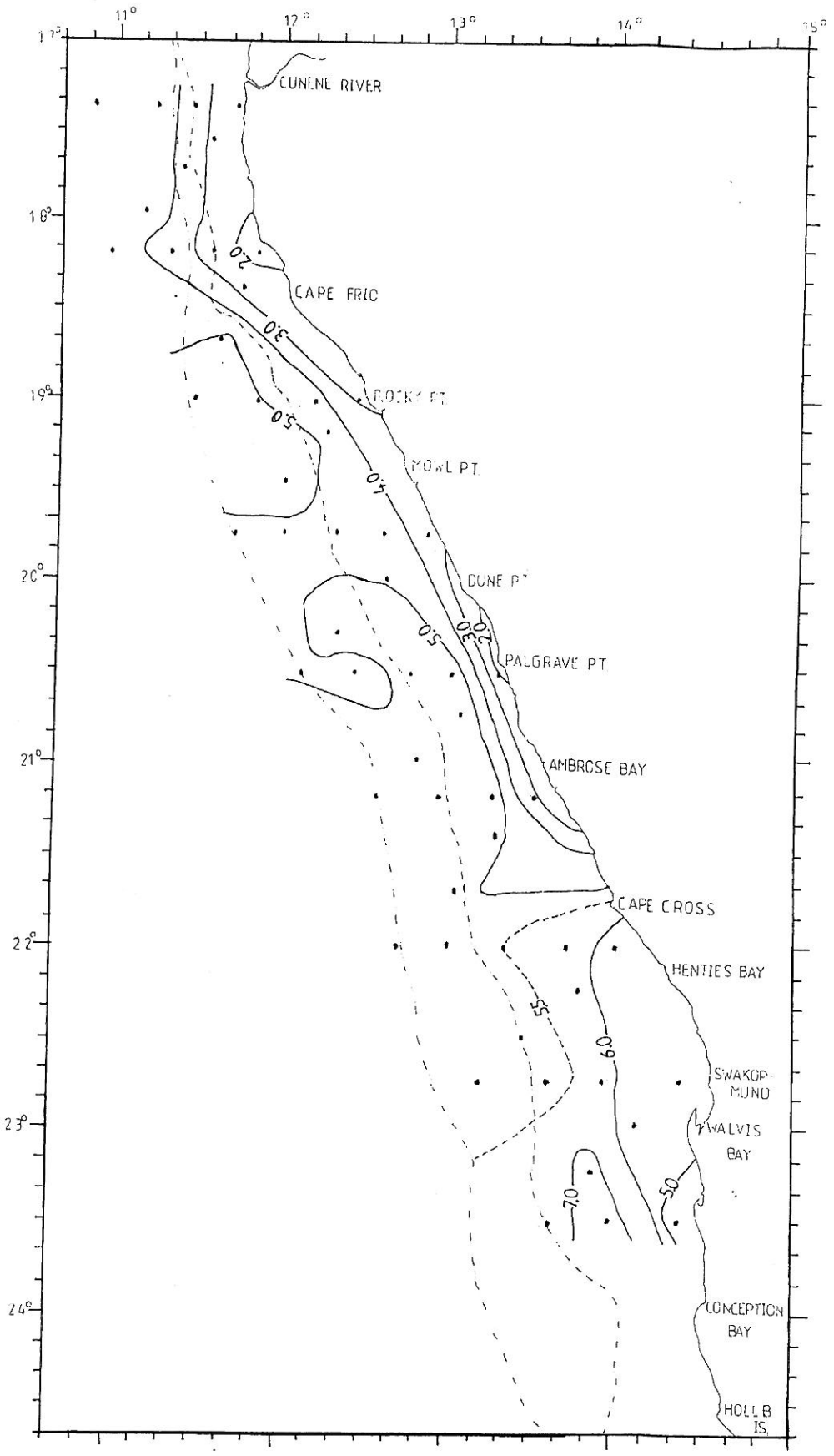


Figure 6a : Dissolved oxygen distributions at 10 m depth in northern Namibia.

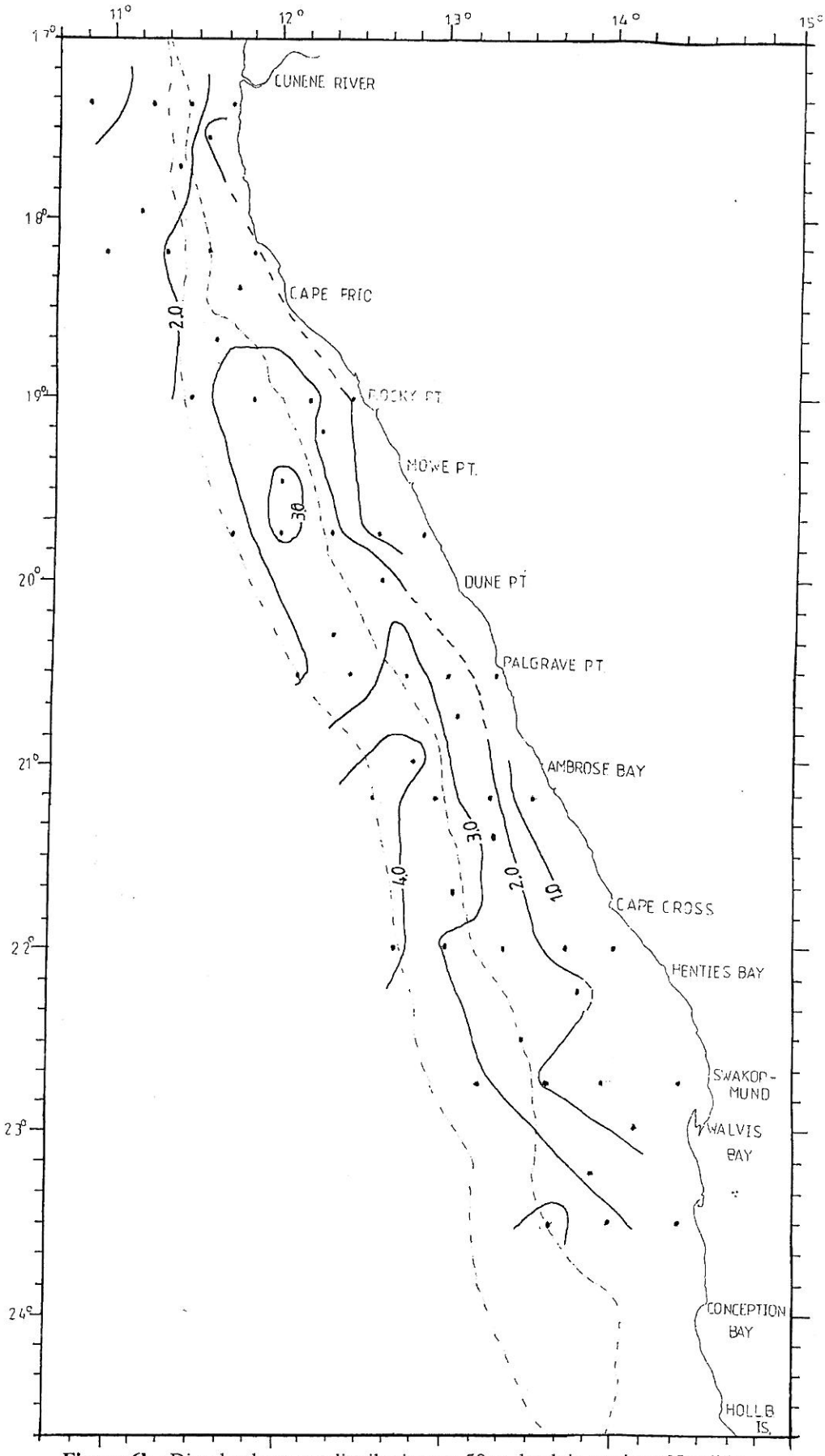


Figure 6b : Dissolved oxygen distributions at 50 m depth in northern Namibia.

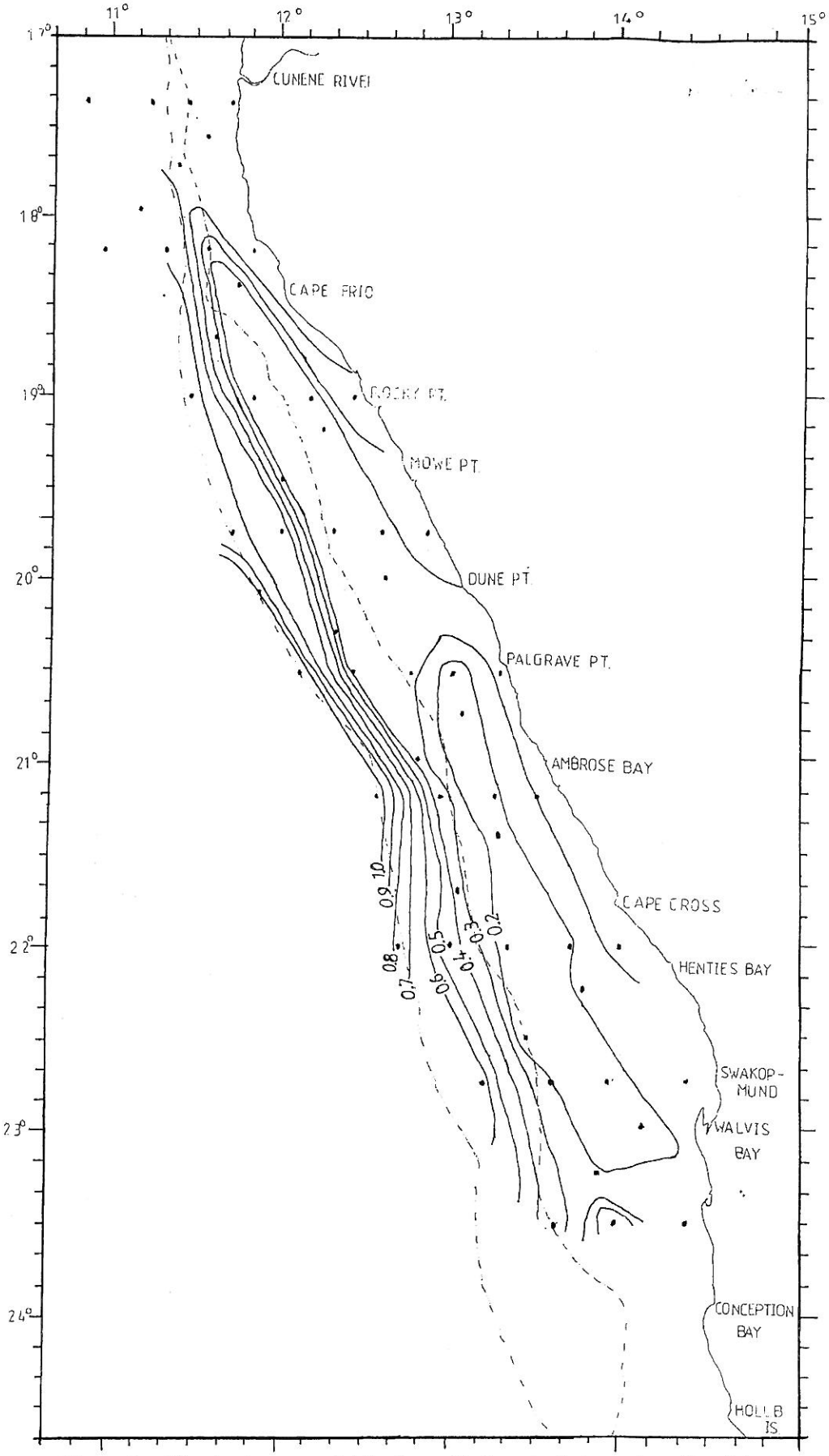


Figure 6c : Dissolved oxygen distributions at bottom depth in northern Namibia.

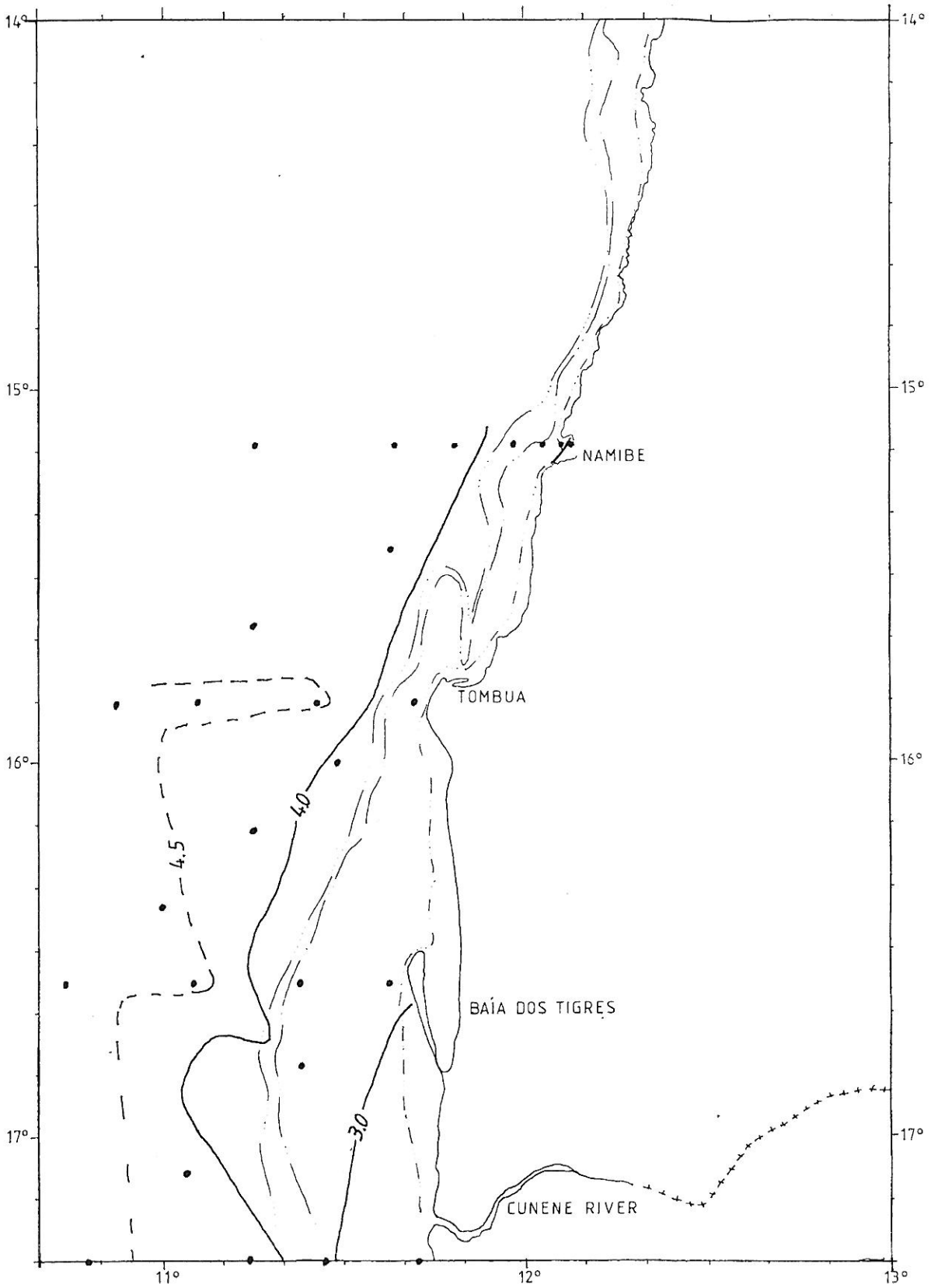


Figure 6d : Dissolved oxygen distributions at 10 m depth in southern Angola.

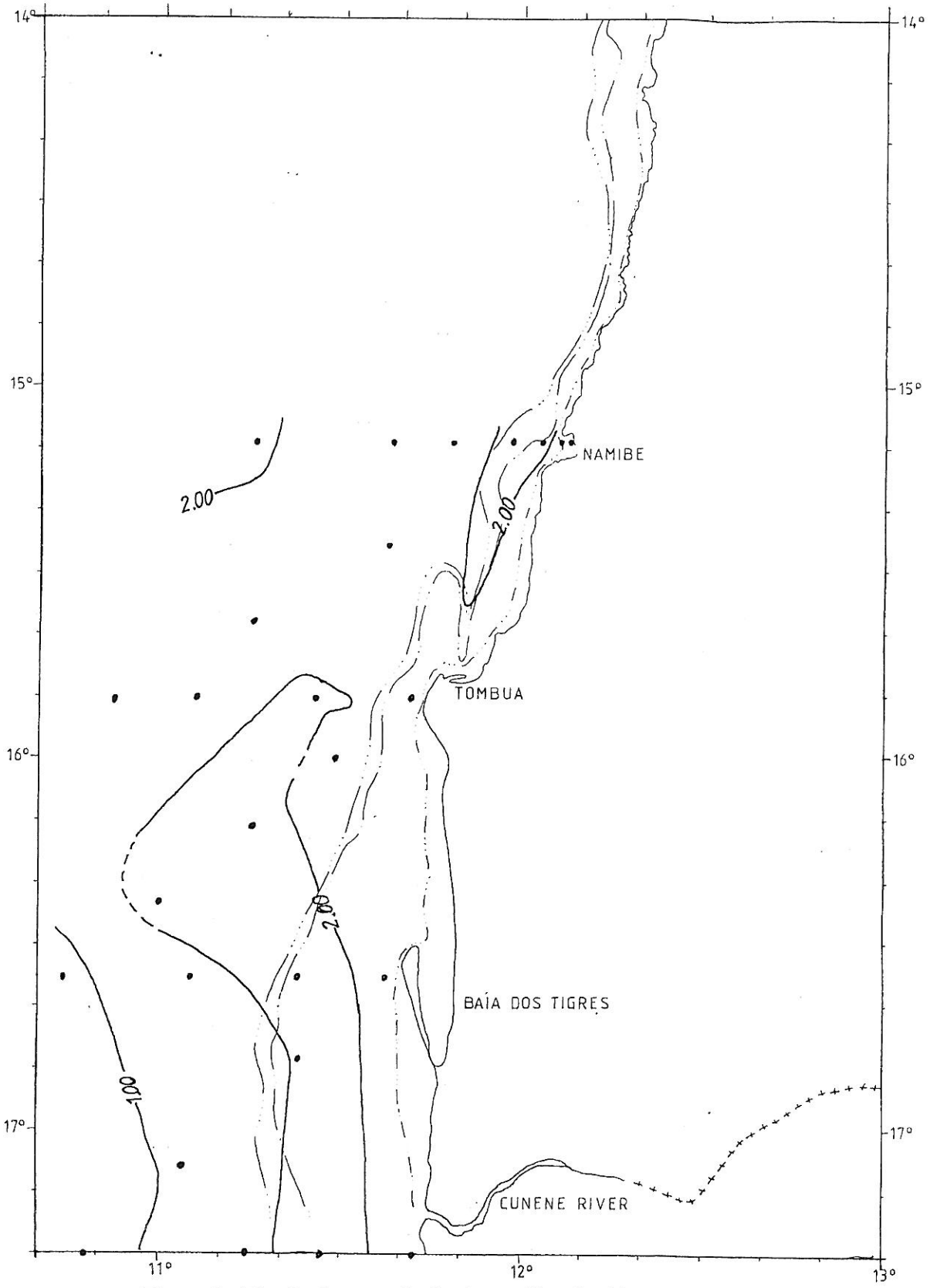


Figure 6e : Dissolved oxygen distributions at 50 m depth in southern Angola.

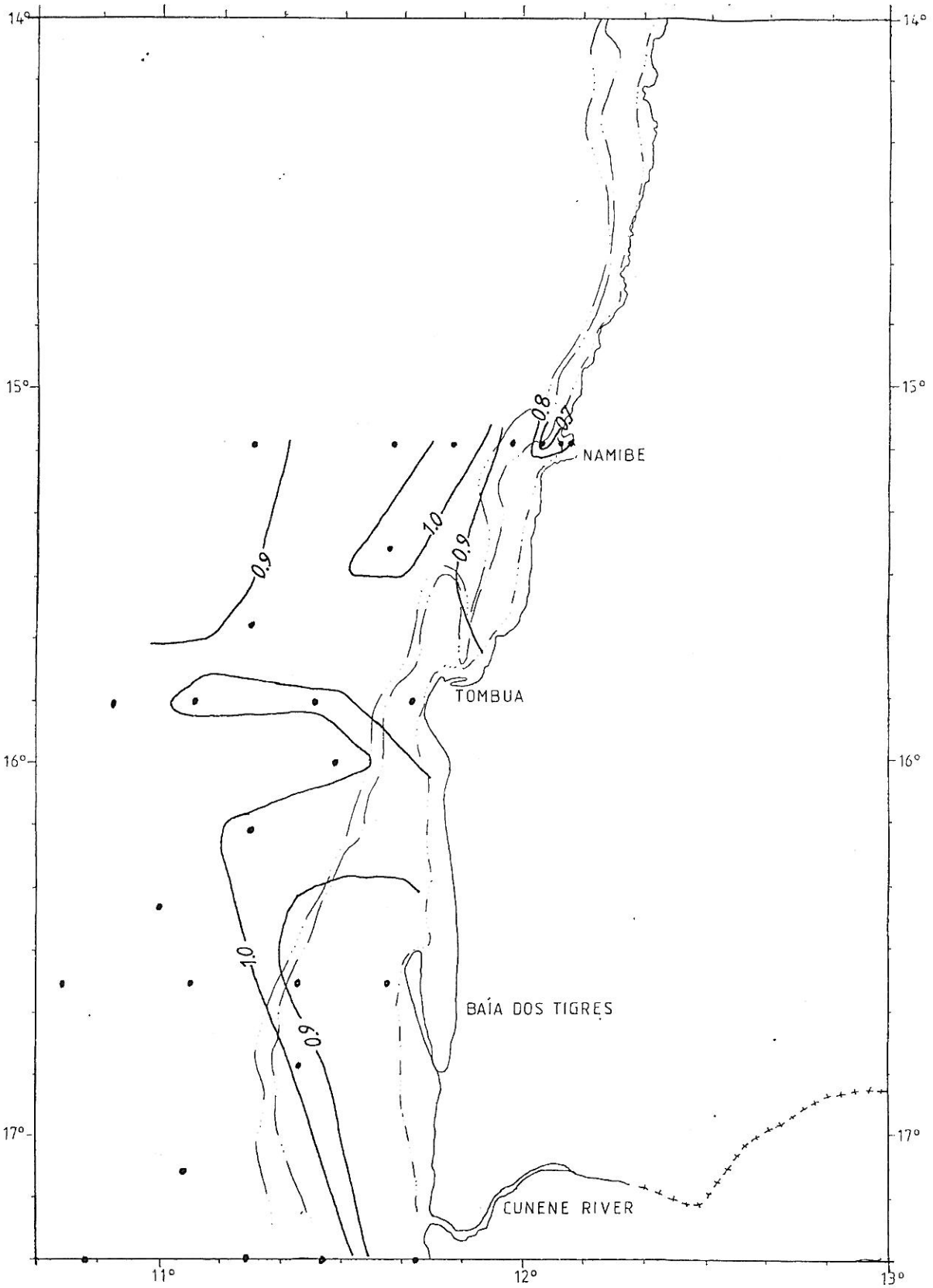
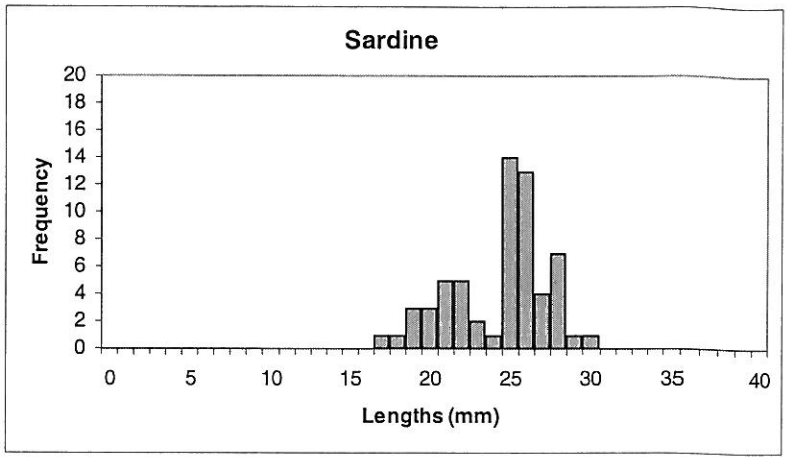
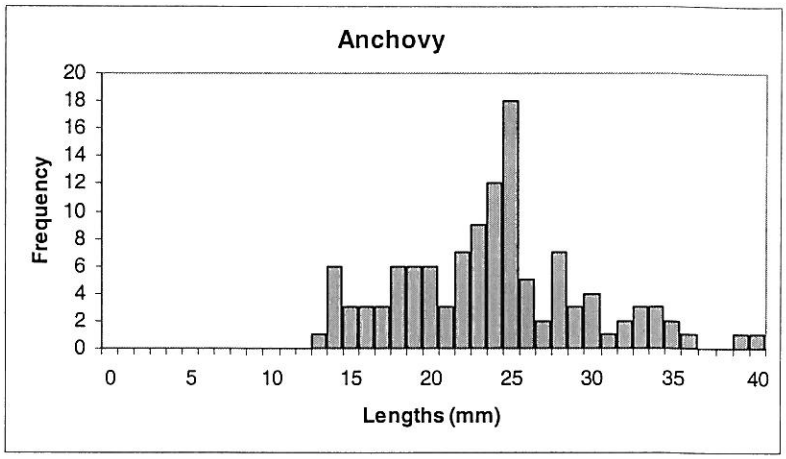


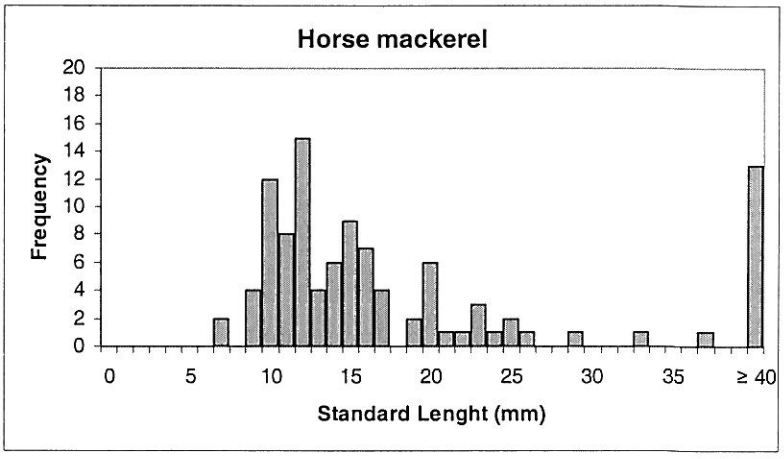
Figure 6f : Dissolved oxygen distributions at bottom depth in southern Angola.



a)



b)



c)

Figure 7 a-c: Length frequencies of a) horse mackerel, b) sardine and c) anchovy larvae caught in the Methot net.

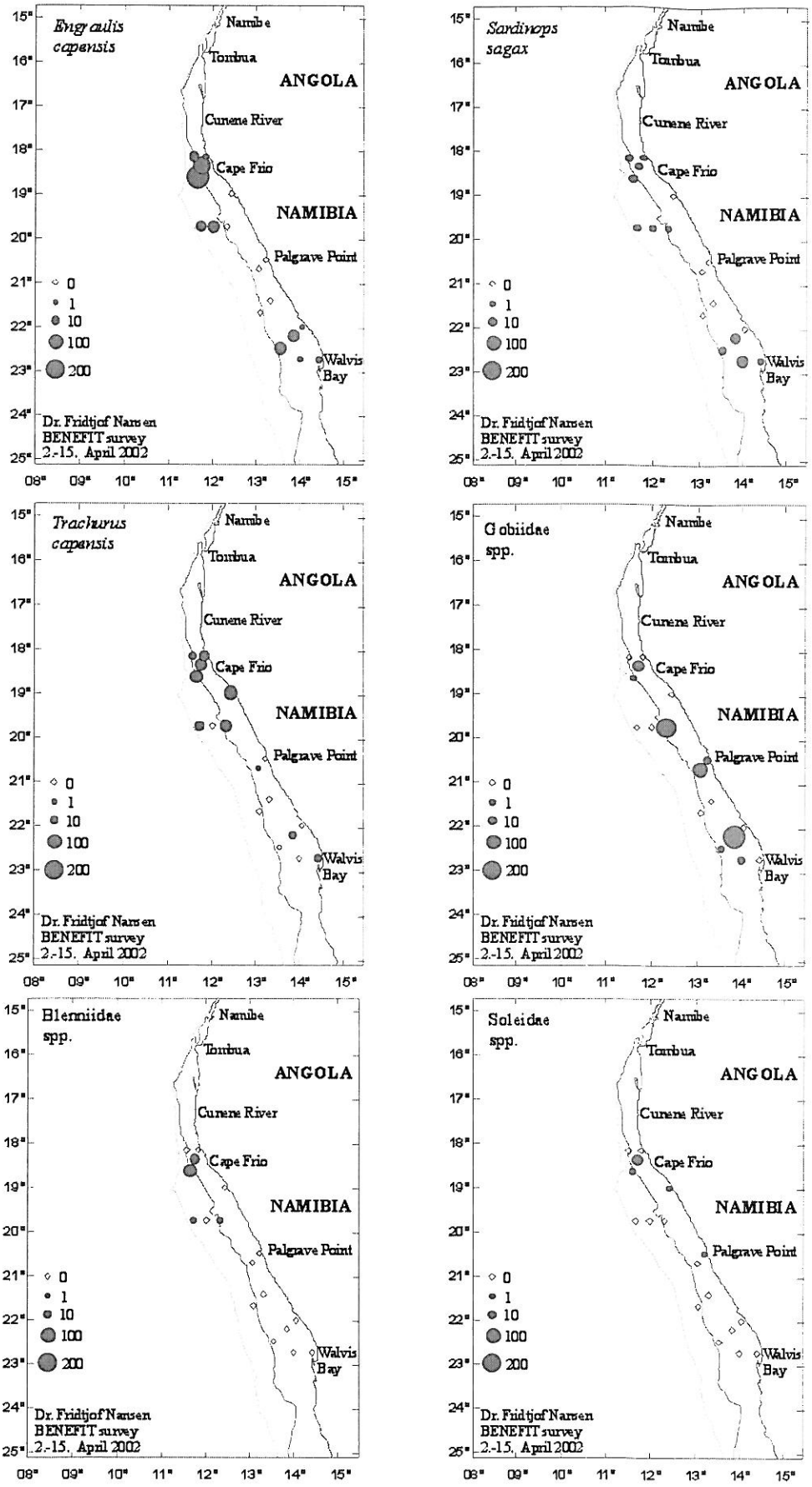


Figure 8: Horizontal distribution of fish larvae/juveniles caught in the Methot. Circles represent the number of larvae in the catch.

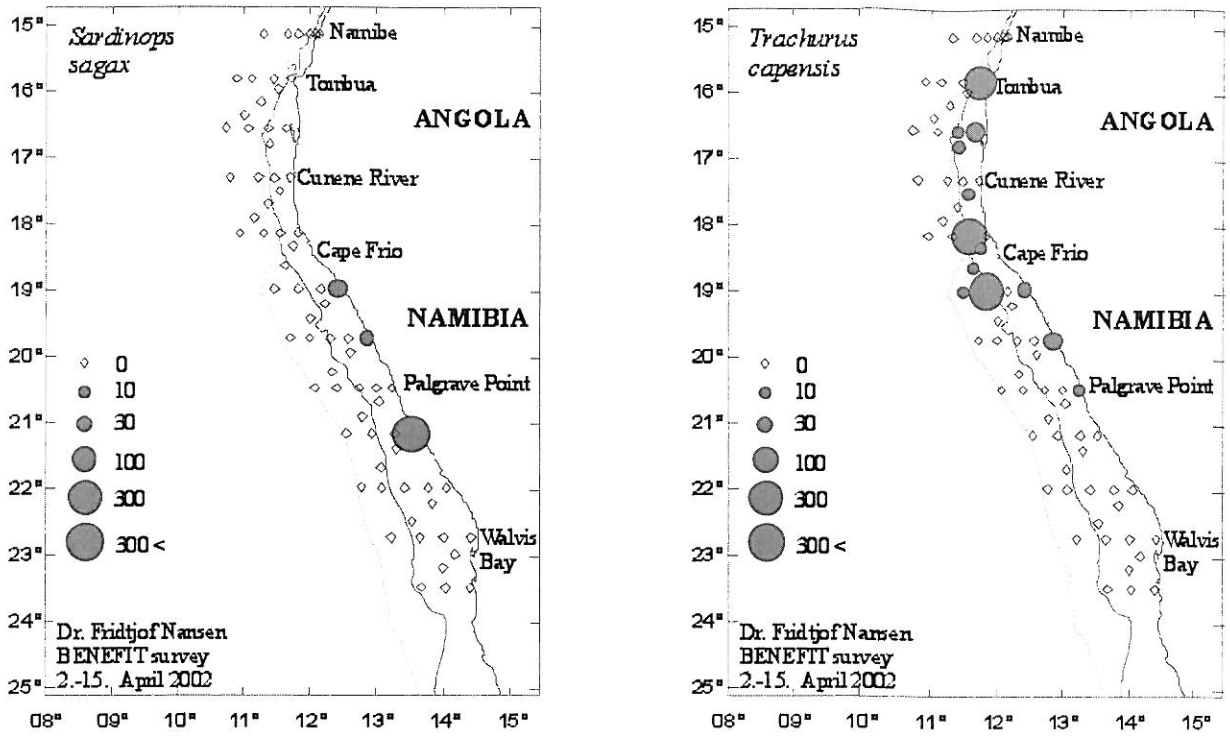


Figure 9: Horizontal distribution of fish eggs caught in the Multinet. Circles represent number of eggs per 10 m^{-2} surface.

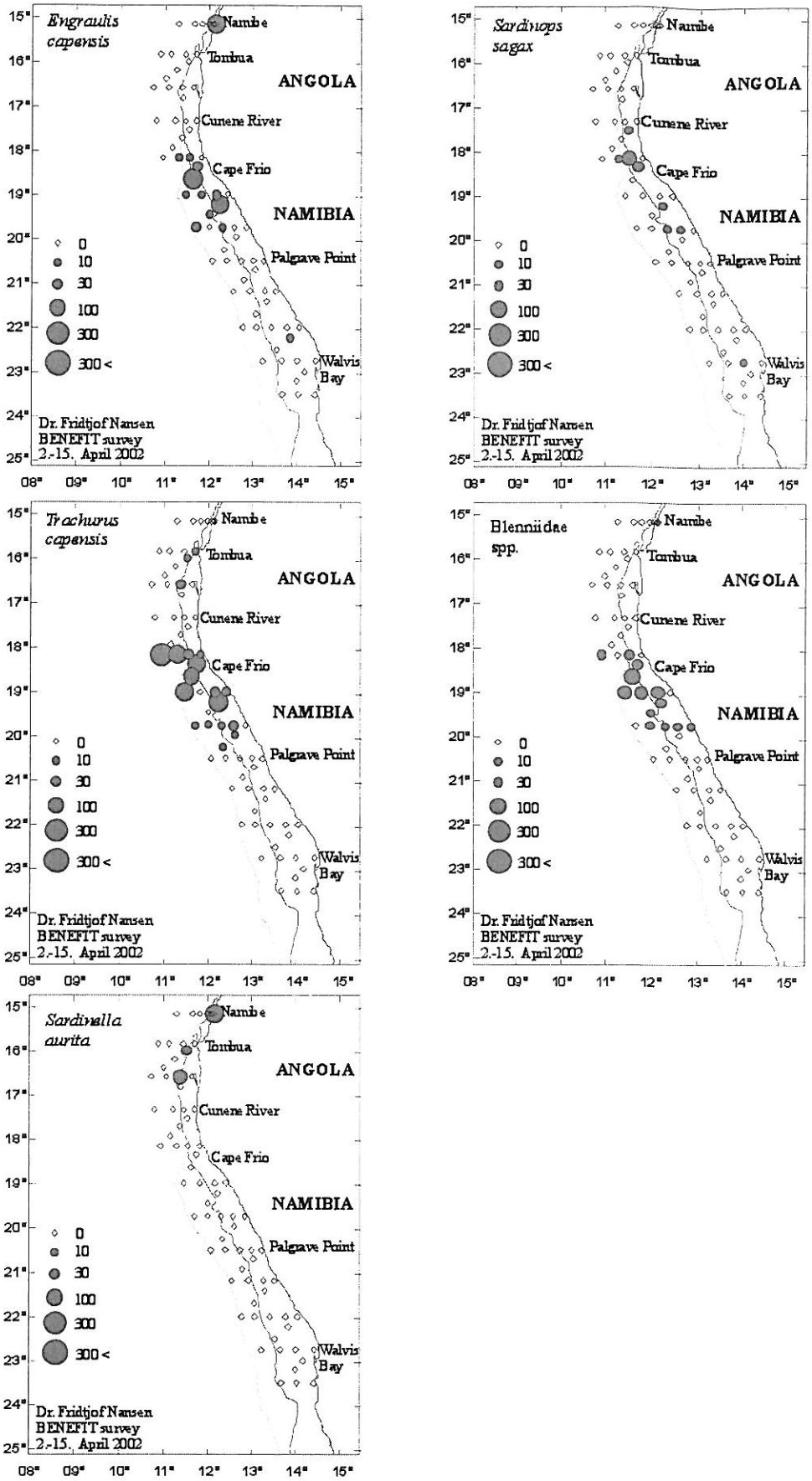


Figure 10: Horizontal distribution of fish larvae caught in the Multinet. Circles represent number of eggs per 10 m^{-2} surface.

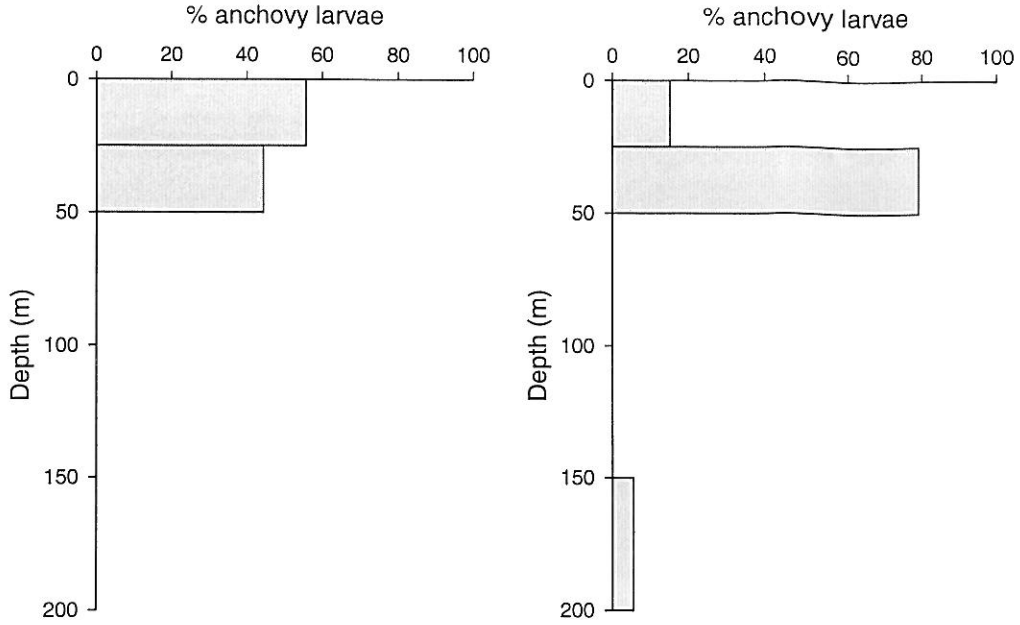


Figure 11: Vertical distribution of anchovy larvae during day (left panel) and night time (right panel).

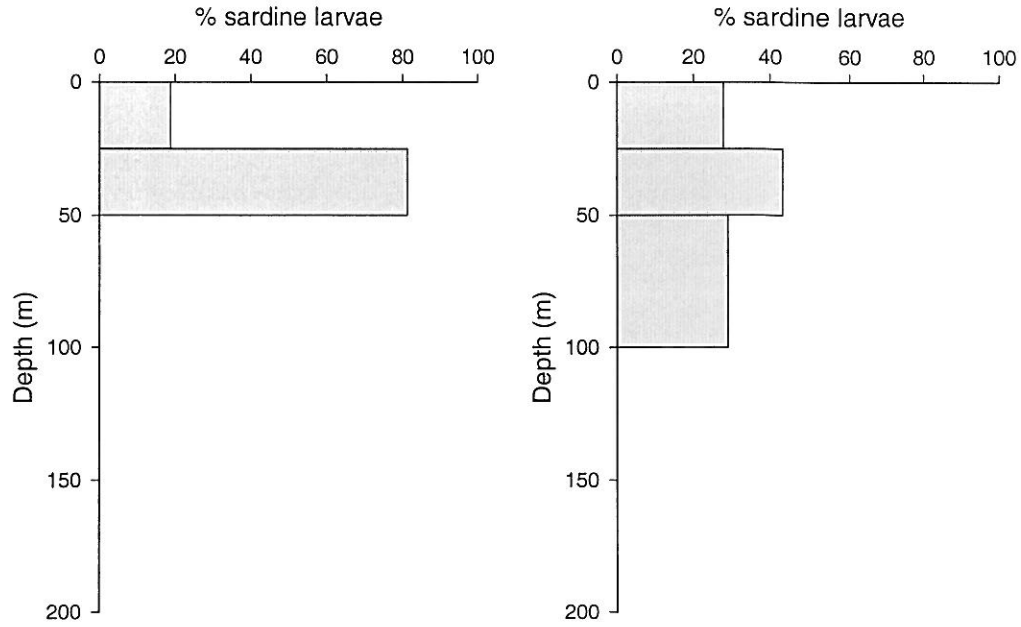


Figure 12: Vertical distribution of sardine larvae during day (left panel) and night time (right panel).

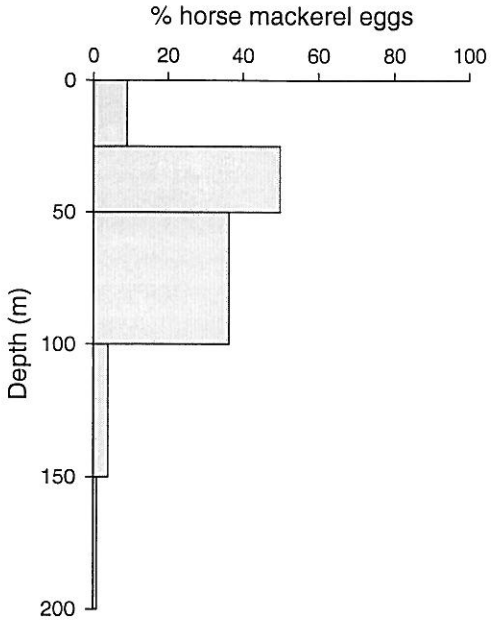


Figure 13: Vertical distribution of horse mackerel eggs.

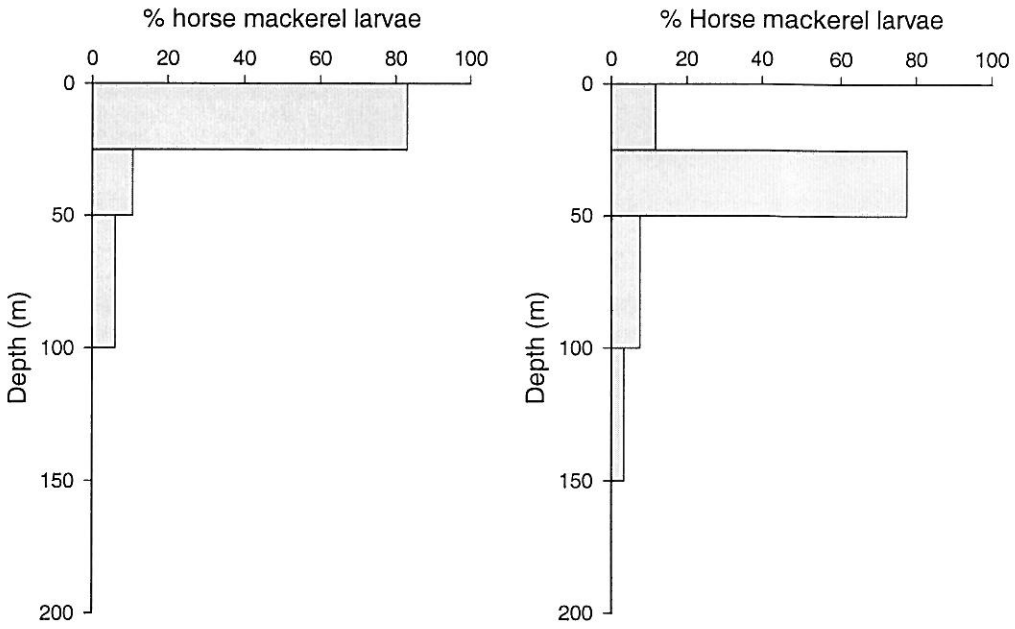


Figure 14: Vertical distribution of horse mackerel larvae during day (left panel) and night time (right panel).

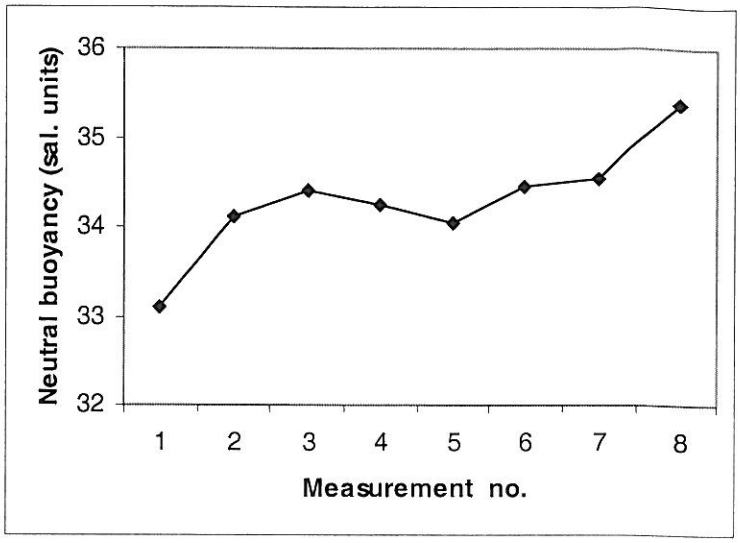


Figure 15: Buoyancy measurements of a pilchard egg.

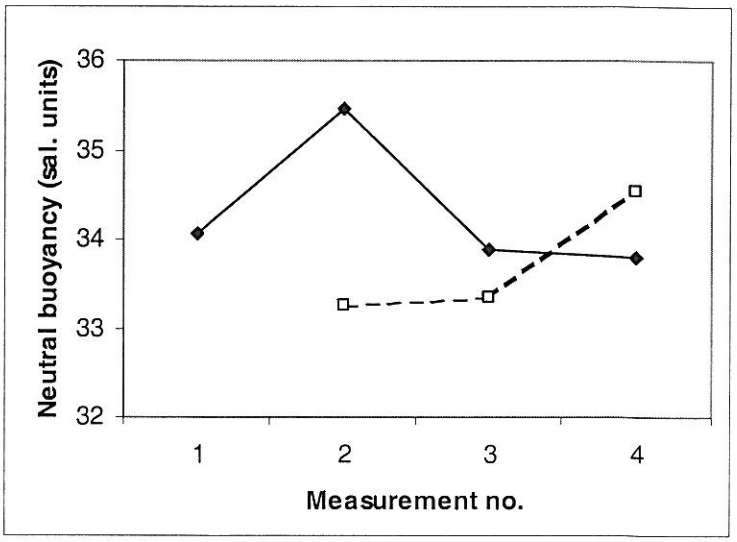


Figure 16: Buoyancy measurements of horse mackerel eggs (solid line) and larvae (broken line).