CRUISE REPORTS "DR. FRIDTJOF NANSEN"

BENEFIT SURVEYS

Cruise Report No 1/2005

Recruitment studies on anchovy, horse mackerel and sardine in the Northern Benguela, 13 - 27 January 2005

by

Erling Kåre Stenevik, Petter Fossum and Berit Endresen

Institute of Marine Research
Bergen
Norway

Anja Kreiner

National Marine Information and Research Centre
Swakopmund
Namibia

Institute of Marine Research
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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 the last in a series of survey 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 horse mackerel, anchovy and sardine.

1.2 Specific objectives of the survey

This main focus of this survey was on eggs and larvae of anchovy, sardine and horse mackerel in the northern Namibia and southern Angola. The horizontal and vertical distributions of the eggs and larvae were mapped and related to the circulation of the water masses and to frontal systems. In addition, buoyancy measurements of the eggs were performed.

1.3 Participation

The scientific members during the cruise were:

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From Namibia:

Suzi Cristof, Justine Kakuuai and Nelda Katjivena

From Norway:

Berit Endresen, Ole Sverre Fossheim, Petter Fossum, Tore Mørk and Erling Kåre Stenevik (cruise leader)

From Angola:

Bernardo Fernandes

1.4 Narrative

The vessel left Walvis Bay on the 24th January at 06:00 UTC and headed for Sandwich Harbour where the survey started on the same day at 14:40. The same survey design as in April 2001, April 2002 and January 2004 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. The survey continued with transects moving northwards. The distances between 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 night-time. On station 47 at 18^{o}10 S, 11^{o}33 E, relatively high concentration of sardine larvae were found. We took the two outer stations on that line and the first station on the northeast section without finding much larvae. It was therefore decided to go east to the 200m isobath (about 12 nm north of station 51) to look for an area to take a repeat station. At this station (17^{o}56 S,11^{o}32 E) there were high concentrations of both sardine and horse mackerel larvae and we decided to take the repeat station there. The first haul (with finer vertical resolution) at the repeat station was on 20 January at 10:00 UTC and we continued with CTD and Multinet hauls every third hour. It was planned to stay at the repeat station for about 24 hours and then to proceed northward and into Angolan water. But we did not get the license to operate in Angolan waters and therefore we stayed at the repeat station until 22 January (10:00 UTC). After the repeat station we continued northward up to the border where we the last section was taken at 17^{o}20 S. We then started to go southward doing Multinet stations to look for anchovy eggs for buoyancy measurements and Methot hauls close to the coast to look for larvae and juvenile fish. We arrived Walvis Bay on 25th January at 15:00. During the survey a total of 89 CTD casts, 85 Multinet stations and 9 Methot stations were conducted.

2 MATERIAL AND METHODS

2.1 Physical measurements

During the survey, CTD casts were taken every 20 nautical miles and in the near shore regions every 15 nautical miles (Figure 1).

2.1.1 Wind

Due to problems with the onboard weather station, wind data was obtained from the Cape Frio weather station, where hourly measurements are taken and sent to Swakopmund.

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) and the surface of the profile. Oxygen samples were analysed within six hours using the standard Winkler method. The result yielded the following regression: $y = 0.8196x - 0.2407$, $R^2 = 0.8967$.

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 μm. 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 - 10 m, 10 – 20 m, 20 – 40 m, 40 – 60 m and 60 – 100 m. When bottom depth was less than 100 m, the deepest net sampled from 10 m above the bottom to the nearest depth interval. During the repeat station the following depth intervals were sampled: 0-10m, 10-20m, 20-30m, 30-40m, 40-50m, 50-60m, 60-70m, 70-80m, 80-100m. To obtain this the Multinet had to be deployed two times at each haul. Multinet stations are shown in Figure 2.

2.2.2 Methot fish larvae sampler

The Methot fish larvae sampler was used to collect juvenile fish. The equipment was produced 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 net 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 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 (2 min) and 20 m (2 min). Methot stations are shown in Figure 2.

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 wet 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 and counted and the standard length was measured.

2.3 Buoyancy measurements of fish eggs and larvae

The onboard equipment from Martin Instrument Co. Ltd. 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 by a ship-mounted cooling unit. A linear salinity gradient was set up in each column by filling the columns 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 filling of each column took about 25 min.

The salinity gradients were prepared before departure on 13th January 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 NatMIRC was used to prepare the salinity solutions for the density gradient columns. The water had been filtered through a 90 μm 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 sodium chloride to 2.5 l of seawater.

The columns were calibrated by inserting glass floats with known specific gravities 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 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 measured. 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, ρ, at 11.5°C and 15°C of glass floats in the three columns.

Column I			**Column II**			**Column III**		
Id. No	**ρ at**		**Id. No**	**ρ at**		**Id. No**	**ρ at**	
	11.5°C	**15.0°C**		**11.5°C**	**15.0°C**		**11.5°C**	**15.0°C**
22635	1.0233	1.0232	23745	1.0228	1.0228	22633	1.0218	1.0217
20381	1.0243	1.0242	20377	1.0248	1.0247	20380	1.0241	1.0240
20375	1.0255	1.0254	20372	1.0262	1.0261	20374	1.0256	1.0255
20366	1.0270	1.0269	20358	1.0281	1.0280	20362	1.0276	1.0275

3 RESULTS

3.1 Physical measurements

3.1.1 Wind

Wind speed measured at Cape Frio ranged between 0.9 and 11 ms^{-1} and averaged 5.9 ms^{-1} during the survey period (Figure 3). Calm conditions prevailed between 20th and 23rd January while highest wind speeds were measured on 24th and 25th January. Wind direction was mainly northerly in the mornings turning southerly during the course of the day (Figure 3).

3.1.2 Hydrography

3.1.2.1 Temperature

Horizontal distributions of temperature at 10, 35 and 50 m depth are shown in Figure 4. The temperature distribution showed the typical gradient with lower temperatures inshore and higher offshore, as well as cooler temperatures in the south than in the north. No clear upwelling centres were observed.

The temperature gradient from south to north was strong in the northern part with temperatures at the Kunene River being around 20°C, while temperature on the inshore station at Cape Frio was only 16°C. The strong temperature gradient was also observed at greater depths. Vertical distributions of temperature through the different sections are shown in Figures 7 to 15.

3.1.2.2 Salinity

Horizontal distributions of salinity at 10, 35 and 50 m depth are shown in Figure 5. Salinity at all three depths showed a gradient from south to north which was strongest at 10 m depth with salinities of 35.1 at Walvis Bay and 35.7 at the Kunene River. The higher salinity waters in the north were the southern extension of the Angola Benguela front. Vertical distributions of salinity through the different sections are shown in Figures 7 to 15.

3.1.2.3 Oxygen

Horizontal distributions of dissolved oxygen at 10, 35, 50 and 5 m above bottom are shown in Figure 6. The oxygen was relatively homogenous above 4ml l^{-1} at 10 m depth throughout the survey region. At 35 and 50m depth an inshore offshore gradient was observed. At bottom depth (measured 5 m above the bottom) the typical band of low oxygen concentrations (lower than 0.3ml l^{-1}) from about 19°30'S to 23°S between the 100 m and 300 m isobaths was observed. Vertical distributions of oxygen through the different sections are shown in Figures 7 to 15.

3.2 Plankton sampling

3.2.1 Horizontal distribution and species composition

Similarly to January 2004, sardine eggs were also this year distributed in three patches (Figure 16). One patch was found off Walvis Bay, one near Palgrave Point and one

patch near Cape Frio. The highest concentrations were observed between the 100 m and the 200 m isobath. Most of the sardine eggs were found in water with temperatures at 10 m depth ranging from 16 to 18 ^{o}C and oxygen concentrations at 10 m depth ranging from 4 to 6 ml l^{-1}. Sardine larvae were only found in one patch (Figure 16) between Cape Frio and Kunene River. Since the survey did not continue into Angolan waters, the northern extent of sardine larvae was not covered. The distribution of sardine larvae indicated a northward transport from the spawning area near Cap Frio. Since only few larvae were found south of this, the spawning in the southern area had probably just started.

Anchovy eggs were found on only one station on the line south of Cape Frio where also the northern patch of sardine eggs were found (Figure 17). Low concentrations of anchovy larvae were observed during the survey.

Very high concentrations of horse mackerel eggs were observed during the survey (Figure 18) and the total number of horse mackerel eggs collected was the highest since these surveys started in 2000. The horse mackerel eggs were distributed in three patches more or less in the same area as the sardine larvae. In previous years, the highest concentrations of horse mackerel eggs have been found in the northern region. This year, however, the highest concentration was observed on a station off Walvis Bay. Horse mackerel larvae were also found in three patches somewhat north of the respective egg patches (Figure 18).

3.2.2 Vertical distribution of eggs and larvae

Only the vertical distributions from stations with ten or more eggs/larvae from the first leg of the survey are presented.

A total of 6429 sardine eggs were found on 11 stations during the first leg of the survey, but only seven stations had ten or more eggs. The vertical distribution of sardine eggs was highly variable (Figure 19). On most stations peak concentration was found in the upper 10 m but on one station the peak was in 10-20 m while one station had peak concentration at 40-60 m. Sardine eggs were found in all depth strata. During the first leg of the survey, 305 sardine larvae were found at 7 stations. Four of these stations had ten or more larvae and the vertical distribution of these is shown in Figure 20. The sardine larvae were mostly distributed in the upper 40 m, but at two stations larvae were found also deeper than 40 m. At the repeat station, 17 hauls were conducted and 2936 sardine larvae were caught. Larvae were found mostly in the upper 50 m (Figure 21). Peak concentrations were mostly found in the upper 10 m during the daytime hauls and between 10 and 20 m during the nighttime hauls.

During the survey, a total of 2442 anchovy eggs were sampled at 3 stations. Of these, 2440 eggs were found at one station (Figure 22). On this station, most of the eggs were distributed between 10 and 40 m. Anchovy larvae were found in relatively low concentrations (60 in total) and during the first leg, no stations had more than 10 larvae. In addition, no anchovy larvae were found on the repeat. Therefore, the vertical distribution of anchovy larvae is not presented here.

High concentrations of horse mackerel eggs were found during the survey. Of the 23 stations where 18574 horse mackerel eggs were sampled, 12 stations had 10 or more eggs and the vertical distribution are shown in Figure 23. Horse mackerel eggs were

found in all depth strata. During the first leg of the survey, horse mackerel larvae were found at 19 stations (253 in total) but only five stations had 10 or more larvae. These larvae were mostly found in the upper 40 m (Figure 24).

3.3 Buoyancy of eggs and larvae

Only wild caught eggs were used for buoyancy measurements during this survey. On 22 January 20 horse mackerel eggs were inserted into column I. The eggs were in a late stage close to hatching and the second day most of the eggs had hatched. Therefore, only two measurements were conducted. The salinity of neutral buoyancy were 33.9 on the first measurement and 34.36 on the second measurement (Figure 25).

3.4 Size distribution

The sardine larvae sampled with the Multinet this year were smaller than last year (Figure 26). The average standard length this year was 8.55 mm compared to 11.9 mm in 2004. The anchovy larvae (13.53 mm), however, were bigger than last year (7.9 mm) and also bigger than the sardine larvae. The average standard length of the horse mackerel larvae was 4.13 mm compared to 4.9 mm in 2004.

4 DISCUSSION

Sea surface temperatures along northern Namibia were warmer during January this year compared to the same time period last year. Satellite images (See Fig. 27) as well as high salinities at the Kunene River show that the Angola Benguela front has moved further south than during January last year. While last year upwelling occurred between Palgrave Point and Walvis bay, seen in temperature and oxygen measurements, this year no upwelling in that area could be observed. Oxygen measurements show typical features for this time of the year for the region.

During the survey, relatively high concentrations of eggs of all the three key species were found. Like last year, the anchovy eggs were only found north of 20^{o}S while sardine eggs were mainly found south of 20^{o}S. Horse mackerel eggs had a horizontal distribution similar to the sardine eggs. Larvae of the three species were found in lower concentrations than eggs. Particularly, few anchovy larvae were caught but opposite to last year those were relatively big. Most of the anchovy larvae were bigger than 10 mm, which corresponds to an age of about 18 days (Stenevik et al., in prep). Most of the sardine and horse mackerel larvae were, however small with few sardine larvae bigger than 13 mm and few horse mackerel larvae bigger than 6 mm.

As usual, the vertical distributions of eggs and larvae of the three species were highly variable both between and within species. Highest concentration of sardine eggs were at a station found in the 40-60 m depth interval (below the upper mixed layer) while on another station the highest concentration was found in the upper 10 m (within the upper mixed layer). The horse mackerel eggs were found throughout the investigated water column and if the hauls had been taken deeper than 100 m, horse mackerel eggs would probably have been found even deeper at some stations. Too few anchovy larvae were found to investigate their vertical distribution. Sardine and horse mackerel larvae were mainly distributed in the upper 40 m. However, on most of the stations, peak concentration was found below the upper 10 m. Data from the repeat station showed that there was a tendency that the sardine larvae had peak distribution deeper during daytime than during nighttime. This is in accordance with previous investigations on anchovy larvae (E.K. Stenevik unpublished data) indicating that the larvae have a type II vertical migration pattern moving towards the surface during daytime and being deeper during nighttime.

5 ACKNOWLEDGEMENTS

Thanks are extended to Tore Mørk and Ole Sverre Fossheim who were responsible for running the instruments and to Suzi Cristof, Justine Kakuuai and Nelda Katjivena from NatMIRC for valuable assistance during the plankton sampling. The officers and crew of the R/V *"Dr. Fritjof Nansen"* are thanked for making everything work smoothly during the survey.

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7 FIGURES

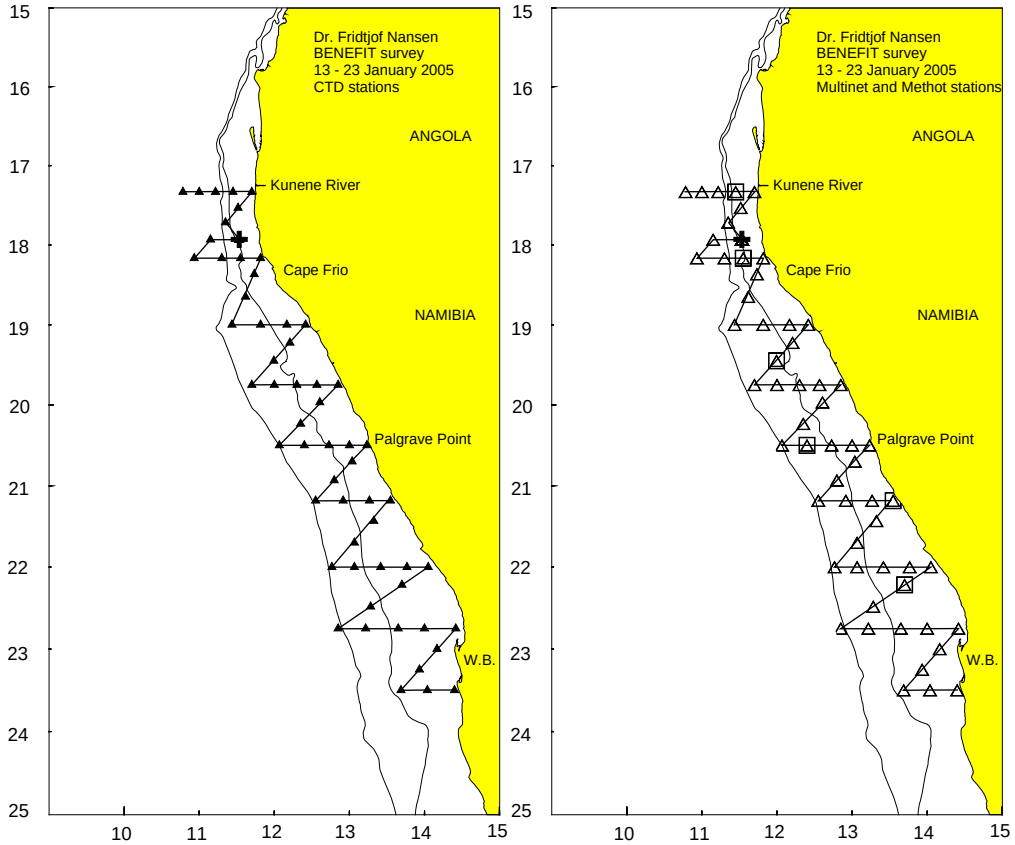


Figure 1. Cruise tracks with CTD (left panel), Multinet (right panel, triangles) and Methot (right panel, squares) stations on the first leg of the survey.

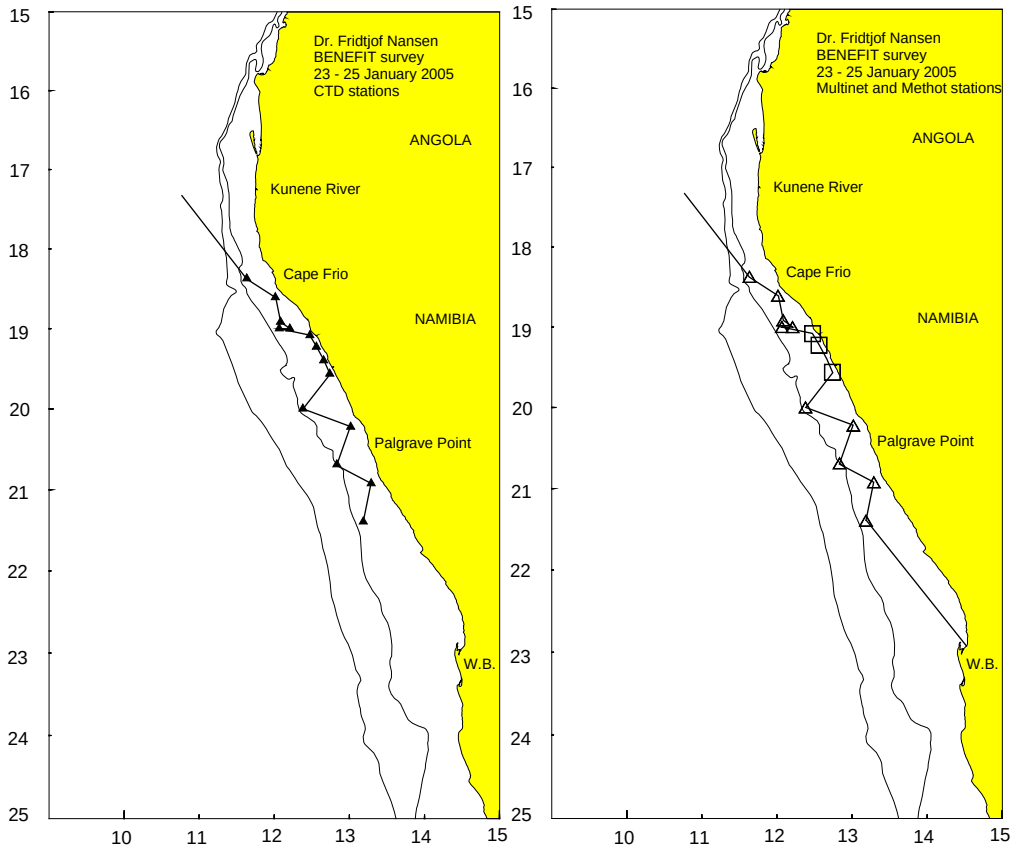


Figure 2. Cruise tracks with CTD (left panel), Multinet (right panel, triangles) and Methot (right panel, squares) stations on the second leg of the survey.

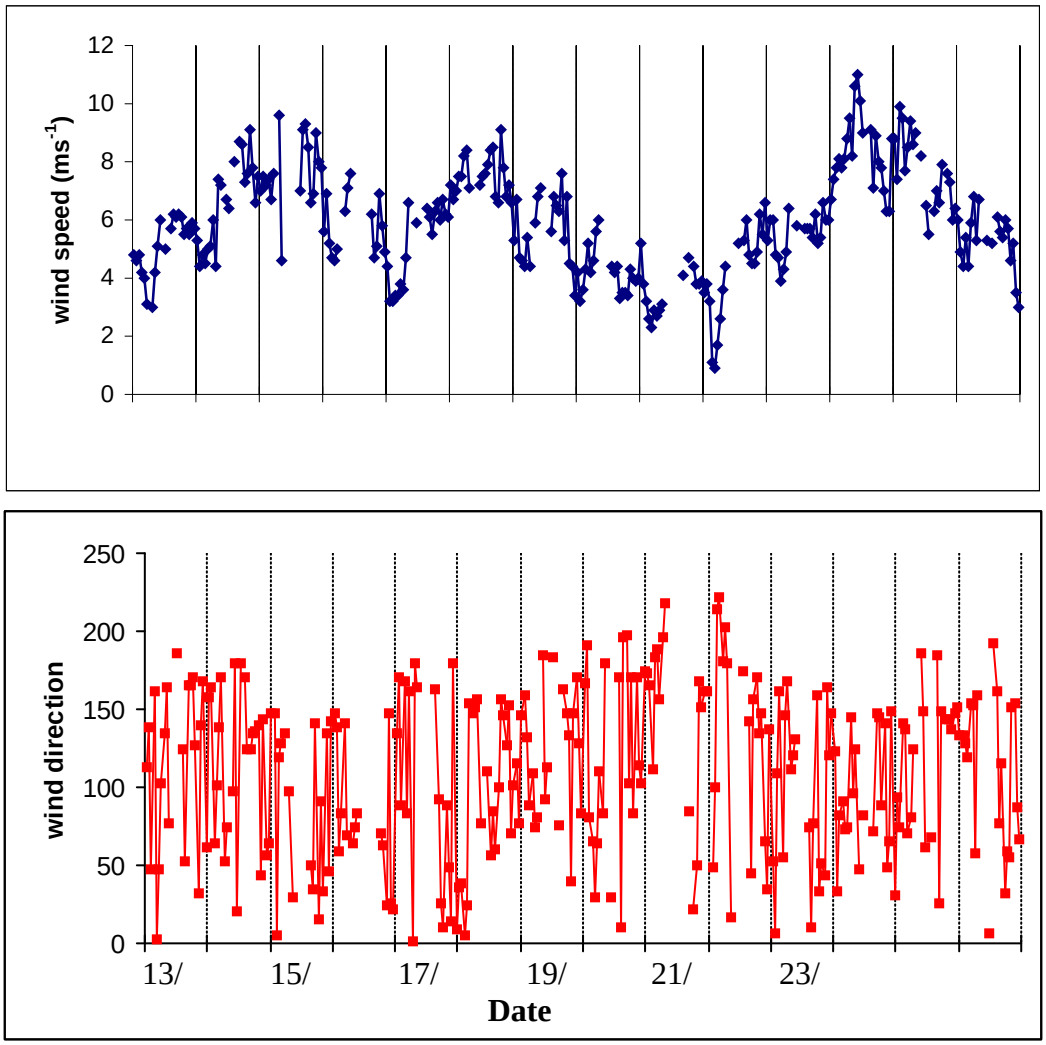


Figure 3. Hourly measurements of wind speed (ms^{-1}) and wind direction (lower panel) at the Cape Frio weather station during the survey period

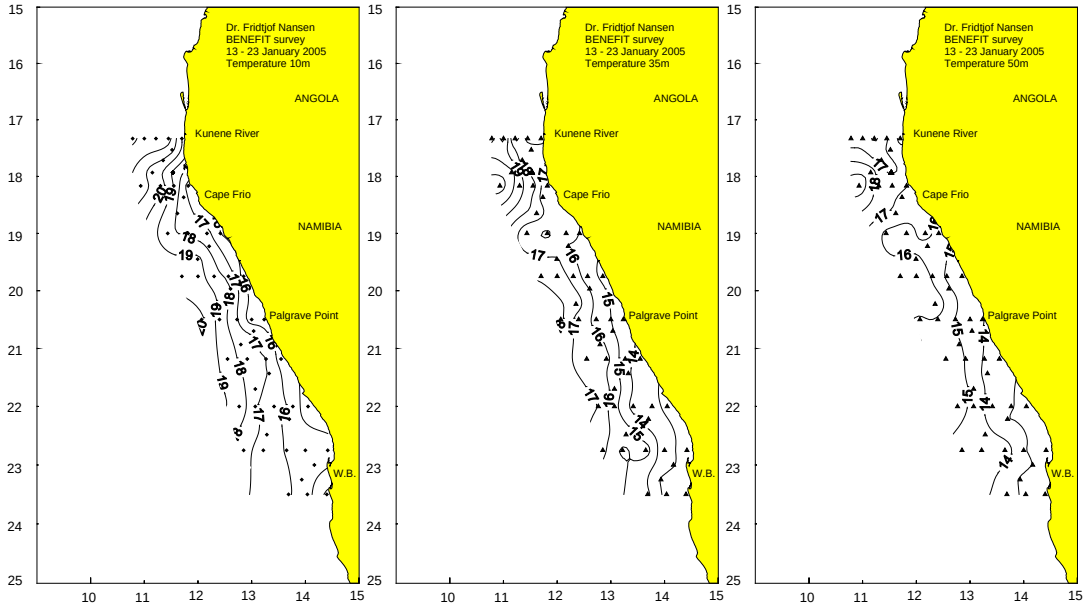


Figure 4. Horizontal distribution of temperature at 10 m (left panel), 35 m (mid panel) and 50 m (right panel) during the survey.

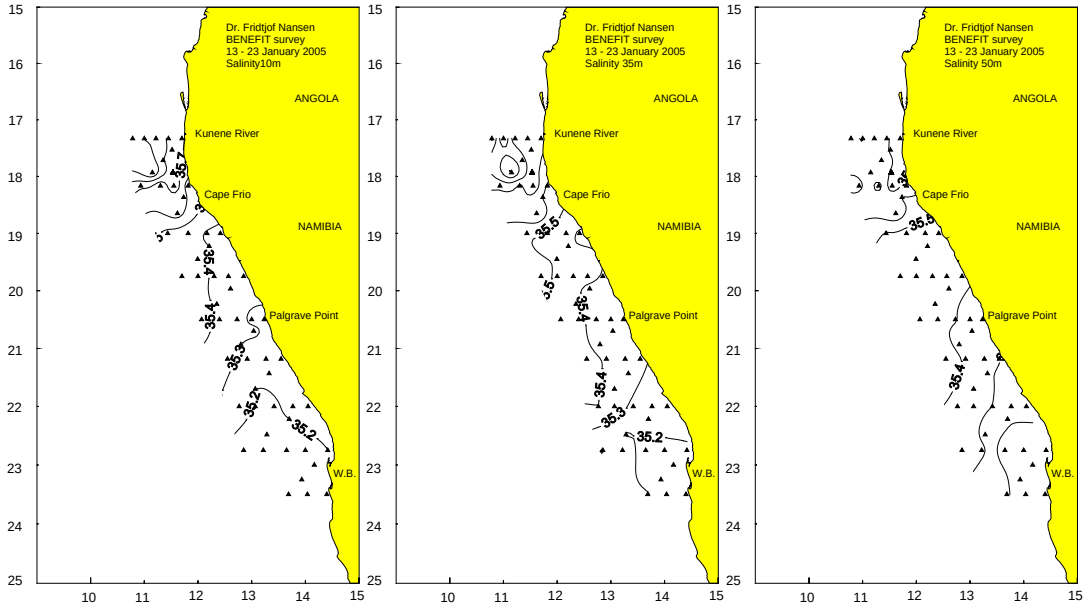


Figure 5. Horizontal distribution of salinity at 10 m (left panel), 35 m (mid panel) and 50 m (right panel) during the survey.

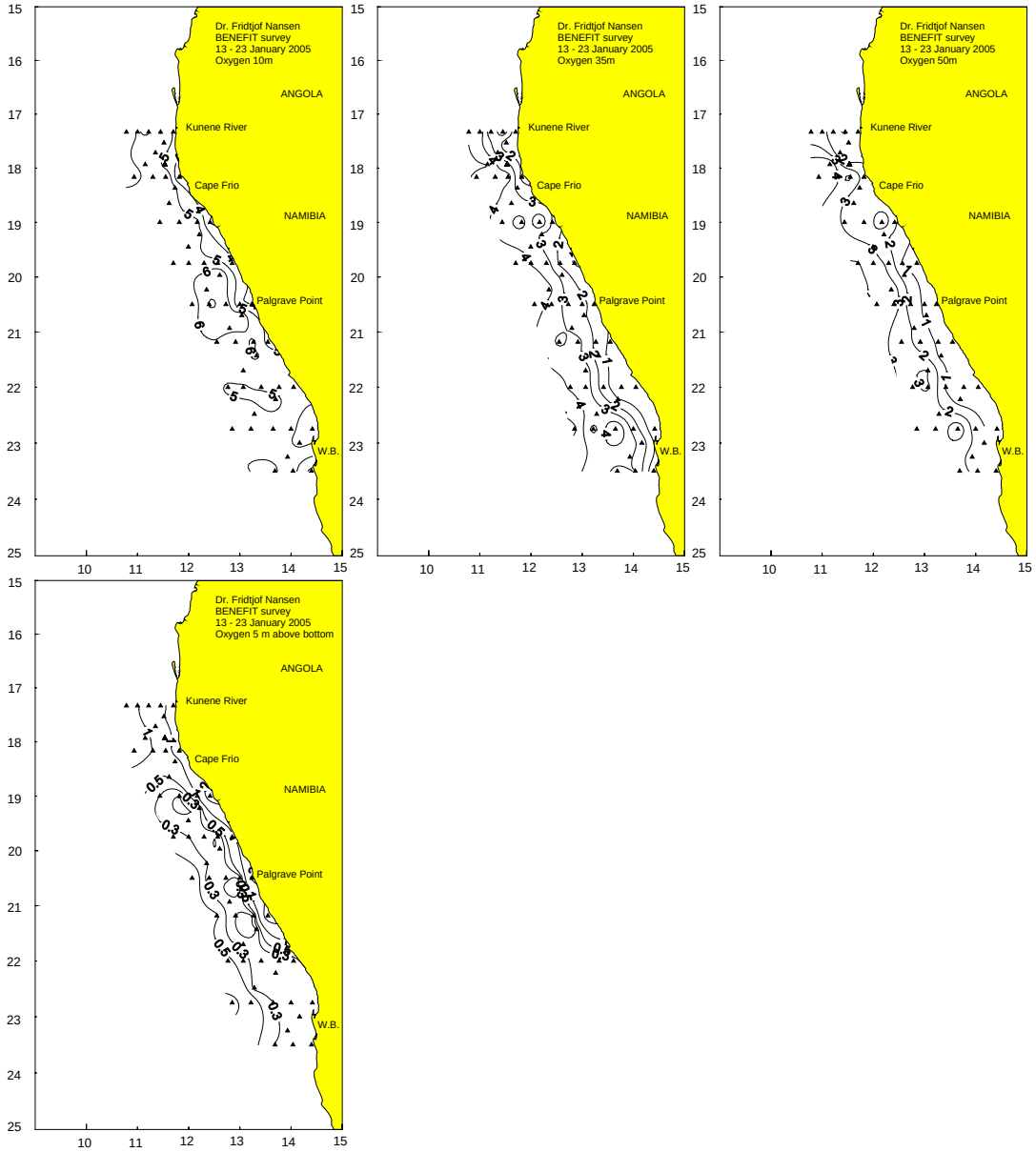


Figure 6. Horizontal distribution of dissolved oxygen (ml l^{-1}) at 10 m (upper left panel), 35 m (upper mid panel), 50 m (upper right panel) and 5 m above bottom (lower panel) during the survey.

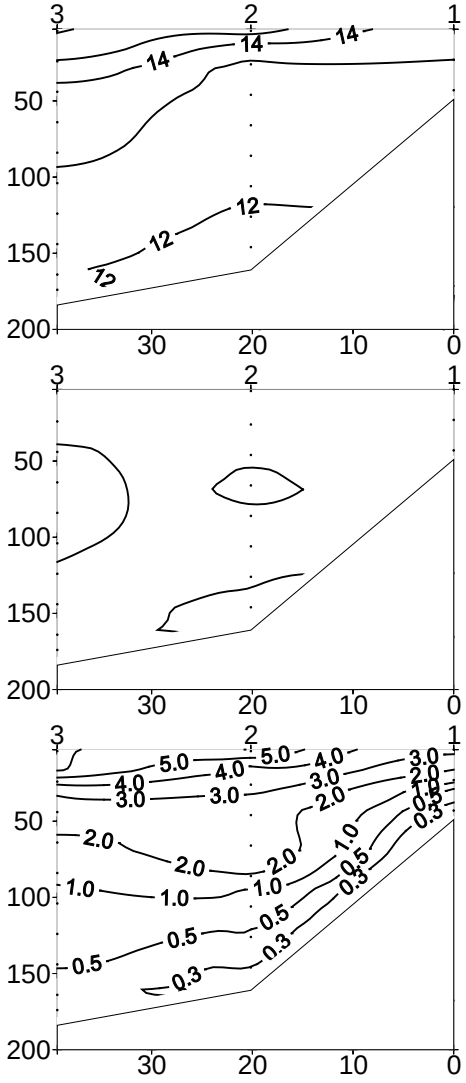


Figure 7. Cross shelf vertical distribution of temperature (upper panel), salinity (mid panel) and oxygen at line 1 (23^{o}30 S).

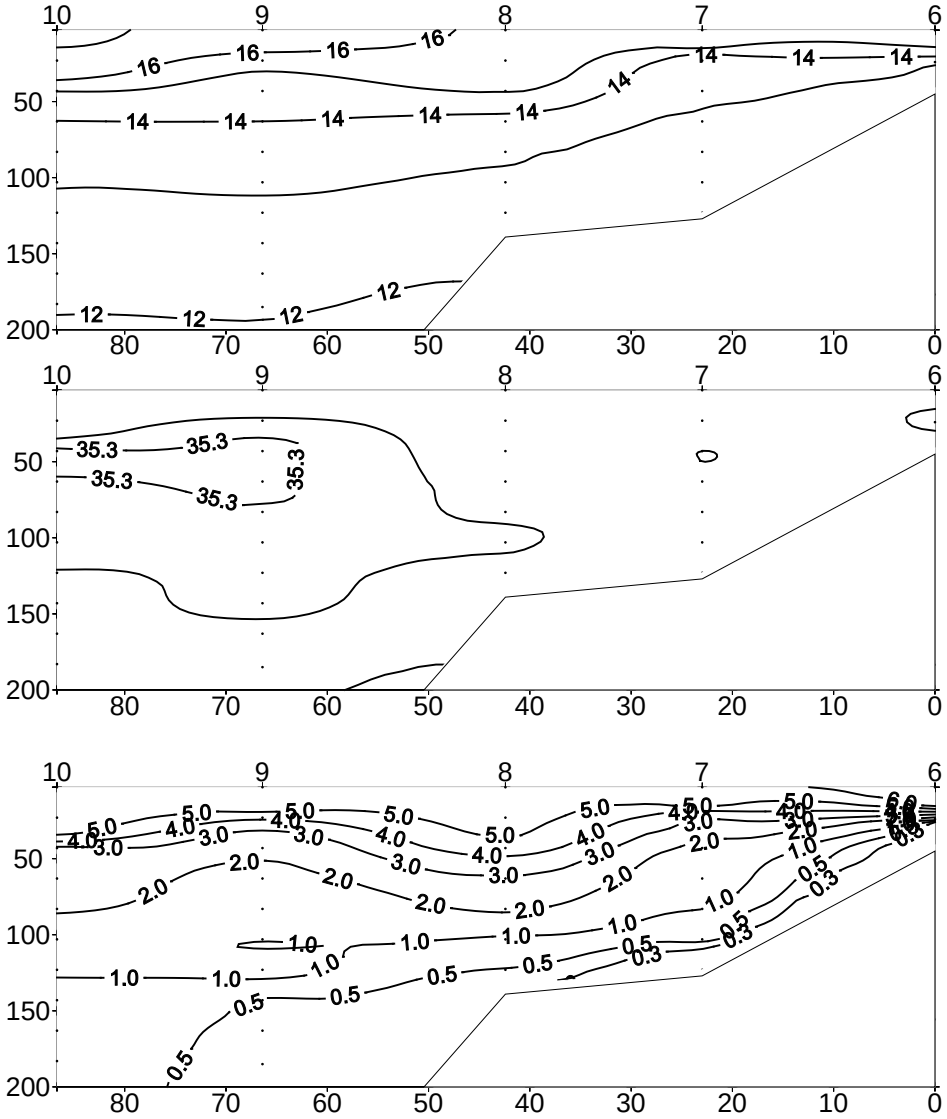


Figure 8. Cross shelf vertical distribution of temperature (upper panel), salinity (mid panel) and oxygen at line 2 ($22^{o}45$ S).

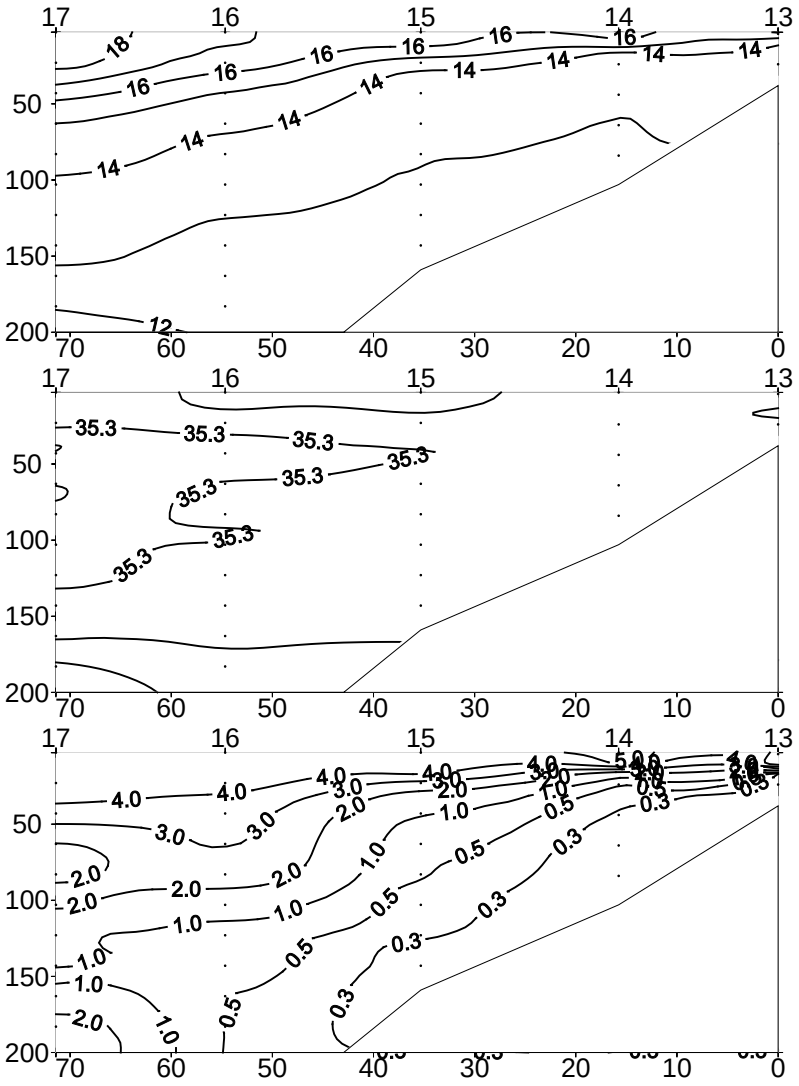


Figure 9. Cross shelf vertical distribution of temperature (upper panel), salinity (mid panel) and oxygen at line 3 (22°00 S).

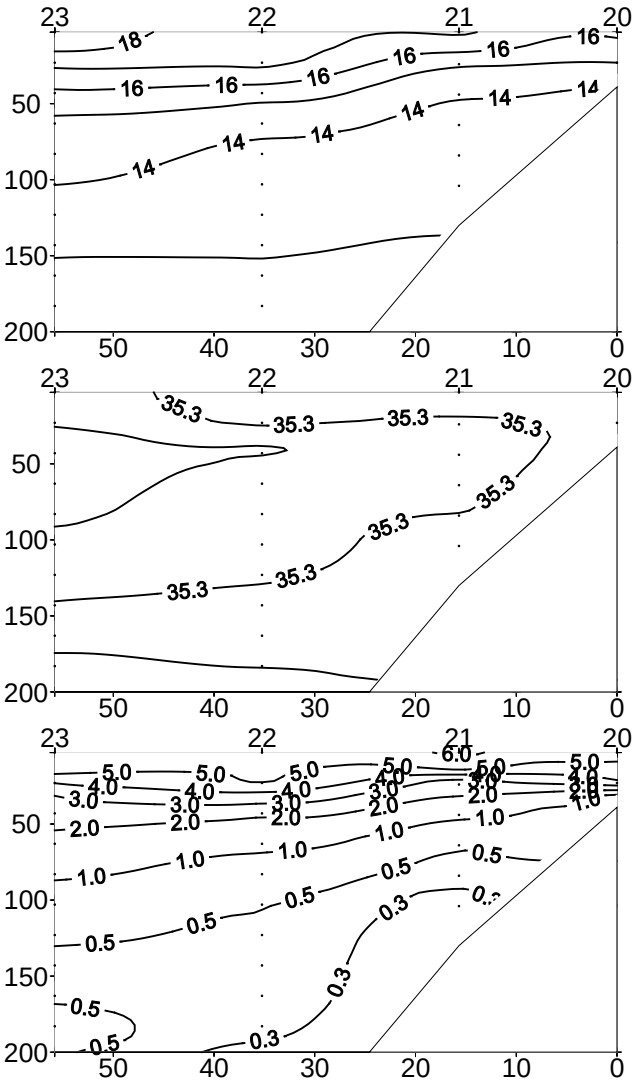


Figure 10. Cross shelf vertical distribution of temperature (upper panel), salinity (mid panel) and oxygen at line 4 (21^{o}11 S).

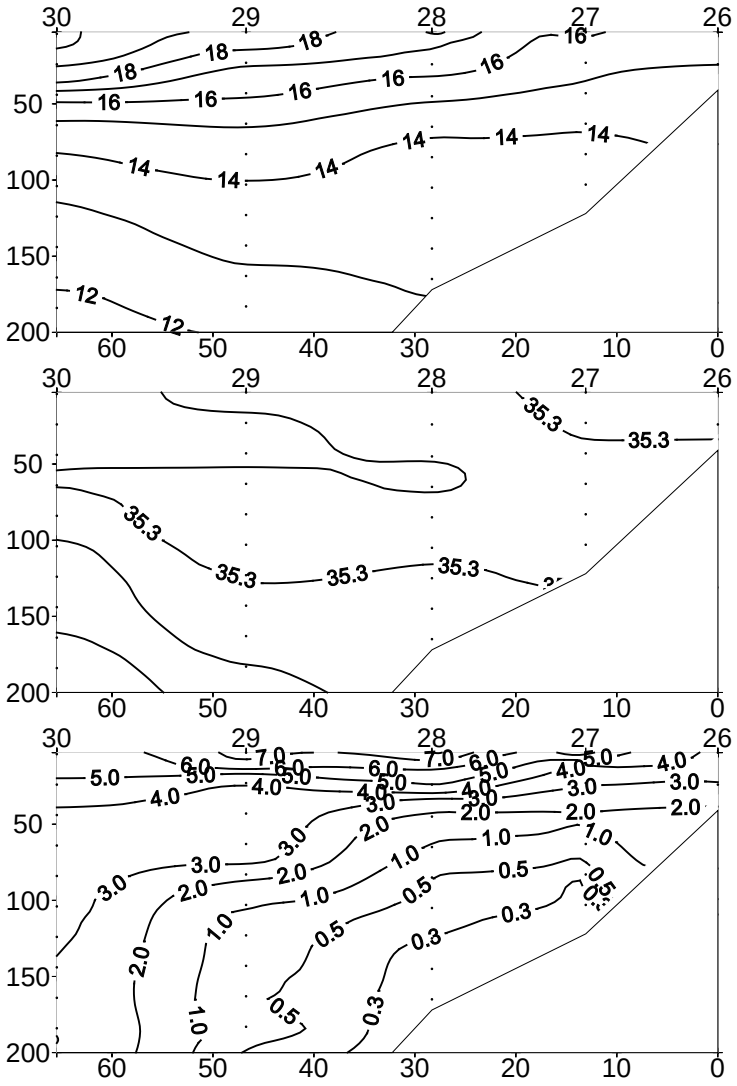


Figure 11. Cross shelf vertical distribution of temperature (upper panel), salinity (mid panel) and oxygen at line 5 ($20^{o}30$ S).

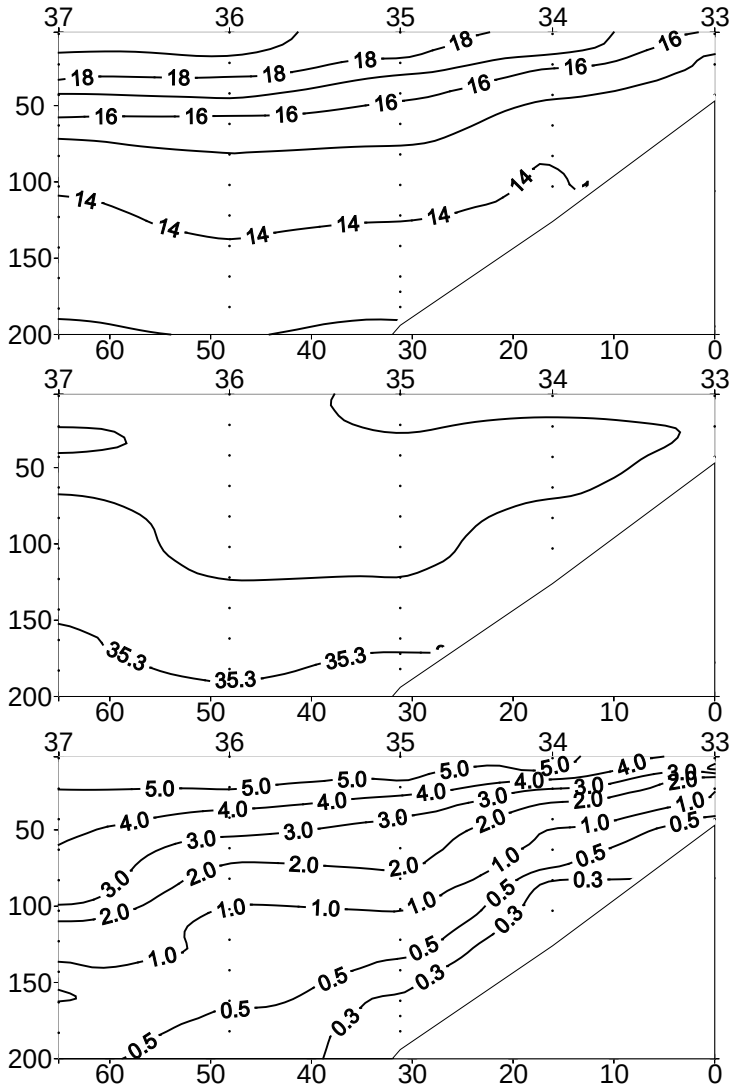


Figure 12. Cross shelf vertical distribution of temperature (upper panel), salinity (mid panel) and oxygen at line 6 (19^{o}45 S).

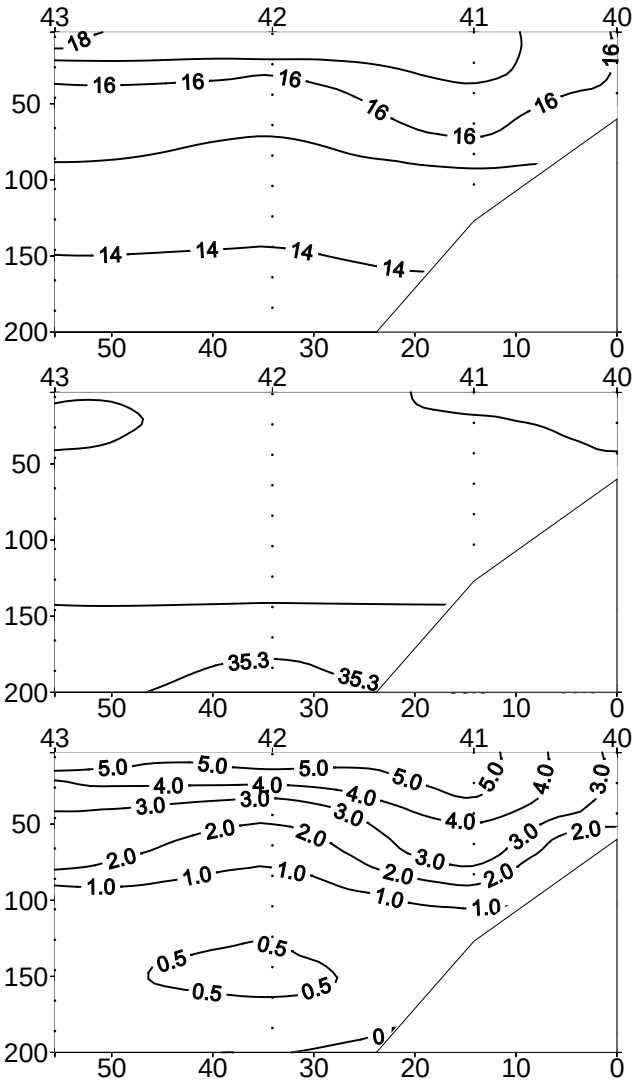


Figure 13. Cross shelf vertical distribution of temperature (upper panel), salinity (mid panel) and oxygen at line 7 (19^{o}00 S).

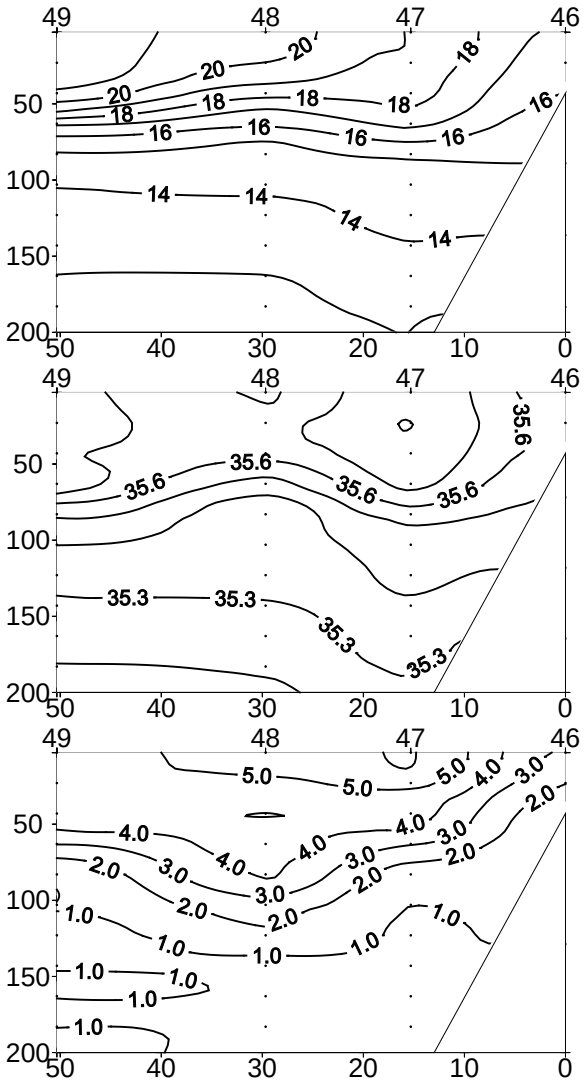


Figure 14. Cross shelf vertical distribution of temperature (upper panel), salinity (mid panel) and oxygen at line 8 (18^{o}10 S).

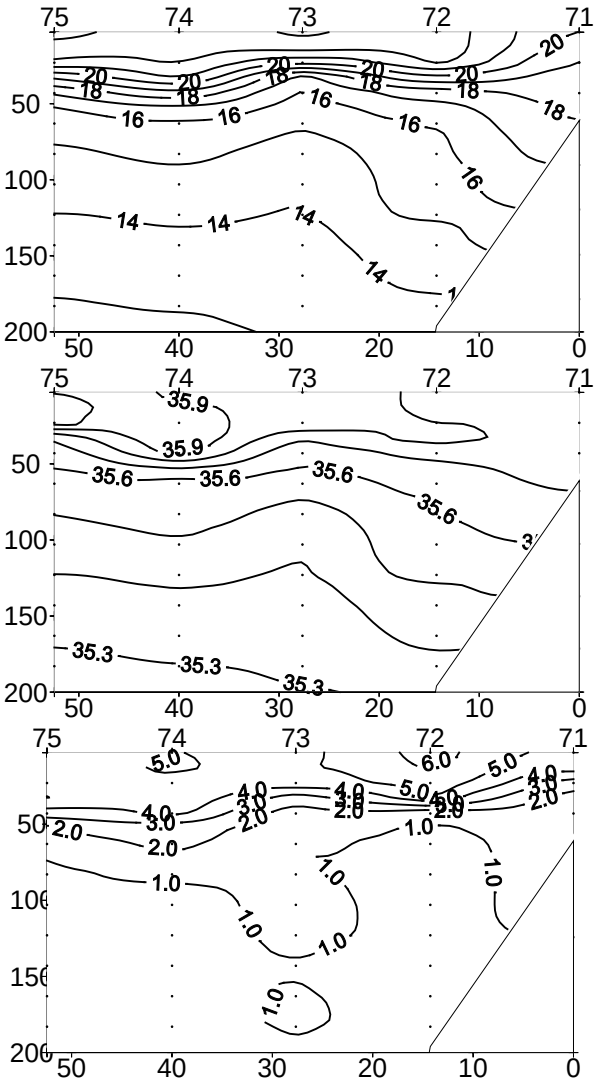
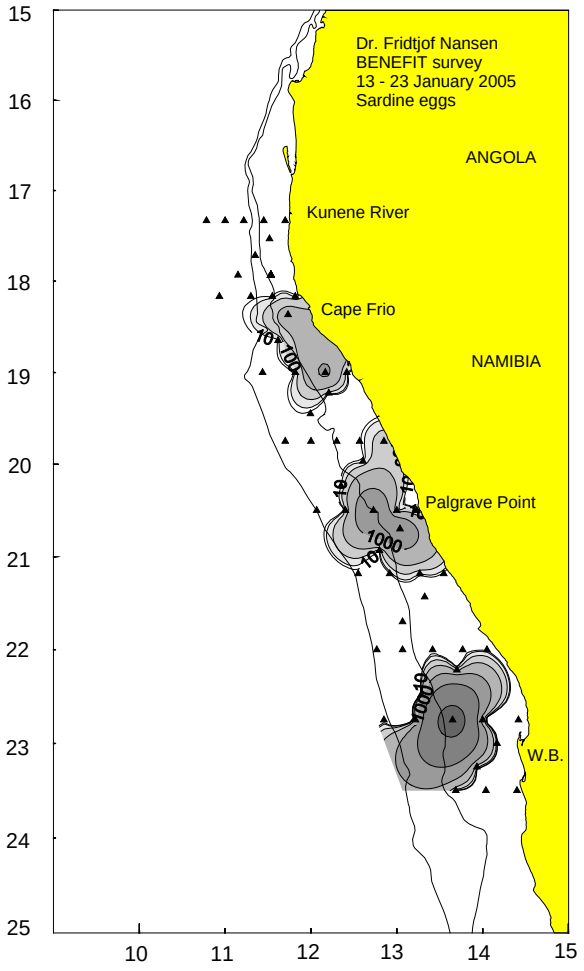


Figure 15. Cross shelf vertical distribution of temperature (upper panel), salinity (mid panel) and oxygen at line 9 (17^{o}20 S).


Dr. Fridtjof Nansen
BENEFIT survey
13 - 23 January 2005
Sardine eggs
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Cape Frio
NAMIBIA
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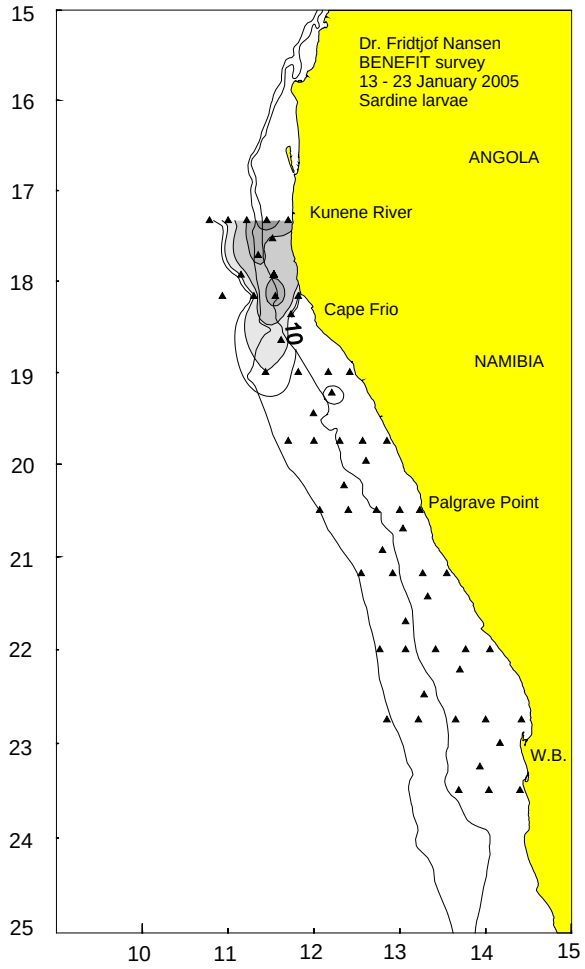


Figure 16. Horizontal distribution of sardine eggs (left panel) and sardine larvae (right panel).

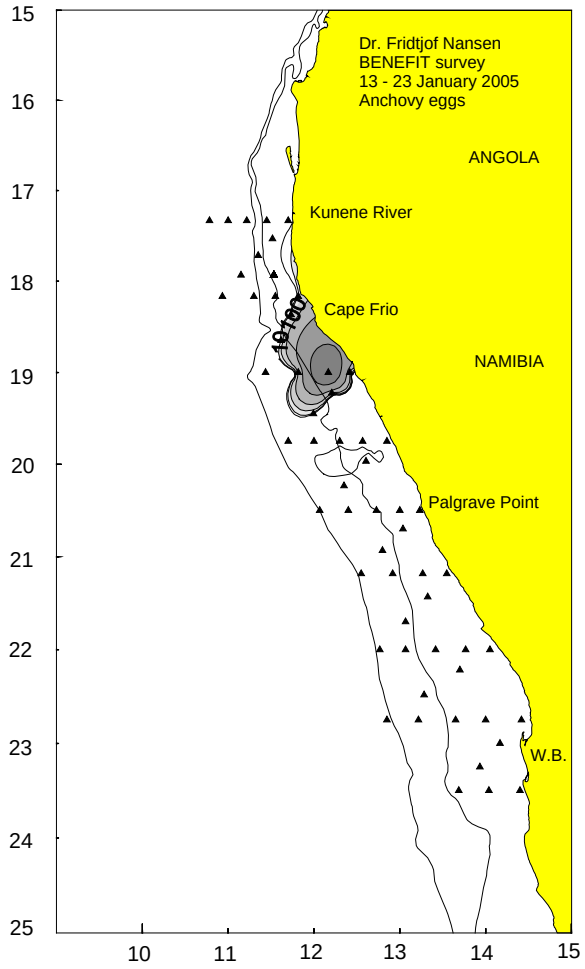
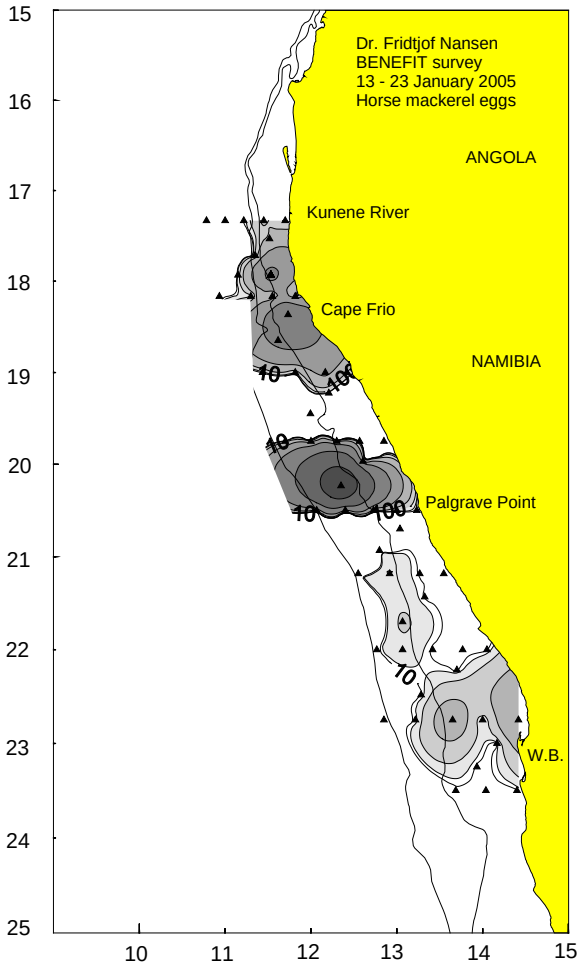


Figure 17. Horizontal distribution of anchovy eggs


Dr. Fridtjof Nansen
BENEFIT survey
13 - 23 January 2005
Horse mackerel eggs
ANGOLA
Kunene River
Cape Frio
NAMIBIA
Palgrave Point
W.B.
10
100
15
16
17
18
19
20
21
22
23
24
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10
11
12
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14
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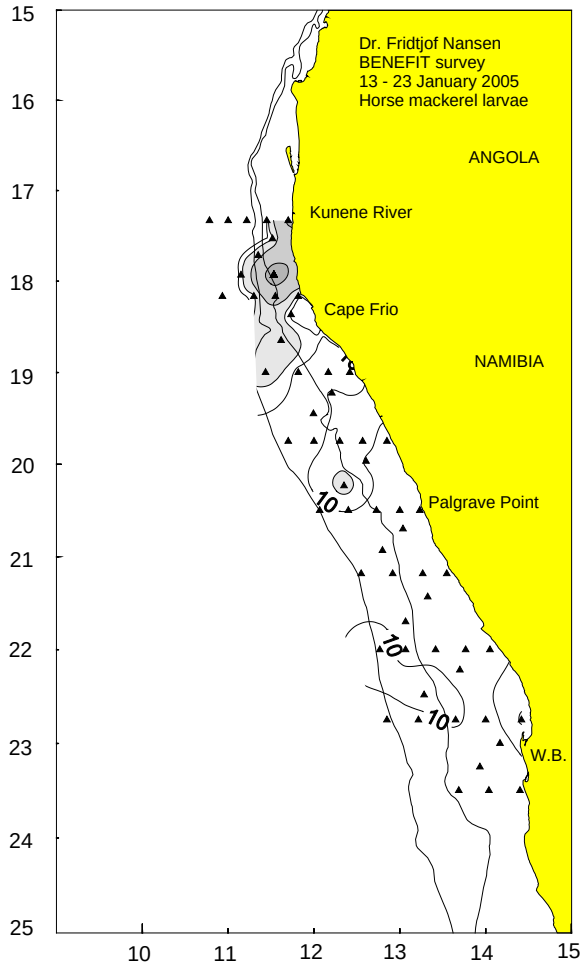

Figure 18. Horizontal distribution of horse mackerel eggs (left panel) and horse mackerel larvae (right panel).

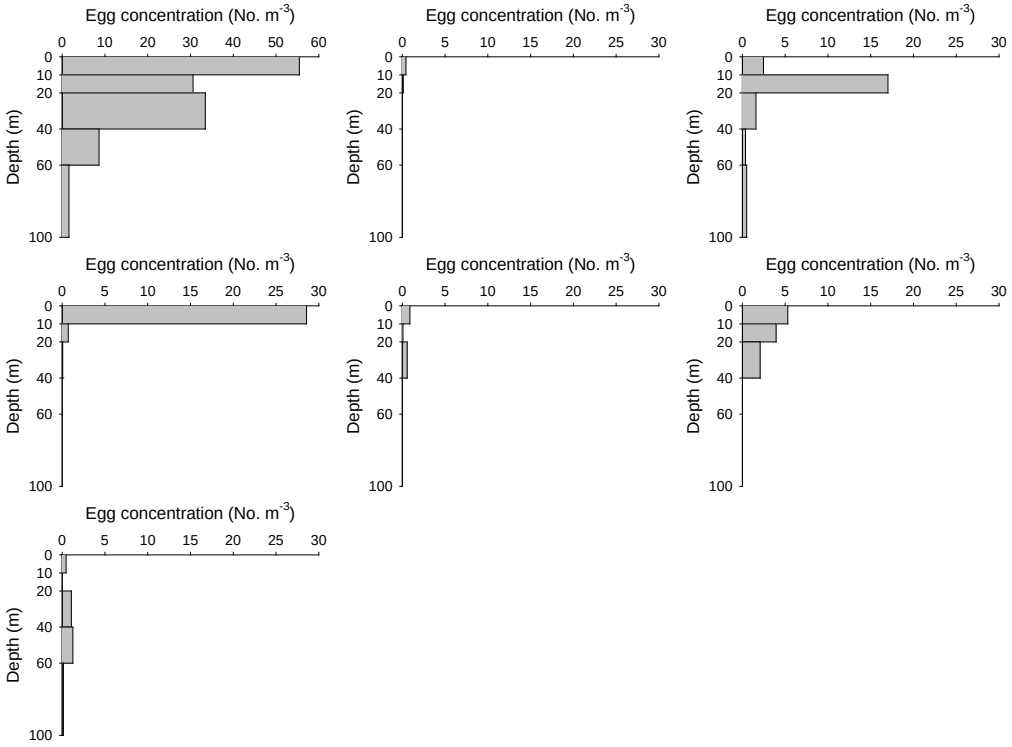

Figure 19. Vertical distribution of sardine eggs from the survey stations.

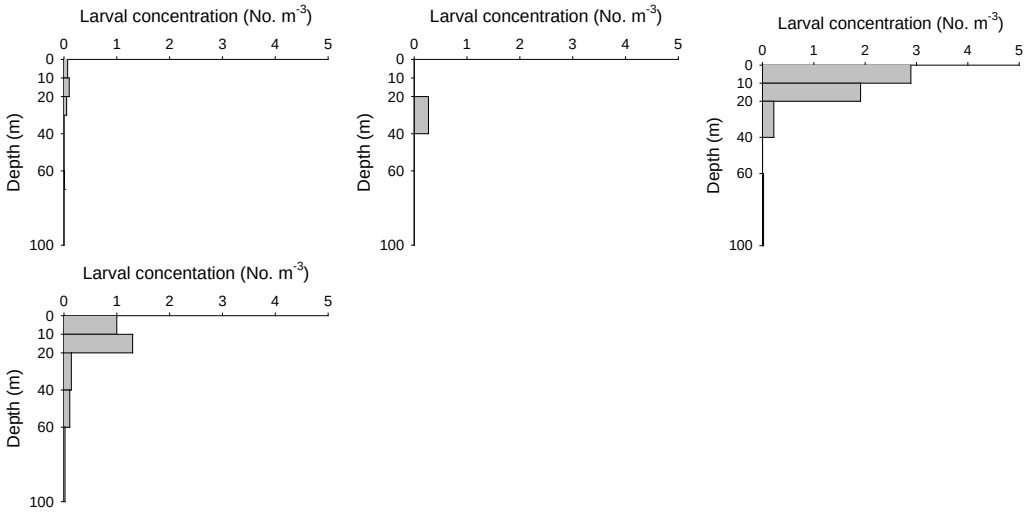

Figure 20. Vertical distribution of sardine larvae from the survey stations.

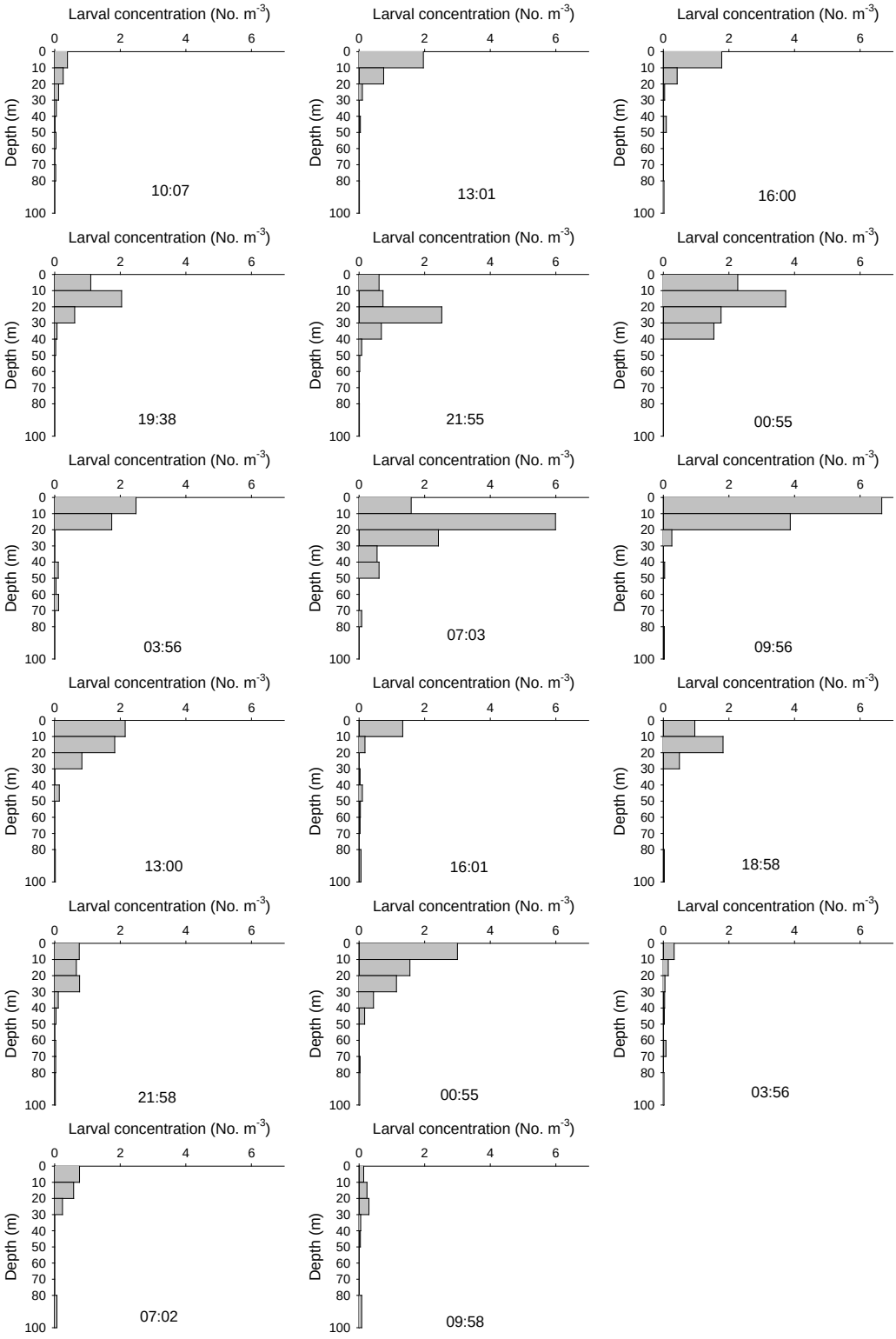

Figure 21. Vertical distribution of sardine larvae from the repeat stations. Time (UTC) of the hauls is given.

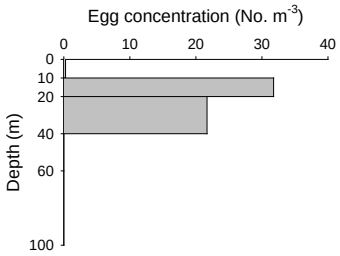

Figure 22. Vertical distribution of anchovy eggs at station 41.

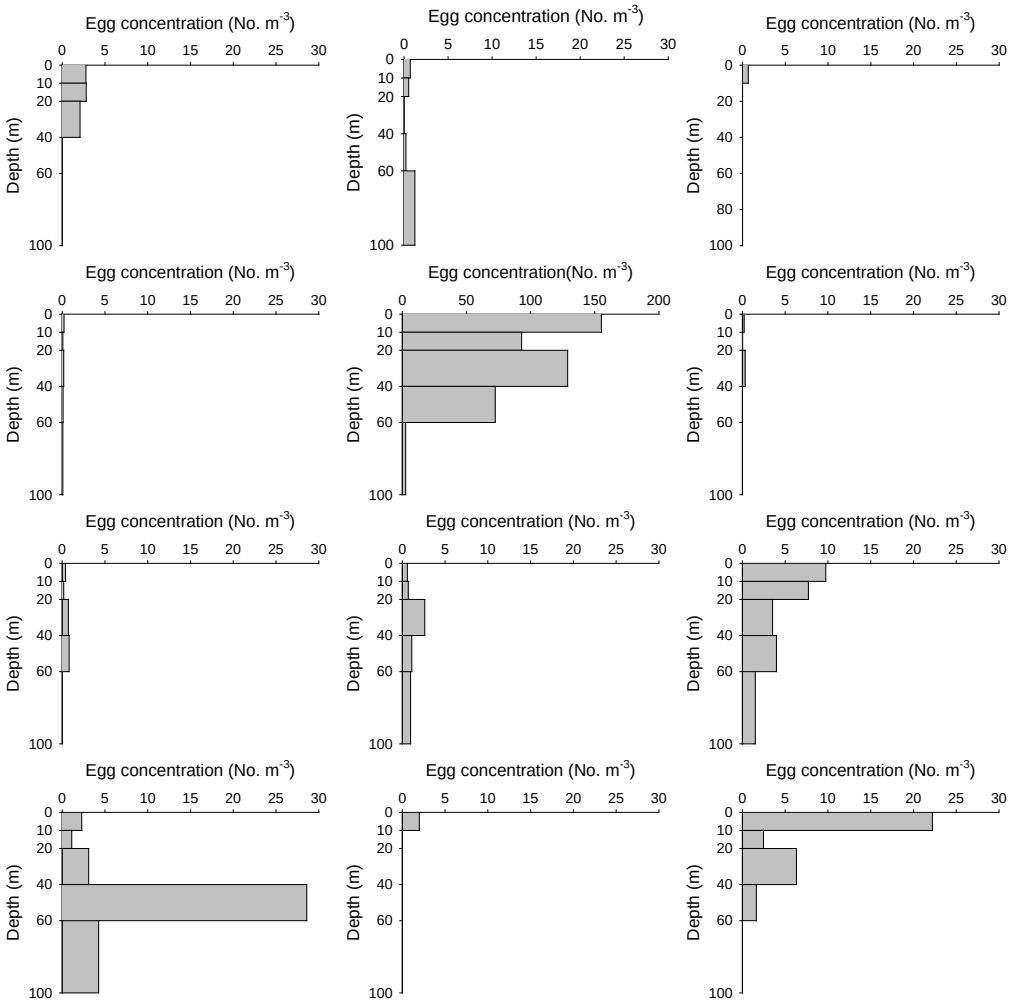

Figure 23. Vertical distribution of horse mackerel eggs from the first leg of the survey.

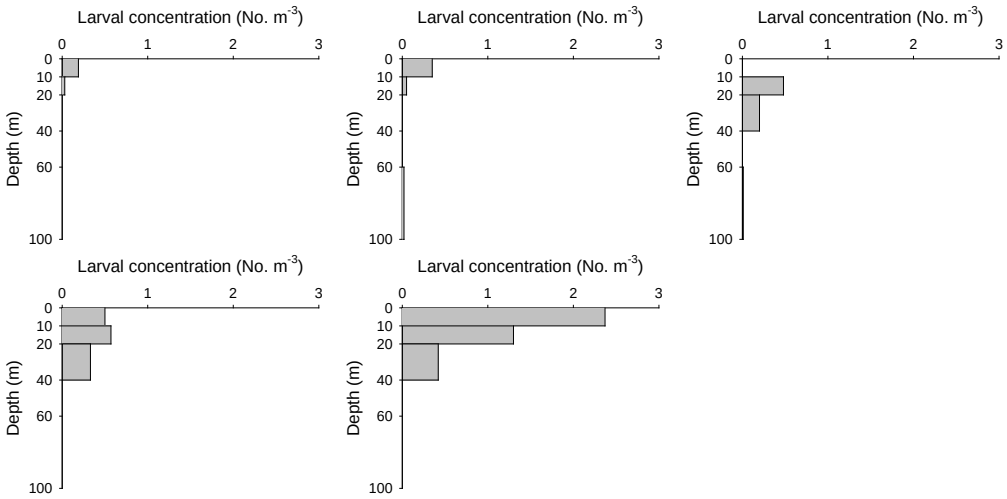

Figure 24. Vertical distribution of horse mackerel larvae from the first leg of the survey.

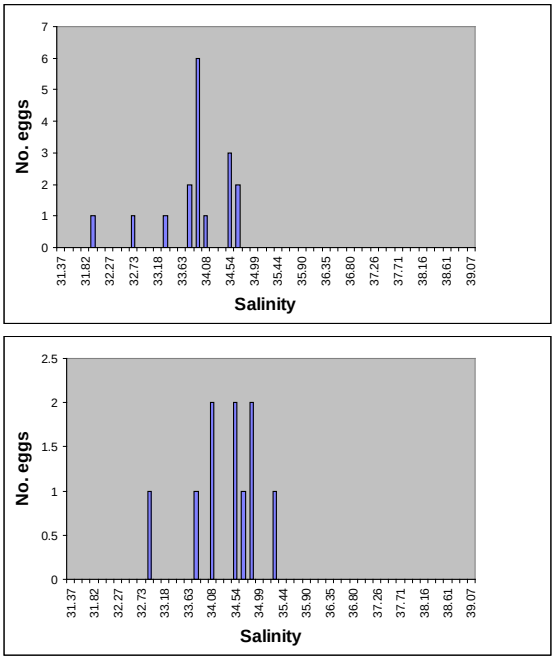

Figure 25. Salinity of neutral buoyancy of horse mackerel egg measured on 22nd January at 21:25 (left panel) and on 23rd January at 12:25 (right panel).

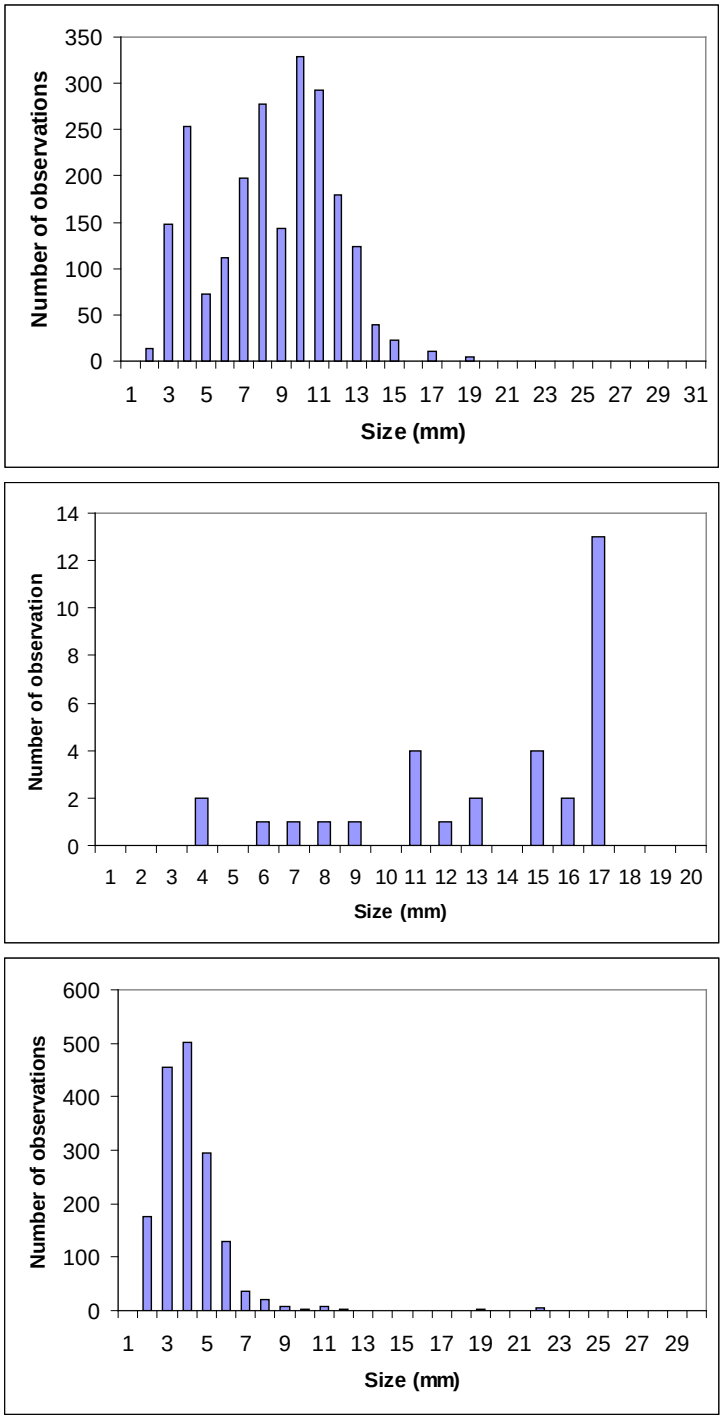

Figure 26. Size distribution (standard length) of sardine larvae (upper panel), anchovy larvae (mid panel) and horse mackerel larvae (lower panel) from the Multinet stations.

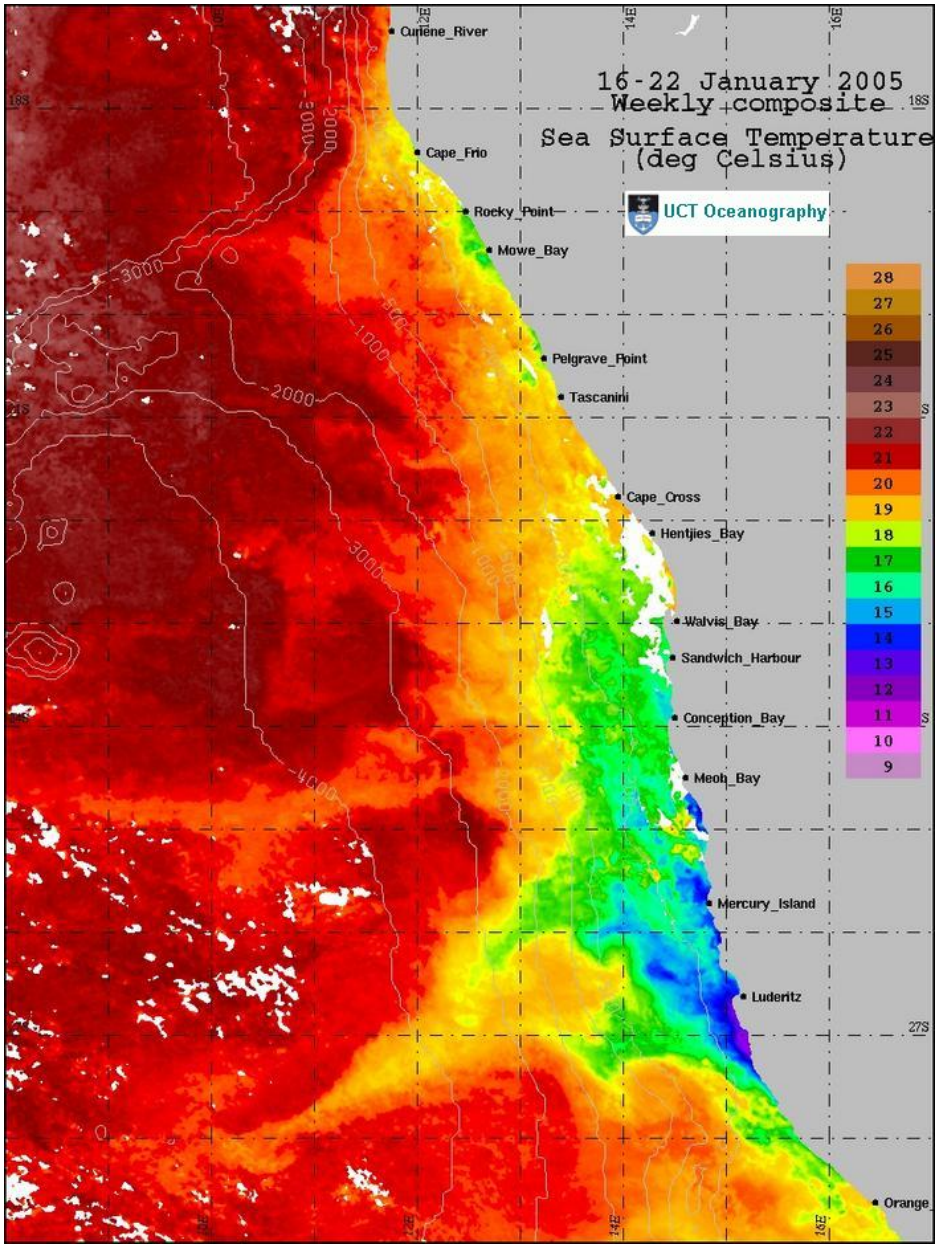

Figure 27. Satellite image showing weekly composite (16-22 January) of sea surface temperature in Namibian waters.