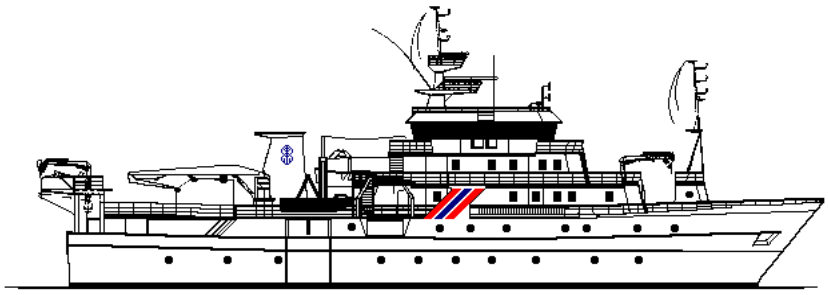

BENEFIT SURVEYS

Cruise Report No 2/2004

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19 January - 1 February 2004

Institute of Marine Research
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CRUISE REPORTS "DR. FRIDTJOF NANSEN"

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19 January - 1 February 2004

by

Erling Kåre Stenevik, Petter Fossum and Berit Endresen

Institute of Marine Research
Bergen
Norway

Anja Kreiner

National Marine Information and Research Centre
Swakopmund
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Bergen, 2004

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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 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 focussed mainly on eggs and larvae of anchovy, sardine and horse mackerel. 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.

1.3 Participation

The scientific members during the cruise were:

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From Namibia:

Chibo Chikilikwa, Johannes Hamakuaya, Justine Kakuuai, Nelda Katjivena, Jan Kheigob and Anna Lucia Mukumangeni.

From Norway:

Berit Endresen, Petter Fossum, Terje Hovland, Tore Mørk and Erling Kåre Stenevik (cruise leader).

1.4 Narrative

The vessel left Walvis Bay on the 20th January at 09:00 UTC and headed for Sandwich Harbour where the survey started on the same day at 14:30. The same survey design as in April 2001 and April 2002 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 nighttime. On 27th January at 21:30 (UTC) the last station of the first leg of the survey was taken at 15°50 S, 10°53 E, on the Tombua line. Thereafter, the ship headed south to an area where high concentrations of eggs and larvae were observed during the first leg. The aim of the second leg of the survey was to take a 24-hours station to investigate diel variation in vertical distribution of the larvae. The first station was taken at 19°45 S, 12°00 E on 28th January at 23:00 (UTC). Some sardine larvae were found there, but it was decided to continue southward to try to find higher concentrations of larvae. At 19:30 (UTC) on 29th, relatively high concentrations of sardine larvae were observed at 21°25 S, 13°18 E, and it was decided to take the 24-hours station there. CTD and Multinet hauls were conducted every three hours until the 30th at 22:00 (UTC) when the station work ended and the ship headed for Walvis Bay. During the survey a total of 84 CTD casts, 87 Multinet stations and 6 Methot stations were conducted.

2 MATERIAL AND METHODS

2.1 Physical measurements

The survey started on 20th January 2004 at 14:30 UTC off Sandwich Harbour (23°30'S) and the Namibian coast was covered northwards into Angola to Tombua (15°50'S). The distance between transects was 40 –50 nautical miles. Between the east-west transects cross sections from southwest to northeast with two stations on these sections were sampled. CTD casts were taken every 20 nautical miles and in the near shore regions every 15 nautical miles (Figure 1).

2.1.1 Wind

Wind speed and direction was 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 relatively tight regression ($y = 1.1671x - 0.0345$, $R^2=0.9766$).

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. Multinet stations are shown in Figure 2.

2.2.2 Methot fish larvae sampler

The Methot fish larvae sampler was used during the first leg of the survey. 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 nighttime 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 and 20 m. Methot stations are shown in Figure 3.

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 19th 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 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 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

Figure 4 shows the 10 min average wind speed for each station. The weather station was not started until the second day of the survey. For the first days, the wind speed was relatively low (<8 m s^{-1}). Then it started to increase as the survey continued northwards, and on the last days of the first leg the wind varied between 8 and 14 m s^{-1}.

3.1.2 Hydrography

3.1.2.1 Temperature

Horizontal distributions of temperature at 10, 35 and 50 m depth are shown in Figure 5. The temperature distributions displayed the typical upwelling features of the region with lowest temperatures inshore and increasing offshore. Strongest upwelling of relatively cold water (14 ^{o}C) was observed at 10 m depth between Walvis Bay and Palgrave Point.

At 10 m depth no strong temperature gradient from south to north was observed in Namibian waters, and at the Kunene River inshore temperatures were around 16°C, while it was 15-16^{o}C near Walvis Bay. At greater depths the temperature gradient from south to north was more pronounced with temperatures in the south being 2 to 4°C lower than at the Kunene River at 50 m depth. Intrusion of relatively warm water from the west was observed at 35 m depth both south of Palgrave Point and near Kunene River.

At the Tombua line (15°50'S) the temperatures at 10 m depth in the inshore stations were 18°C, increasing to 23°C at the offshore stations. There was also a relatively strong alongshore temperature gradient here. A similar increase was not observed at greater depths and it was interpreted as the southern border of the front between the cold Benguela Current water and the warm Angolan water.

3.1.2.2 Salinity

Horizontal distributions of salinity at 10, 35 and 50 m depth are shown in Figure 6. The salinity was relatively homogenous from the Walvis Bay area, but a small alongshore increase was observed in all three depths from 35.2 in the south to 35.5 at the Kunene River. North of the border, there was a relatively large increase in salinity at 10 m depth, and at the two westernmost stations on the Tombua line the salinity was 36.0. This high salinity water

was the southern extension of the Angolan water flowing over the colder and denser Benguela Current water and pushing it down towards the coast.

3.1.2.3 Oxygen

Horizontal distributions of dissolved oxygen at 10, 35, 50 and 5 m above bottom are shown in Figure 7. The oxygen was relatively homogenous at 10 m depth from Walvis Bay to around 20°S (ca. 5 ml l^{-1}). However, at the inner station on the 21°11 line (south of Palgrave Pint), where upwelling was observed, the oxygen concentration at 10 m depth was low (1.8 ml l^{-1}). In the northern part from Cape Frio there was a general increase in oxygen concentrations at 10 m depth from inshore to offshore. At 35 m and 50 m depth this increase from east to west was observed throughout the survey area. Bottom concentrations of oxygen showed a typical band of low oxygen concentration (lower than 0.3 ml l^{-1}) from 19°S to 23°S between the 100 m and 300 m isobaths.

3.2 Plankton sampling

3.2.1 Horizontal distribution and species composition

The sardine eggs were distributed in three patches (Figure 8). One patch was found off Walvis Bay, one just north of Palgrave Point and one patch between Kunene River and Tombua. The highest concentrations were observed between the 100 m and the 200 m isobath. In the area between Palgrave Point and 22°S, where upwelling of cold, low oxygen water was observed near shore, no eggs were found. Most of the sardine eggs were found in water with temperatures at 10 m depth ranging from 17 to 19 °C and oxygen concentrations at 10 m depth ranging from 3 to 6 ml l^{-1}. Sardine larvae were also found in three patches (Figure 9), although in lower concentrations than the eggs. All three larval patches were found close to the area were the egg patches were observed. However, the distribution of the two southernmost patches indicated a relatively slow northward transport from the spawning area. The distribution of the northernmost larval patch did not indicate any northward transport and in this area the front between the northward flowing Benguela Current and the southward flowing Angola Current probably prevents any further northward transport. As for the eggs, the main concentrations of larvae were found between the 100 m and 200 m isobath.

The anchovy eggs (Figure 10) had a more northern distribution than sardine eggs, and were only found north of Palgrave Point. Relatively high concentrations of anchovy eggs were found in the same area where the two northern patches of sardine eggs were observed but anchovy eggs were in addition distributed between these two patches. Similarly to sardine eggs, the main concentrations of anchovy eggs were observed just inside of the 200 m

isobath. Relatively low concentrations of anchovy larvae were found during the survey and all larvae were found north of Palgrave Point (Figure 11).

Relatively high concentrations of horse mackerel eggs were observed during the survey (Figure 12) and the total number of horse mackerel eggs collected was the highest since these surveys started in 2000. The horse mackerel eggs were observed throughout the survey area except for the area between Walvis Bay and Palgrave Point where few eggs of all of the three species were found. The highest concentrations of horse mackerel eggs were found in the northern region between Cape Frio and Kunene River. Like the two other species, the horse mackerel eggs were mostly found inside of the 200 m isobath except for the southernmost patch, which was located between the 200 m and 500 m isobath. Horse mackerel larvae were found in three patches between 21^{o}30S and Tombua (Figure 13). The distribution indicated a slow northward transport except for the northernmost area.

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 722 sardine eggs were found on 14 stations during the survey, but only five stations had ten or more eggs. The vertical distribution of sardine eggs was highly variable (Figure 14). On the two southernmost stations (in the Walvis Bay area), the peak concentrations were observed relatively deep (deeper than 40 m) while at the next two stations (at about 20^{o}N) the peak concentration was observed in the upper 10 m. Then on the northernmost station (outside Baía dos Tigres) sardine eggs were only found in the 60-100 m depth interval. During the first leg of the survey, 99 sardine larvae were found at 18 stations. Nine of these stations had ten or more larvae and the vertical distribution of these is shown in Figure 15. The sardine larvae were mostly distributed in the upper 40 m, but at three stations larvae were found also deeper than 40 m. Peak concentration at most of the stations were in the 10-20 m depth interval and only three stations had peak concentration in the upper 10 m. At the 24-hour station, ten hauls were conducted and 450 sardine larvae were caught. Larvae were found mostly in the upper 60 m (Figure 16). In three hauls, peak concentration was observed in the upper 10 m. Two of these hauls were conducted at 10 pm (local time) a few hours after sunset.

During the survey, a total of 903 anchovy eggs were sampled at 10 stations. Of these, 7 stations had 10 or more eggs (Figure 17). At the four southernmost stations (between Palgrave Point and Cape Frio), most of the anchovy eggs were observed in the upper 10 m, while at two of the northernmost stations, peak concentration was observed deeper. Anchovy

larvae were found in relatively low concentrations and during the first leg, no stations had more than 10 larvae. In addition, no anchovy larvae were found on the 24-hours station. Therefore, the vertical distribution of anchovy larvae is not presented here.

Of the 23 stations where 2458 horse mackerel eggs were sampled, 12 stations had 10 or more eggs and the vertical distribution are shown in Figure 18. Horse mackerel eggs were found in all depth strata with maximum concentrations always deeper than 10 m. Horse mackerel larvae were found at 28 stations (154 in total) but only six stations had 10 or more larvae. These larvae were mostly found in the upper 40 m (Figure 19) with peak concentrations at five of the stations being in the 10-20 m depth interval.

3.3 Buoyancy of eggs and larvae

Only wild caught eggs were used for buoyancy measurements during this survey. On station 34 (the inner station on the 19^{o} 58'S line), both sardine and anchovy eggs were caught in the Multinet. An additional haul in the upper 10 m was conducted and from this haul 50 sardine eggs were inserted in column II and 100 anchovy eggs were inserted in column III. The experiment lasted for about 24 hours after which most of the eggs had hatched or died. Mortality was highest in the anchovy group. Three buoyancy measurements were conducted on each of these groups in addition to one measurement of newly hatched larvae. The experiments were conducted under continuous light at temperatures ranging from 12.6 to 12.9 ^{o}C. The larval measurements were conducted while the larvae showed very little swimming behaviour and are therefore regarded as representative of buoyancy of the newly hatched larvae. One day after the measurements, the larvae in both groups started to swim towards the surface of the columns and after that they were mainly observed towards the surface. They were swimming in intervals with a resting phase of about 10 second following each swimming phase. During resting the larvae sank with their head facing downward.

There was relatively high individual variation in the buoyancy of the sardine egg (Figure 20). The mean buoyancy, however, did not change much from the first to the third measurement. There was a slight increase in mean neutral buoyancy from a salinity of 32.56 on the first measurement to 32.29 on the third measurement. The newly hatched sardine larvae had higher buoyancy than the eggs with mean neutral buoyancy at a salinity of 31.25. There was lower individual variation in the buoyancy of the anchovy eggs (Figure 21), and the mean buoyancy of these eggs was lower compared to sardine eggs. Similar to the sardine eggs, the buoyancy of the anchovy eggs also increased during the experiment (mean neutral buoyancy at a salinity of 34.41 on the first measurement and 33.80 on the third measurement). The

buoyancy of the newly hatched anchovy larvae was similar to the late eggs (mean neutral buoyancy at a salinity of 33.87).

3.4 Size distribution

The sardine larvae sampled with the Multinet were larger than the anchovy larvae (Figure 22). While the mean standard length of the sardine larvae was 11.9 mm, it was 7.9 mm for the anchovy larvae. The mean standard length of the horse mackerel larvae was 4.9 mm.

4 DISCUSSION

During the survey, relatively high concentrations of eggs of all the three key species were found. The anchovy eggs were only found north of 21^{o}S while sardine eggs were mainly found south of 20^{o}S. Horse mackerel eggs were observed throughout the area except for the region between 20^{o}30 S and 22^{o}S. In this area eggs of the other two species were also absent and this could be related to the upwelling of cold low oxygen water observed there. The horse mackerel survey done by the R/V *Welwitchia* in February confirmed that horse mackerel adults were distributed in exactly the same areas where the eggs were found. Larvae of the three species were found in lower concentrations than eggs. Particularly, few anchovy larvae were caught and those were relatively small. Only one of the anchovy larvae was bigger than 15 mm, which corresponds to an age of about 25 days (Stenevik et al., in prep). It is therefore concluded that the survey was conducted early in the spawning season and that the spawning season for sardine started earlier than for anchovy.

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 (station 8) found in the 40-60 m depth interval (below the upper mixed layer) while on another station (station 33) the highest concentration was found in the upper 10 m (within the upper mixed layer). At both of these stations the eggs were mostly in stage 7, which means that they were 20-30 hours old (Le Clus and Malan, 1995). Buoyancy measurements from this survey and earlier surveys (Stenevik et al., 2001) have shown that sardine eggs are highly buoyant and will rise towards the surface relatively fast but with increasing wind an increasing fraction of the eggs will be mixed down. But still, the highest concentrations should be expected in the surface after the eggs have reached an equilibrium vertical distribution. The wind during the beginning of the survey was low and the only explanation for the deep distribution of the eggs at station 8 is that the eggs were spawned close to bottom at about 140 m and that the eggs were still rising when sampled. The anchovy eggs also had a variable vertical distribution. However, at five of seven stations the maximum concentration was found in the upper 10 m. At the two other stations peak concentrations were observed at 10-20 m and at 20-40 m. 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.

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.

5 ACKNOWLEDGEMENTS

Thanks are extended to Chibo Chikilikwa, Johannes Hamakuaya, Justine Kakuuai, Nelda Katjivena, Jan Kheigob and Anna Lucia Mukumangeni who participated in working up the plankton samples and the oxygen titrations. Tore Mørk and Terje Hovland were responsible for running the instruments. A special thanks to the officers and crew of the R/V *"Dr. Fridtjof Nansen"* for making everything work smooth, sometimes under difficult weather conditions.

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7 FIGURES

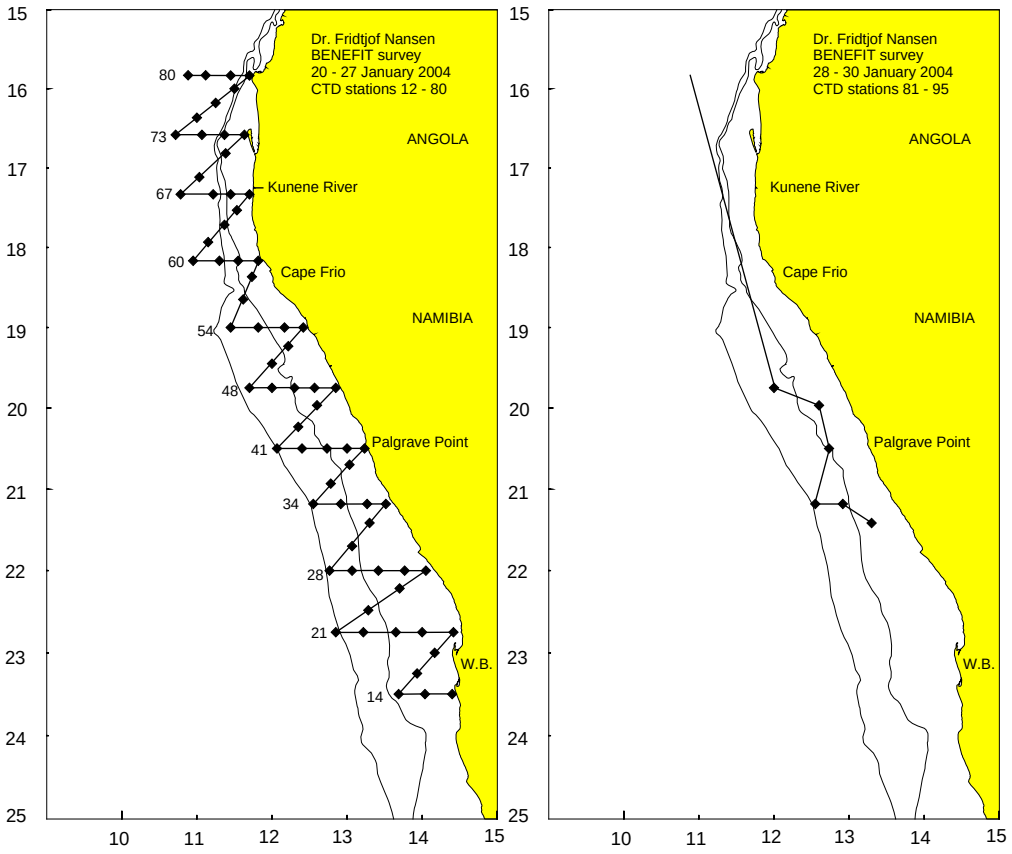

Figure 1. Cruise tracks and CTD stations on the two legs of the survey.

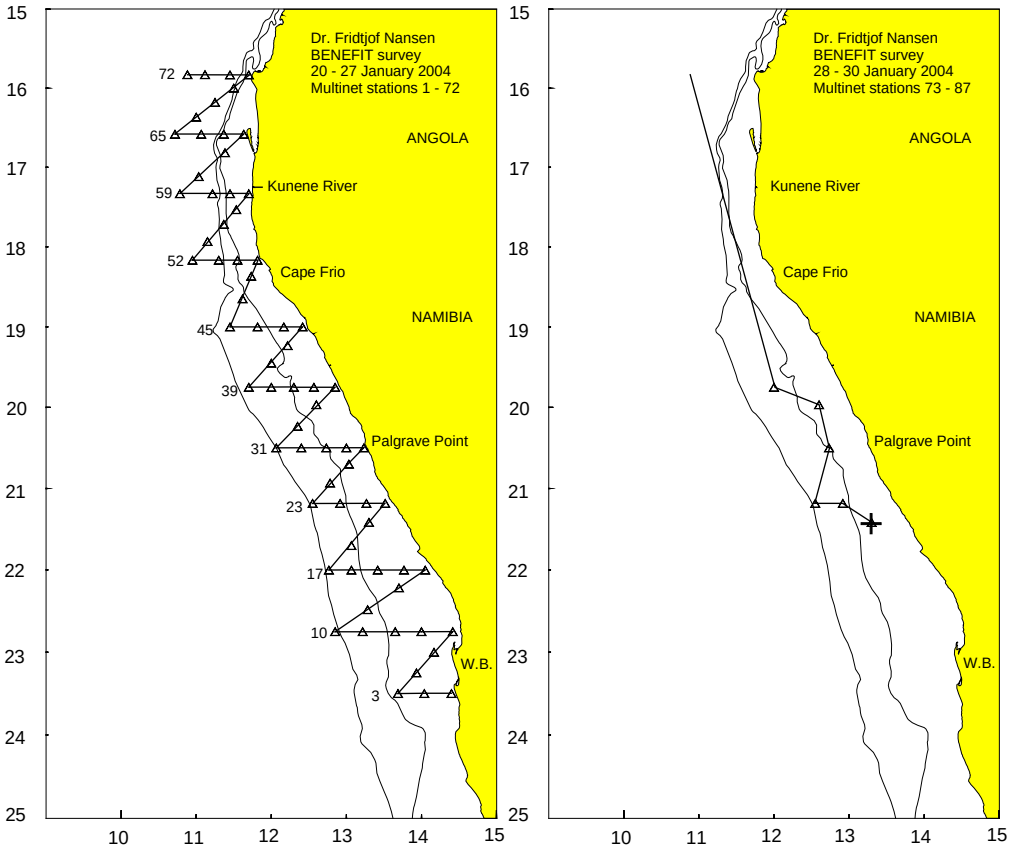

Figure 2. Multinet stations on the two legs of the survey.

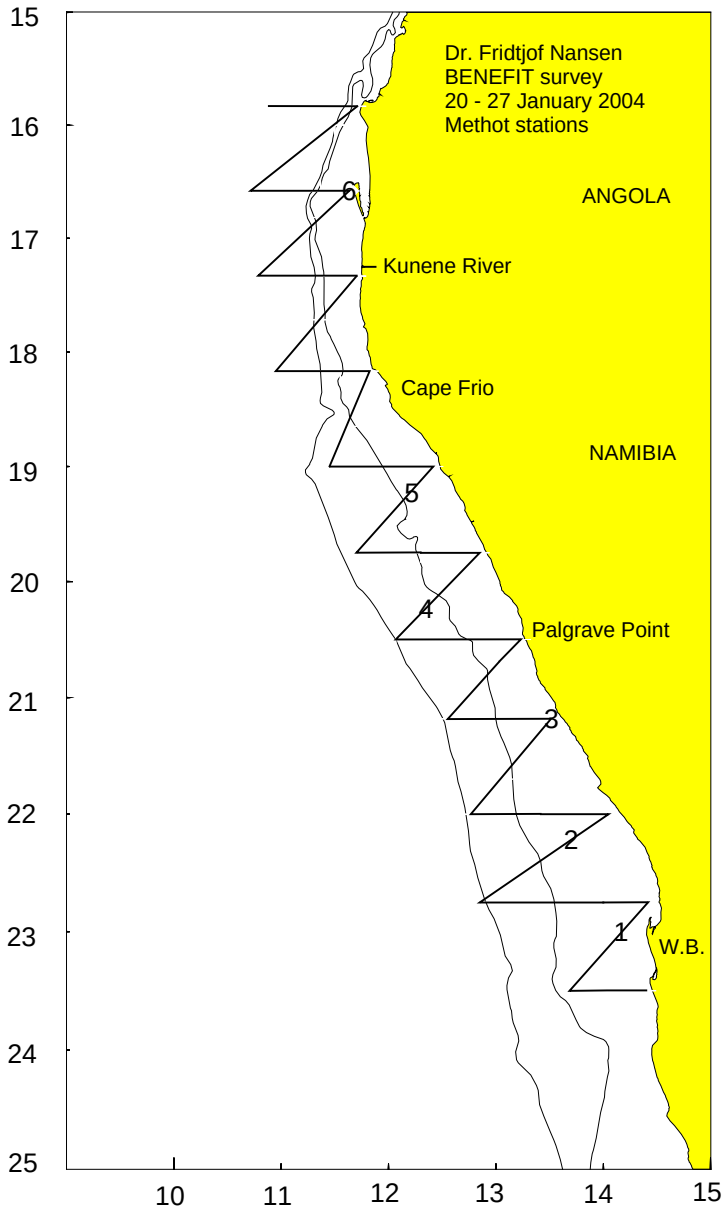

Figure 3. Methot stations taken during the first leg of the survey.

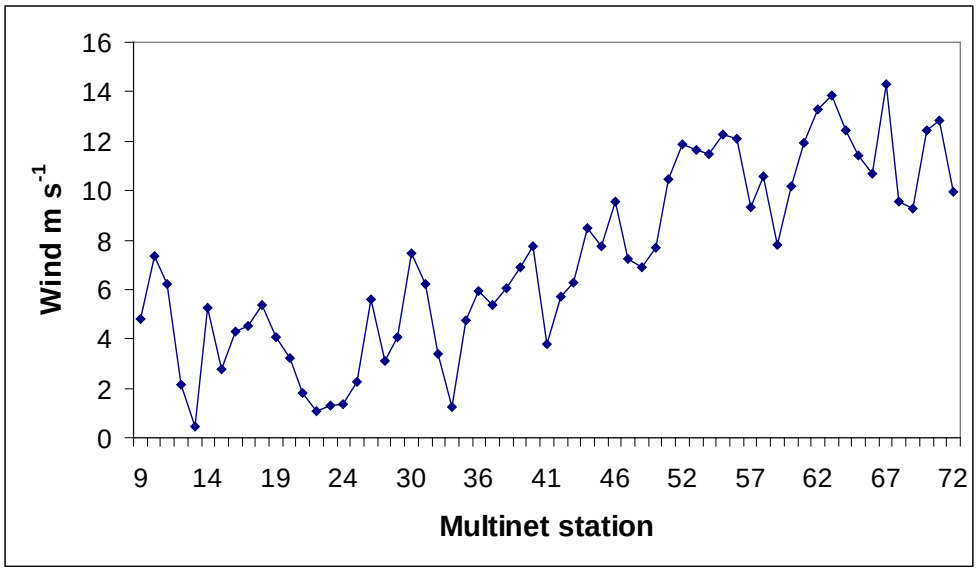

Figure 4. 10 min average wind speed during the survey.

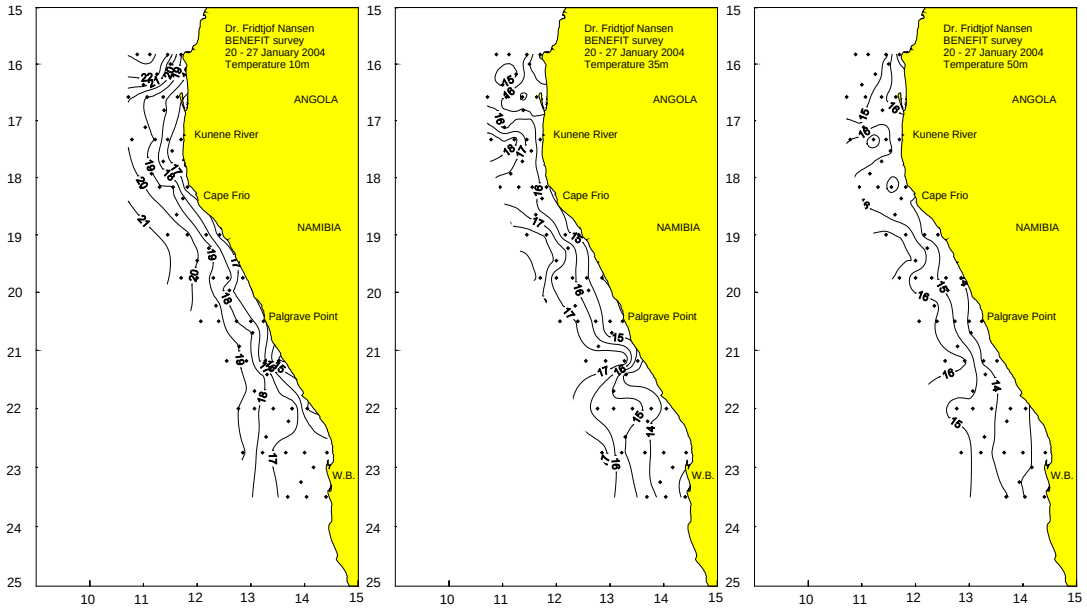

Figure 5. Horizontal distribution of temperature in 10 m (left panel), 35 m (mid panel) and 50 m (right panel).

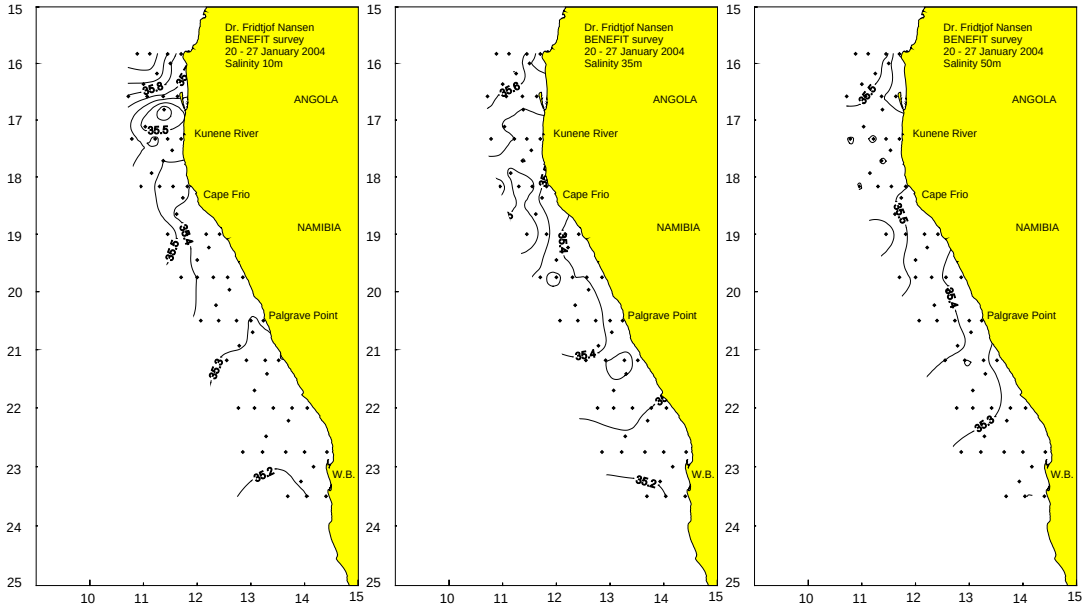

Figure 6. Horizontal distribution of salinity in 10 m (left panel), 35 m (mid panel) and 50 m (right panel).

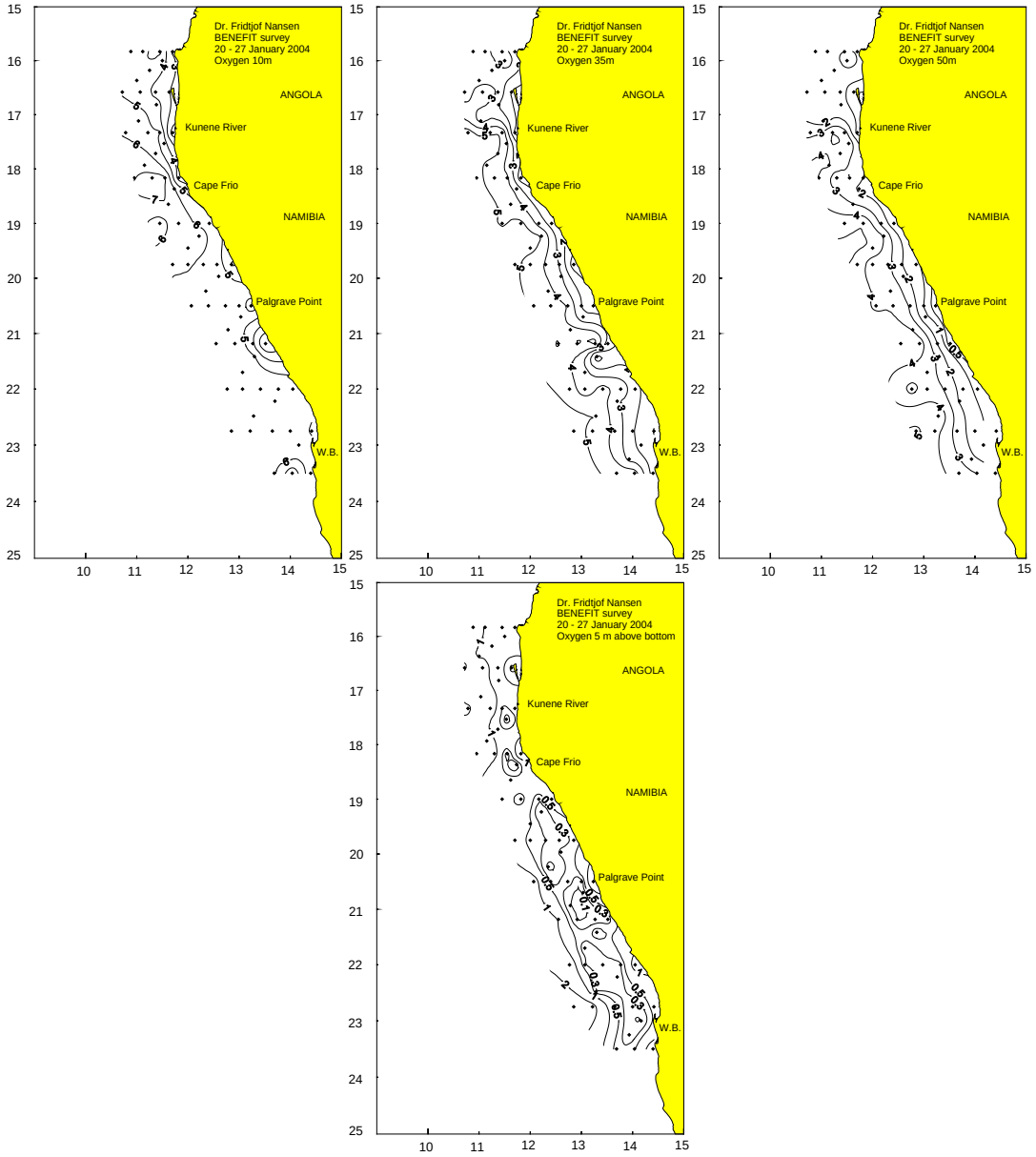

Figure 7. Horizontal distribution of oxygen (ml l^{-1}) in 10 m (upper left panel), 35 m (upper mid panel), 50 m (upper right panel) and 5 m above bottom (lower panel).

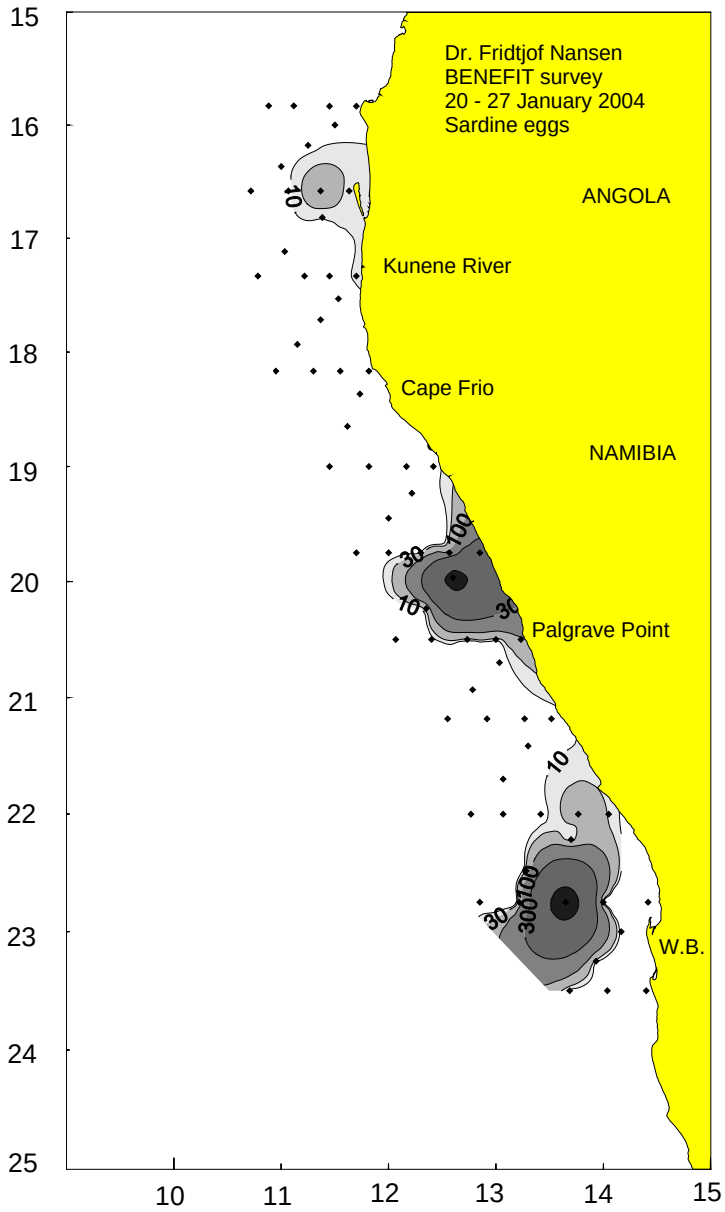

Figure 8. Horizontal distribution of sardine eggs.

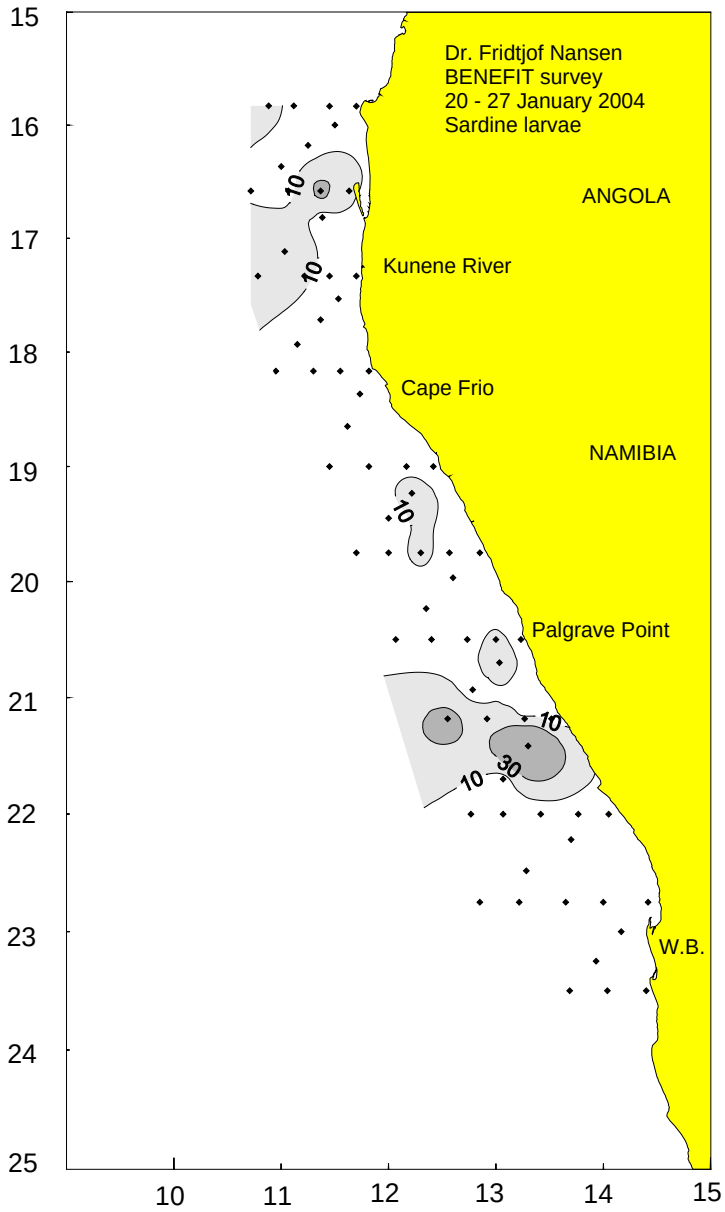

Figure 9. Horizontal distribution of sardine larvae.

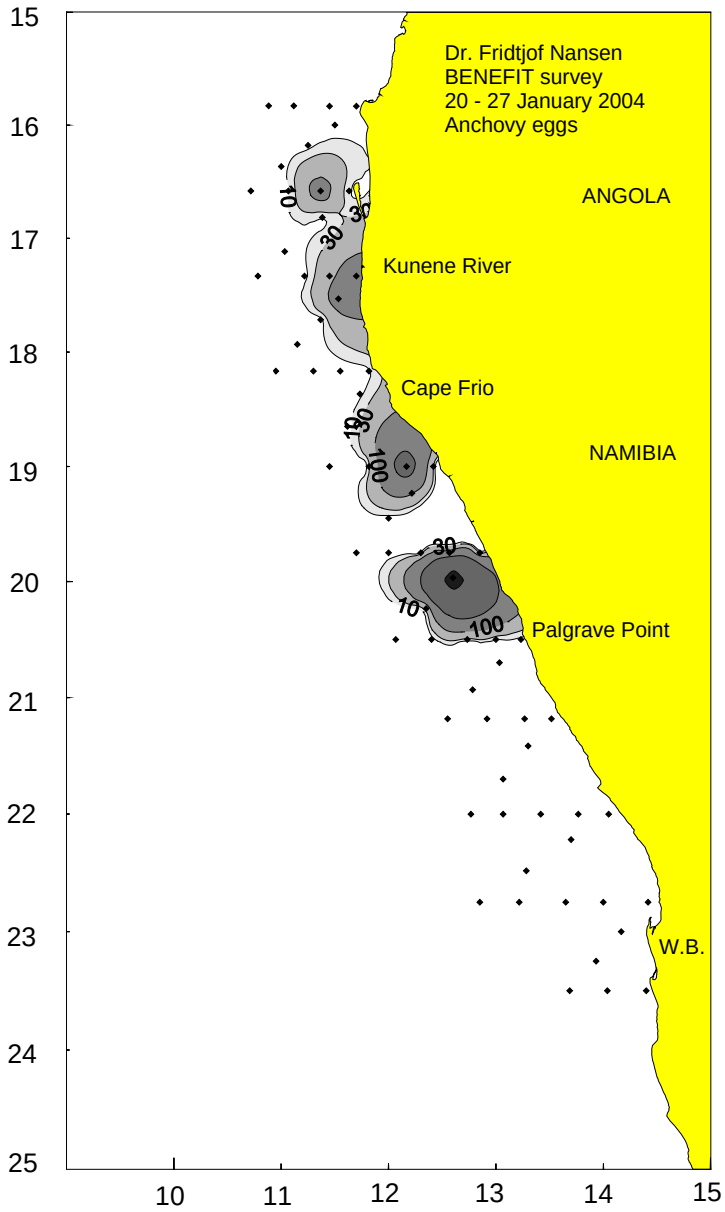

Figure 10. Horizontal distribution of anchovy eggs.

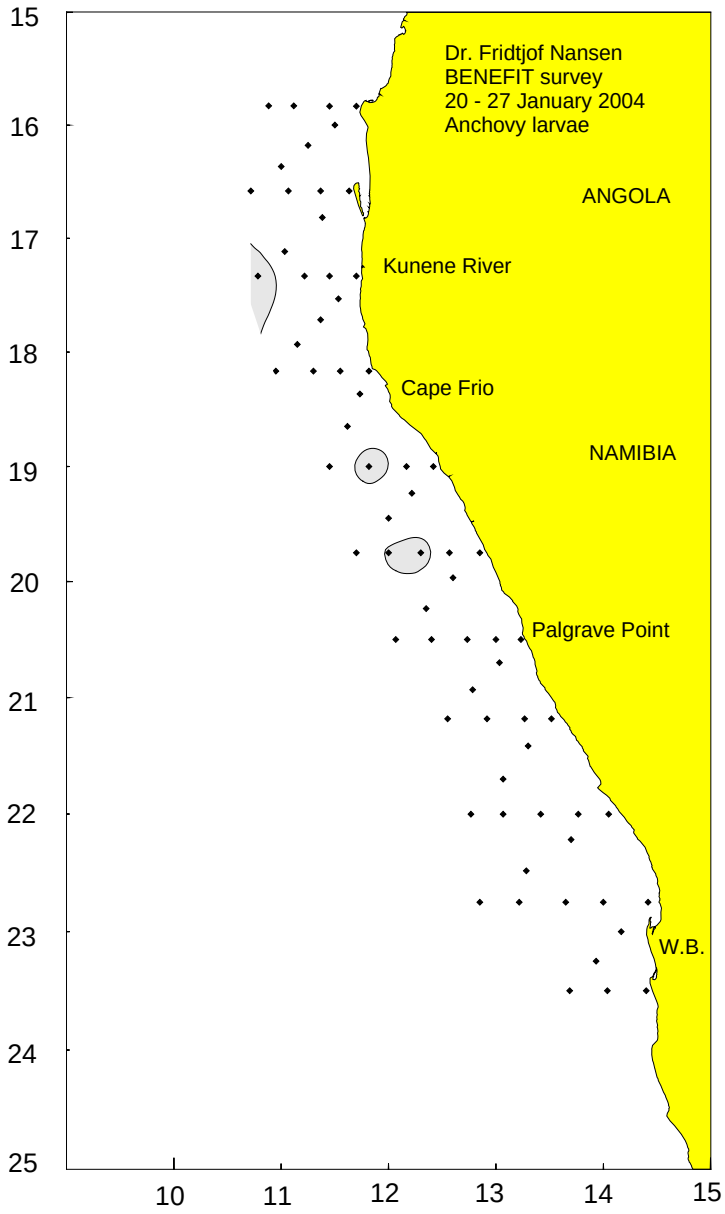

Figure 11. Horizontal distribution of anchovy larvae.

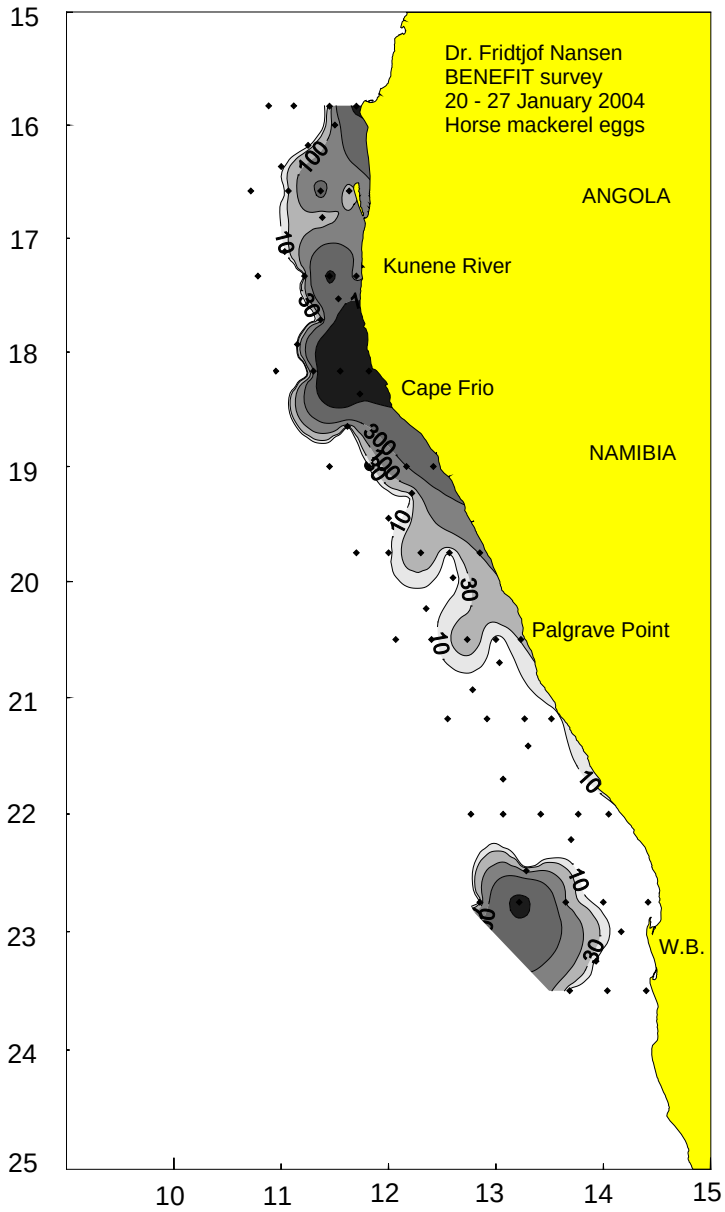

Figure 12. Horizontal distribution of horse mackerel eggs.

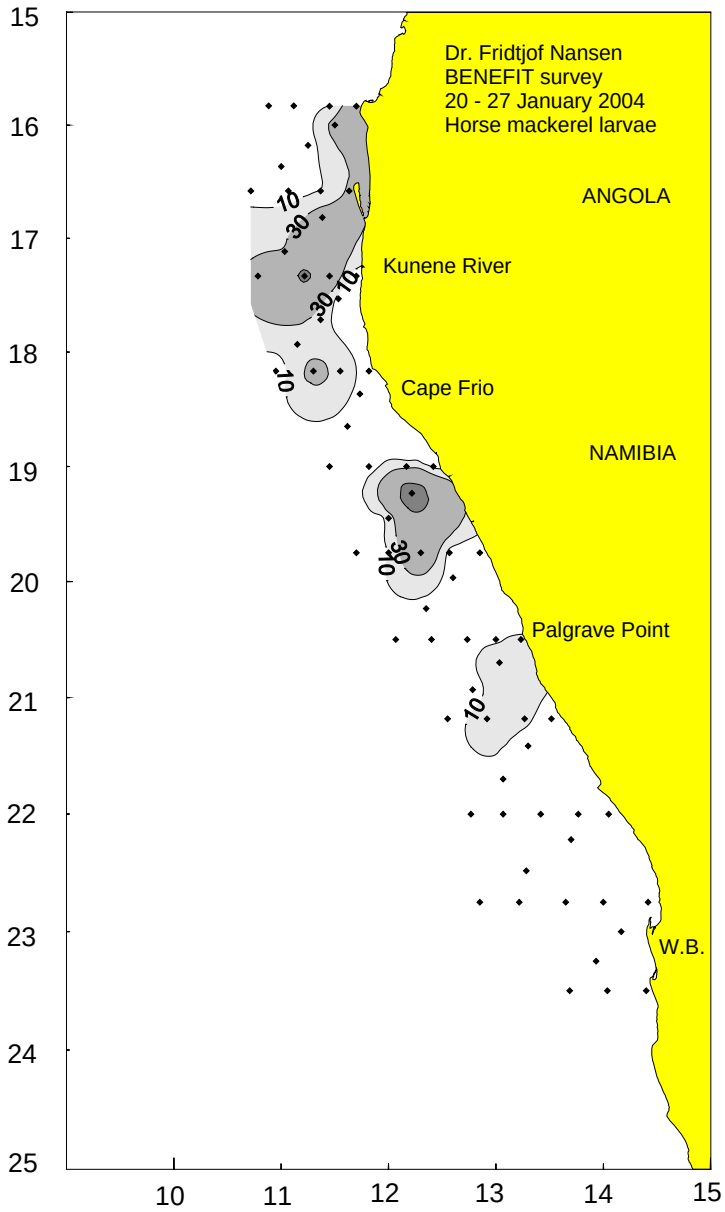

Figure 13. Horizontal distribution of horse mackerel larvae.

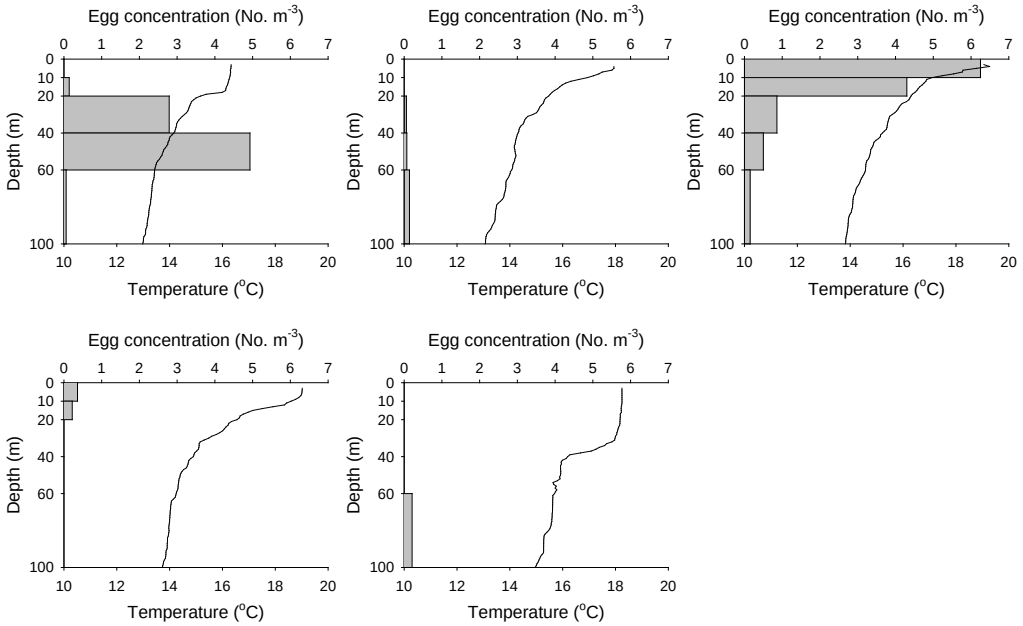

Figure 14. Vertical distribution of sardine eggs from Multinet stations and profiles of temperature.

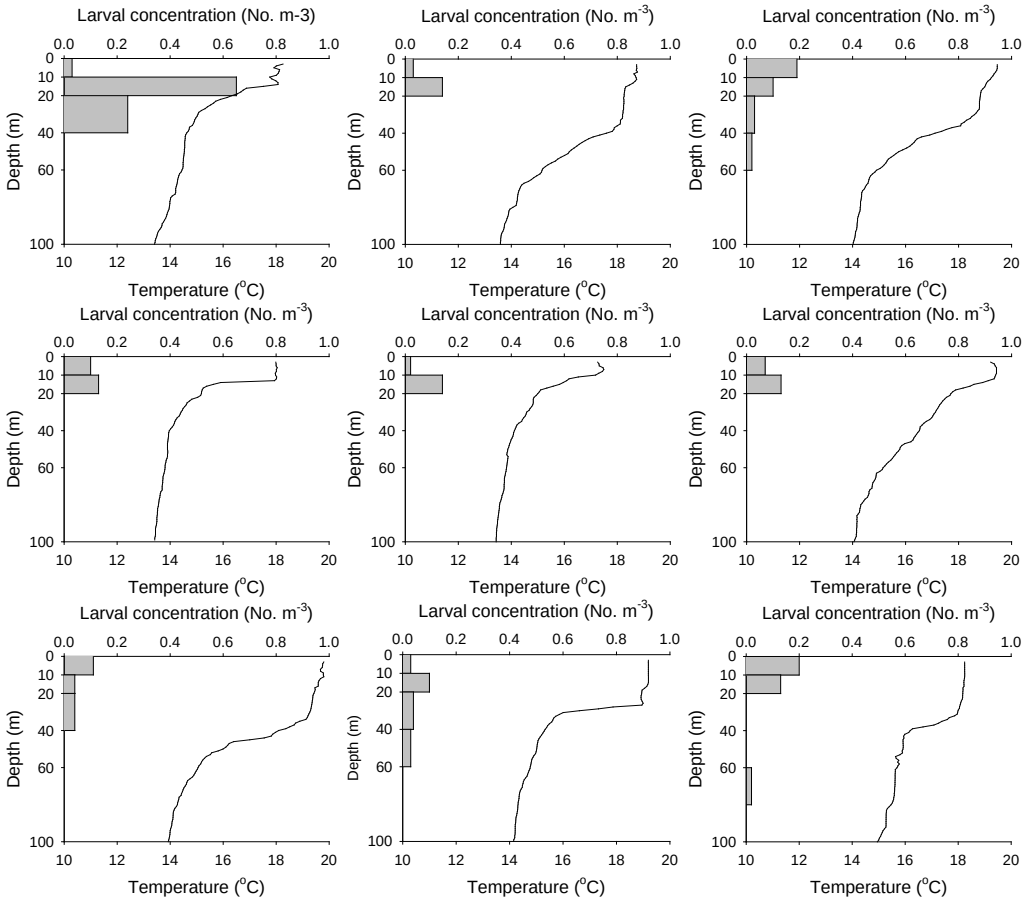

Figure 15. Vertical distribution of sardine larvae from Multinet stations during the first leg of the survey and profiles of temperature.

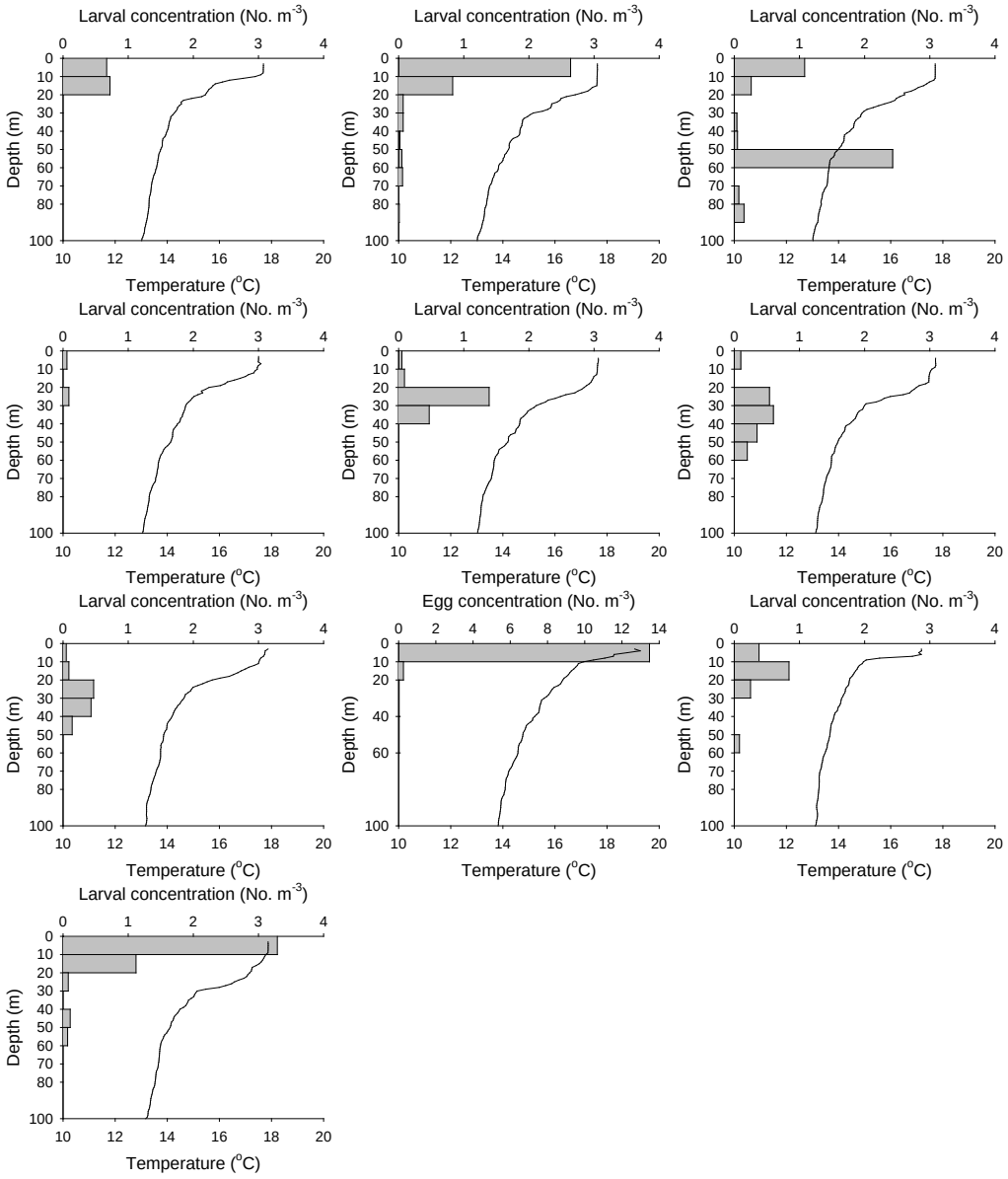

Figure 16. Vertical distribution of sardine larvae from the 24-hours station and profiles of temperature.

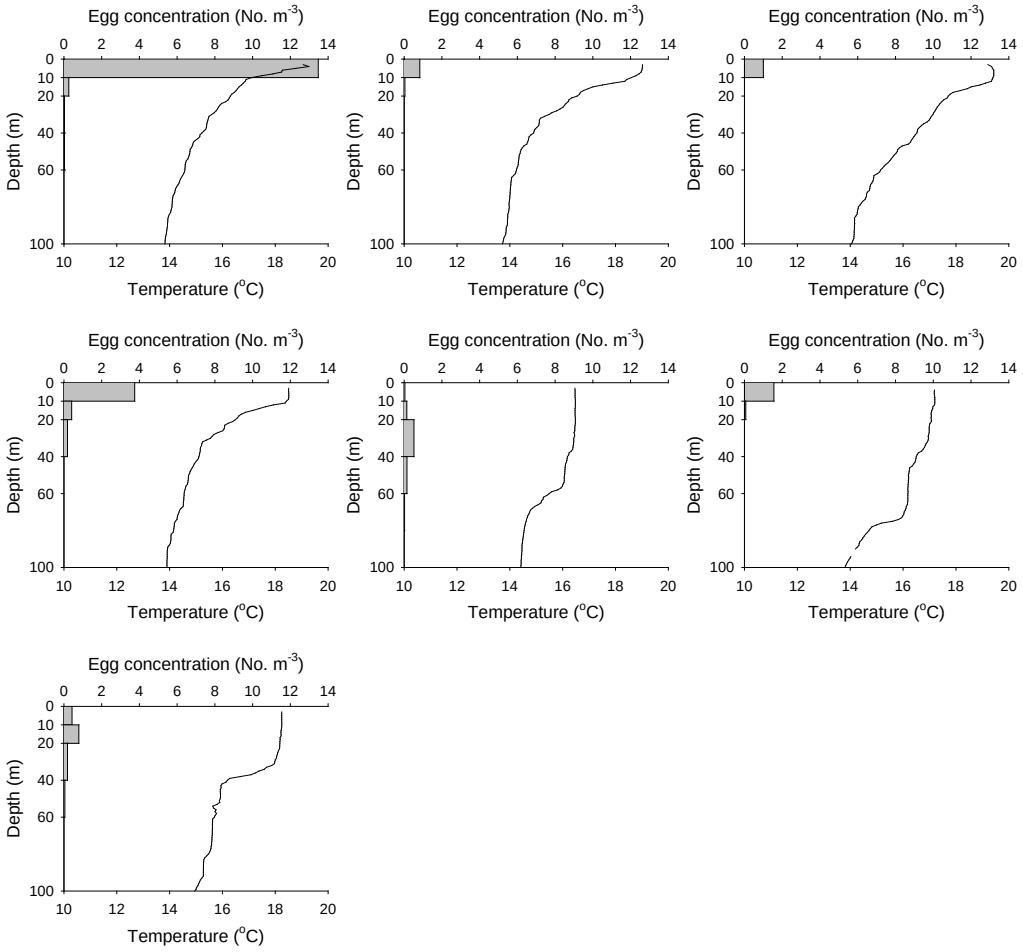

Figure 17. Vertical distribution of anchovy eggs from Multinet stations during the first leg of the survey and profiles of temperature.

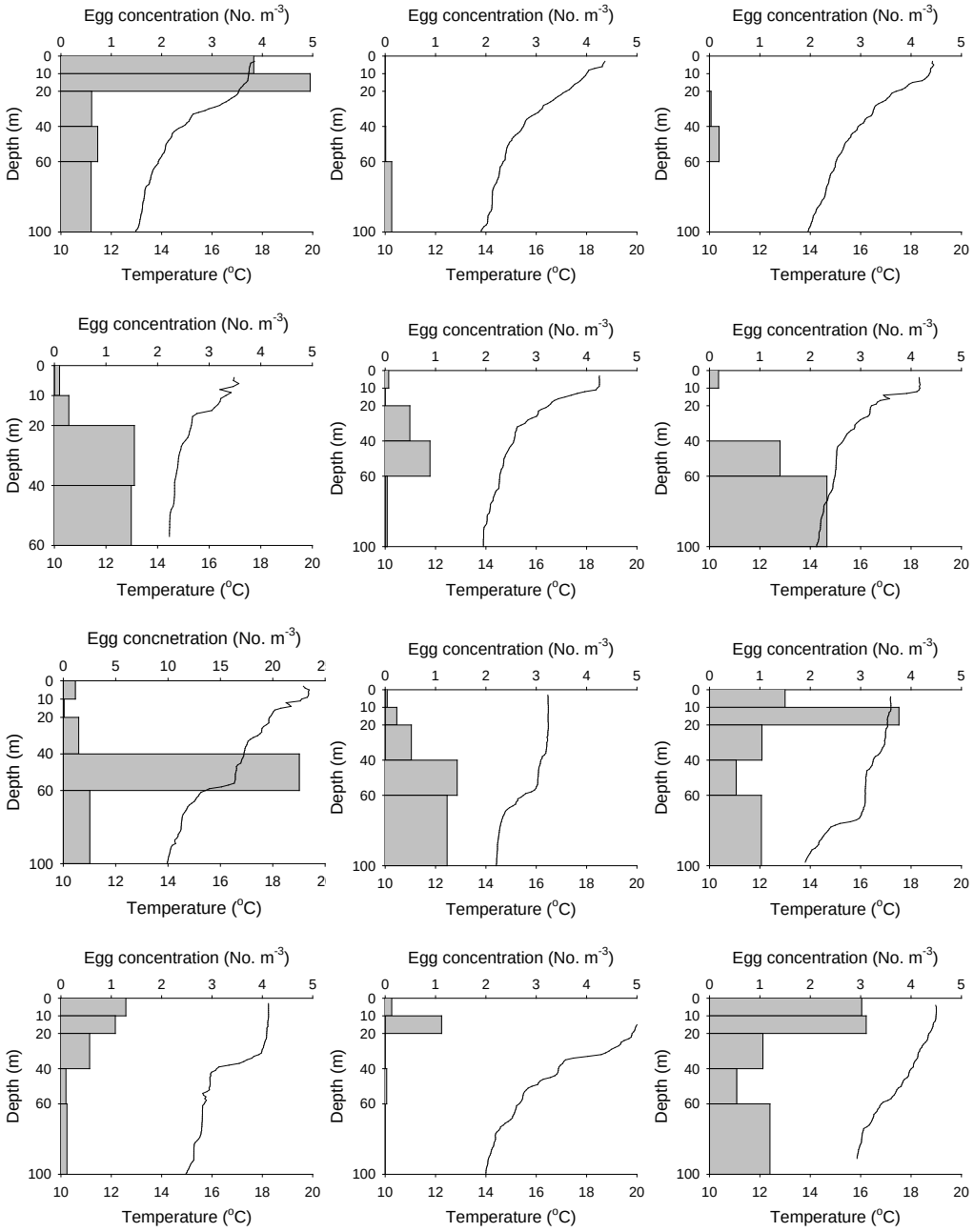

Figure 18. Vertical distribution of horse mackerel eggs from Multinet stations during the first leg of the survey and profiles of temperature.

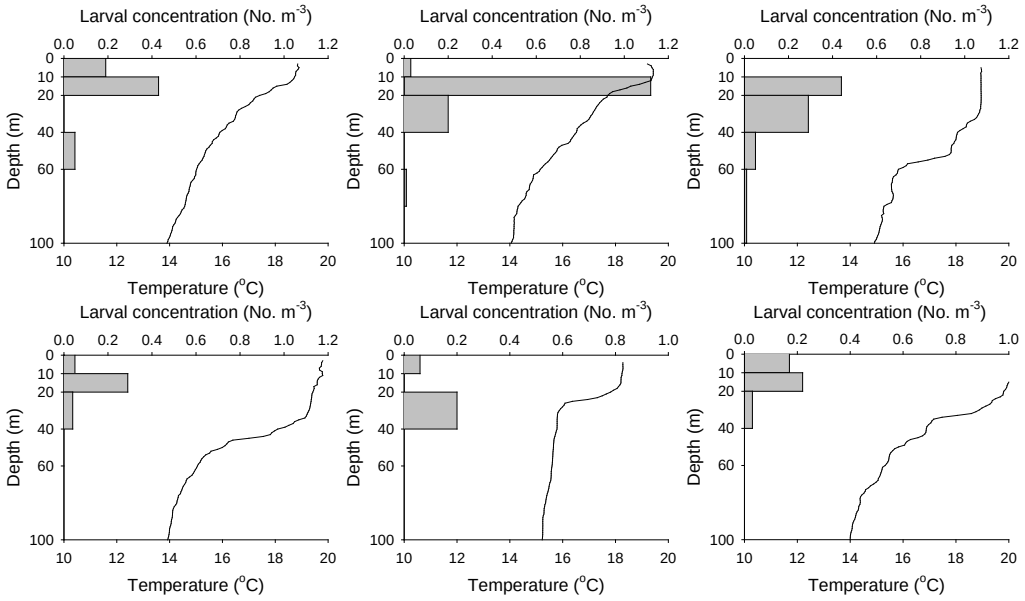

Figure 19. Vertical distribution of horse mackerel larvae from Multinet stations during the first leg of the survey and profiles of temperature.

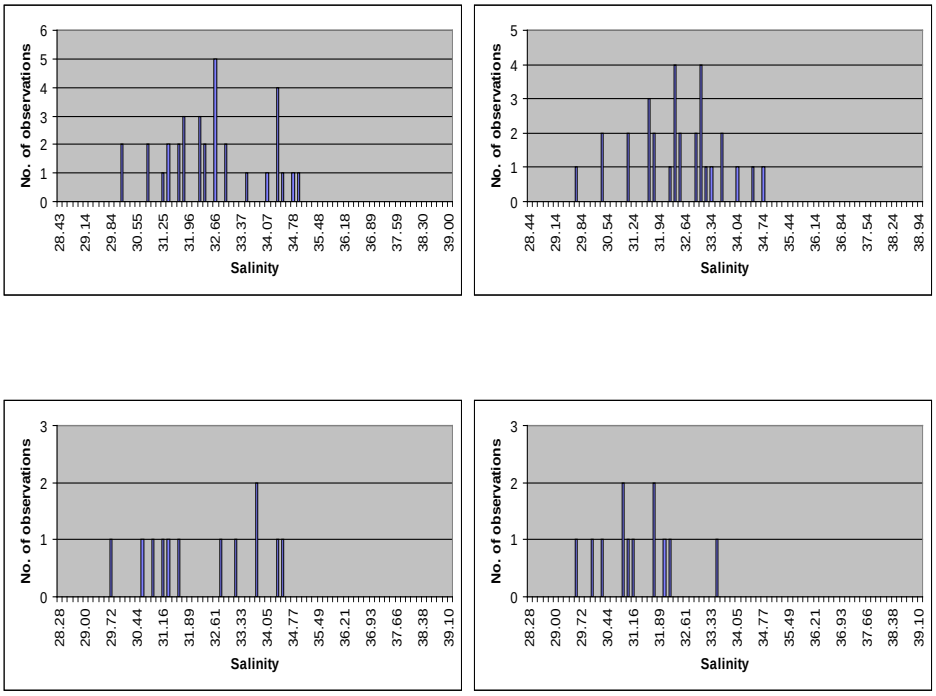

Figure 20. Buoyancy of sardine eggs from three consecutive measurements (upper left panel, upper right panel and lower left panel) and buoyancy of newly hatched sardine larvae (lower right panel).

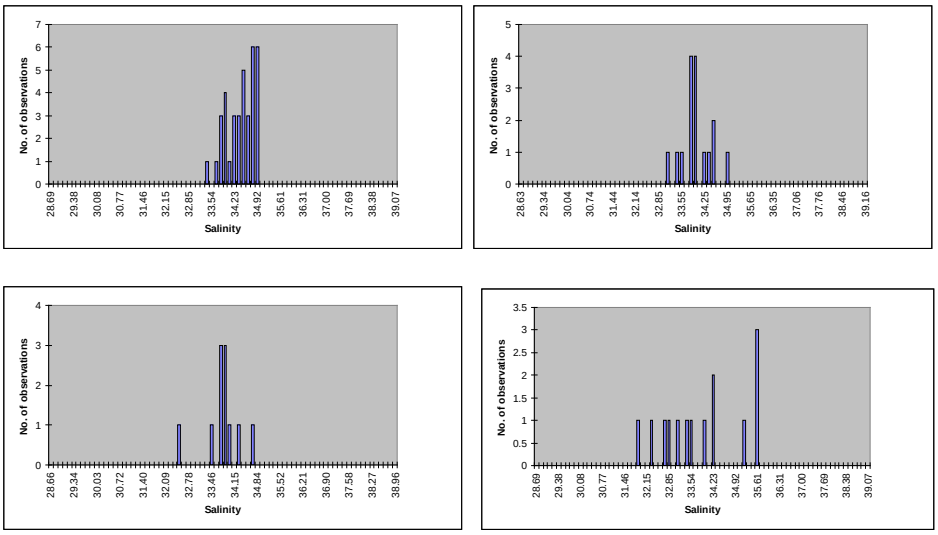

Figure 21. Buoyancy of anchovy eggs from three consecutive measurements (upper left panel, upper right panel and lower left panel) and buoyancy of newly hatched anchovy larvae (lower right panel).

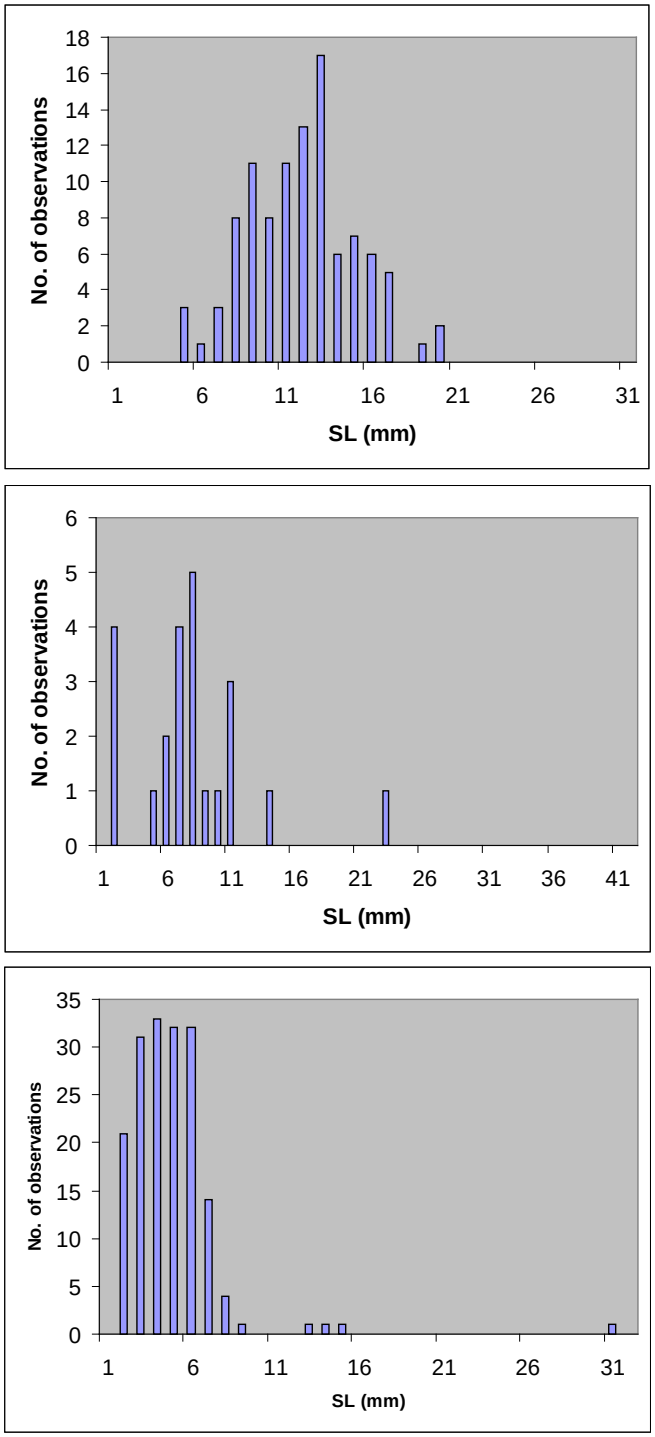

Figure 22. Size distribution of sardine larvae (upper panel), anchovy larvae (mid panel) and horse mackerel larvae (lower panel) caught in the Multinet.