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Recruitment studies on anchovy and sardinella in the coastal waters of Guinea, Guinea Bissau, Senegal and the Gambia

By

Erling Kåre Stenevik, Jens-Otto Krakstad, Espen Bagøyen, Tor Ensrud and Ines Bernardes

Institute of Marine Research
Norway

Fambaye Ngom, Modou Thiaw and Ismaila Ndour
Centre de Recherches Océanographiques de *Dakar*-Thiaroye,
Senegal

Tatiana Helena Andrade Cabral
From Instituto Nacional De Desenvolvimento Das Pescas,
Cape Verde:

Sidi Ahmed Hemed
From Mauritanian Institute for Oceanographic Research and Fisheries,
Mauritania:

Ebou Mass Mbaye
From Department of Fisheries Banjul,
The Gambia:

Duarte Bucal
From Centro de Investigação Pesqueira Aplicada,
Guinéa Bissau:

Ousmane Tagbe Camara
From Centre National de Sciences Halieutiques de Boussoura,
Guinéa:

Abdoulaye Djiba and Koenraad Van Waerebeck
Independent consultants:

Institute of Marine Research
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INTRODUCTION

1.1 General objectives

This aim of the survey was to define the distribution of eggs and larvae of sardinella and anchovy in the region south of Cape Vert. The horizontal and vertical distributions of the eggs and larvae were mapped and related to mapping of water mass circulation and frontal boundaries.

1.2 Specific objectives of the survey

1. Identify the distribution area of sardinella and anchovy egg and larvae south of Cape Vert
2. Identify oceanographic features that are affecting their distribution
3. Explain the retention and distribution mechanisms of the egg and larvae in the survey area

1.3 Participation

The scientific members during the cruise were:

From Institute of Marine Research Norway:
Erling Kåre Stenevik (Cruise leader 1/5-7/5), Jens-Otto Krakstad (Cruise leader 8/5-23/5), Tore Mørk, Jan Arne Vågenes (until 7/5), Håkon Langøen (from 8/5), Espen Bagøien, Tor Ensrud, Marek Ostrowski (from 8/5) and Inês Bernardes

From Instituto Nacional De Desenvolvimento Das Pescas, Cape Verde:
Tatiana Helena Andrade Cabral

From Mauritanian Institute for Oceanographic Research and Fisheries, Mauritania:
Sidi Ahmed Hemed

From Centre de Recherches Océanographiques de *Dakar*-Thiaroye, Senegal:
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From Centre National de Sciences Halieutiques de Boussoura, Guinéa:
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Independent consultants:
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1.4 Narrative

The vessel left Dakar on the 1.5.2013 at 15:10 after a survey meting onboard together with representatives of the CCLME where the general sampling program was agreed on. It was agreed to attempt two full coverage's of the region between Cape Vert and Guinea to cover the main spawning grounds of sardinella and to observe possible changes in egg and larvae distribution between the two coverage's. Between these, a few days were set aside for more in depth process studies to map the oceanographic conditions responsible for the egg and larva distribution.
The sampling started immediately after leaving port with three CTD and WP2 transects across the shelf at 14°N, 13°15'N and at 12°N. The southern limit of the survey region and the start of the first full coverage were reached on the 3.5. at 08:45. Sampling stations with CTD, WP2 and multinet (one net from bottom to surface) were set out with 10 NM intervals along transects starting from 20 m bottom depth to roughly 1000 m depth. The transects were spaced 15 NM apart. On the 6.5. the vessel had almost surveyed the whole region south of Dakar, when it had to break off for a crew change. It returned to Dakar and docked at 11:00 the same day. After the crew change the vessel departed on the 8.5. 12:25 and returned to complete the 1st survey coverage. This was determined completed on the 10.5. at 20:00 midway between Cayar and St. Louis, when very few egg and larvae had been seen on two consecutive transects. The vessel then steamed southwards to start the process studies. Three oceanographic transects were completed in different directions from the tip of Cape Vert to describe the distribution of water masses off Cape Vert. During the first survey coverage dense concentrations of egg and larvae of anchovy was observed on the last transect south of Cape Vert. This transect was repeated with a more detailed coverage to better determine the horizontal and vertical distribution of egg and larvae. The process study of anchovy was completed on the 13/5 at midnight, and the vessel steamed southwards to prepare for the process study of sardine off Casamance where the concentration of sardinella egg and larvae was high. Only very few sardinella larvae was observed in some initial multinet in the southern part of the survey area. It was therefore decided to start the second coverage on the 14/5. The coverage was commenced with a ctd line to capture the oceanographic features in the southern part of the region. Once this was completed we came into areas with higher sardinella concentrations. We increased the sampling for two transects and used five vertical nets (standard depths) to get a better resolution of the samples. We thereafter continued the sampling using one net only. On the 17/5 in the morning at 09:00 we broke of the survey in the south of Senegal, on the border to the Gambia to celebrate the Norwegian national day. The survey commenced the next day at 08:00. During our first transect in Gambia large concentrations of sardinella egg and larvae was observed. It was therefore decided to repeat the transect and increase the sampling resolution using 5 nets and only 5 nm between stations.

During the survey a total of 84 CTD casts, 87 Multinet stations

Figure 1.1. Course track Conacry – "Petite Cotê" during the 1st coverage of the survey. a) Bottom trawl (▫) and pelagic (Δ) trawl stations, b) Hydrographic (Z), plankton (×) and benthos (◊) stations. The 20, 50, 100, 200, 500 and 1000 m depth contours are indicated

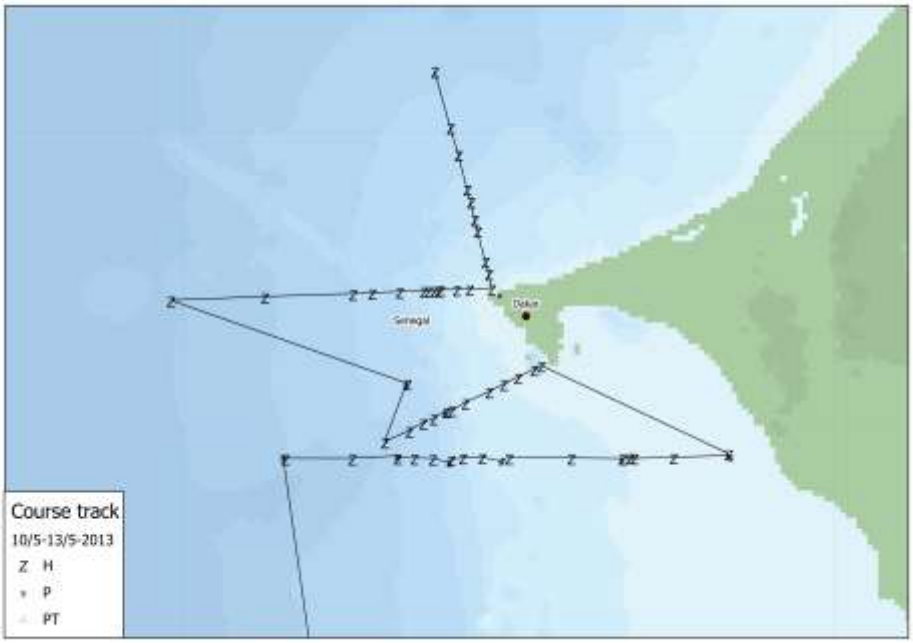


Figure 1.2. Course track Conacry – "Petite Cotê" during the process studies. a) Bottom trawl (▫) and pelagic (Δ) trawl stations, b) Hydrographic (Z), plankton (×)stations. The 20, 50, 100, 200, 500 and 1000 m depth contours are indicated

Figure 1.3. Course track Conacry – "Petite Cotê" during the 2nd coverage of the survey. a) Bottom trawl (▫) and pelagic (Δ) trawl stations, b) Hydrographic (Z), plankton (×)stations. The 20, 50, 100, 200, 500 and 1000 m depth contours are indicated

MATERIAL AND METHODS

1.1 Meteorological observations

Wind direction and speed, air temperature, air pressure, relative humidity, and sea surface temperature (5 m depth) were logged automatically every 60 sec. with an WIMDA meteorological sensor.

1.2 CTD

Vertical temperature and salinity profiles were obtained by a Seabird 911 CTD, while *in situ* concentrations of dissolved oxygen were measured using a CTD-mounted oxygen-sensor. Real time logging and plotting was done using the Seabird Seasave software installed on a PC. Above the shelf and slope, the profiles ranged from the surface to within a few metres above the bottom. Offshore, the maximum sampling depth was 1500 m.

Niskin water-bottles (10 l) attached to a CTD-mounted rosette were used to collect water at predefined depths (see below). For calibration of the salinity (conductivity) measurements of the CTD, the salinity of seawater from the Niskin-bottle containing the deepest water-sample from each shallow, intermediately deep, and deep plankton-station was analyzed using a Portasal salinometer (mod. 8410A) onboard the vessel. The salinometer confirmed the CTD sensor data readings.

For calibration of the oxygen-measurements from the CTD-mounted sensor, the oxygen-concentrations in water-samples from all Niskin-bottles at the deep plankton-stations were analyzed by the Winkler redox titration method, following the procedures of Hagebø (2008). Oxygen-concentrations were analyzed from 23 out of a total of 31 deep stations during the cruise. From each Niskin-bottle, a water sample for oxygen-analyses was collected first, and then the water temperature in the same bottle was measured. These temperature-data were used to calculate potential temperature at the time when the Winkler-reagents were added. The potential temperature is used in the calculation of oxygen-concentration per weight-unit of seawater.

For calculation of chlorophyll *a* and phaeopigment concentrations, water-samples (263 ml) were collected from the same standardized depths as described above for the nutrients. The water-samples were filtered on Munktell glass fiber filters (GF/C, 25 mm diameter) using a custom-made filtration system. The filters were then stored at -18°C in the dark for subsequent analysis on shore.

Also attached to the CTD was a Chelsea Mk III Aquatracka fluorometer which measures *in situ* fluorescence on a relative scale. This again, can be related to the absolute chlorophyll concentrations obtained from the analyses of the samples collected from the water-bottles.

1.3 Thermosalinograph

The SBE 21 Seacat thermosalinograph was running continuously during the survey, obtaining samples of sea surface salinity and relative temperature and fluorescence (5 m depth) every 10 seconds. An attached in-line Turner Design SCUFA Fluorometer measured Chlorophyll a levels [RFU] at 5 m below the sea surface while underway during the entire cruise.

1.4 Current speed and direction measurements (ADCP)

A vessel-mounted Acoustic Doppler Current Profiler (VMADCP) from RD Instruments was run continuously during the survey. The frequency of the VMADCP is 150 kHz. The system was run in narrow band mode and data were averaged in 8 m vertical bins and stored on files for post survey processing.

1.5 Single beam acoustic sampling

Acoustic data were recorded continuously during the survey using a Simrad ER60 scientific echo sounder equipped with keel-mounted transducers at nominal operating frequencies of 18, 38, 120 kHz.

1.6 Biological fish sampling

Trawl hauls were sampled for species composition by weight and number. The deck sampling procedure is described in detail by Strømme (1992). Length measurements were taken for selected target species on most stations. An Electronic Fish Meter (SCANTROL) connected to a customised data acquisition system (Nansis) running on a Windows PC was used for length measurements. The total length of each fish was recorded to the nearest 1 cm, rounding down when this was between sizes. Sex and other biological parameters were collected from the first randomly selected 20-30 individuals of target species.

1.7 Zoo- and ichthyoplankton sampling

Zooplankton, including fish eggs and larvae, were collected from the whole study area by a Hydro-Bios Multinet (Anonymous 1990) as well as a WP2-net (Anonymous 1968).

The multinet was rigged with 5 nets with mesh-size 405 μm for depth-stratified sampling, a pressure sensor and an electronic flow-meter. The side-panel of each cod-end was fitted with mesh-size 180 μm. The purpose of using the smaller mesh-size in the side panels of the cod-ends was to reduce the stress on the fish larvae and eggs in the samples. The multinet was deployed and retrieved at a speed of ~ 1.5 m per second, and towed obliquely behind the vessel. The typical towing speed of the net was about XX m s^{-1} .

For the large-scale survey, only the first net of the Multinet was used, covering the entire water column in areas with bottom depths less than 200 m, and ranging from 200 m to the surface in deeper areas.

For process studies in selected target areas, as many as 5 nets could be used to obtain vertically stratified plankton samples. The number of nets actually employed at any given station depended on the bottom depth. The following standardized sampling depths were used:

200-100 m, 100-75 m, 75-50 m, 50-25 m and 25-0 m.

Once the Multinet was back onboard after a haul, the depth-stratified samples represented by each net were collected. These depth-specific samples were then divided into equal parts using a Motoda plankton splitter (Motoda 1959).

The samples were transferred onto Petri-dishes and examined with a stereomicroscope. All fish larvae were removed from the total sample. Larvae of the species *Sardinella aurita* (or *S. maderensis*) and *Engraulis encrasicolus* were identified using the key of Olivar and Fortuño (1991), and their standard lengths measured, and in many cases the individuals were also photographed for documentation purposes. Fish larvae of these species were then preserved in 96 % ethanol and in many cases additionally borax buffered formaldehyde. All fish larvae belonging to other species were counted, and then preserved in 4% borax buffered formaldehyde.

Once the fish larvae had been removed from the Multinet samples, a fraction of the sample that permitted the enumeration of eggs was examined with a stereomicroscope. Fish eggs were sought identified, counted, and the diameters of the eggs and their embryos and lipid globules were measured. Fractions of the total samples without fish larvae were then preserved in borax buffered formaldehyde

From the large scale survey stations, the WP2 net (56 cm in diameter, mesh-size 180 µm) was hauled vertically from near the bottom to the surface. One half was preserved with borax-buffered formalin resulting in a 4% final concentration on a 100 ml plastic bottle for later taxonomic analysis on shore. The other half of the sample was sequentially sieved through three filters to obtain the plankton biomasses representing the size-fractions >2000 µm, 2000-1000 µm, and 1000-180 µm. The biomass samples were stored on preweighed aluminium dishes, and dried at ~70 °C for periods of 6–24 h. Limited storage capacity in the drying chamber restricted the drying period. The samples were thereafter kept frozen at -18°C for subsequent weighing of biomass dry weight on shore (following a second drying period).

1.8 Cetacean visual observations

The R/V Fridtjof Nansen was used as a platform of opportunity for by two independent marine mammal observers during the survey. The animals were observed in 'passing mode', as the vessel's operation did not allow closing on marine mammal sightings, nor adapt speed in function of sightings. The cruise design, dedicated to fisheries and oceanographic research, requires multiple daily stations for bottom trawling, CTDs, plankton-net hauls and other experiments when the vessel's speed is greatly reduced, typically ranging from 0-5km/h (3 knots or less). Full stops and back-tracking on a completed transect line may also occur.

Evidently, such an operation mode does not allow a line transect sampling protocol for marine mammals as basic assumptions of the model are not fulfilled. Even between stations, cruise speed fluctuates around 10 knots, a borderline velocity, as many cetacean species can match this speed. Mean progress (velocity) along the major track lines is further reduced due to the sampling stations, therefore the probability that the same groups and individuals being re-sighted are high. An evaluation of likely re-sightings is made in situ.

Some measure of relative abundance between-species, such as an encounter rate, will be considered in the data analysis, but comparability with other (non-CCLME) cruises will necessarily be limited.

During transit legs, the single observer visually scans from -90° (port) to 90° (starboard) both with 7x50 binoculars and by naked eye (to spot cetaceans close to the ship) preferentially

from the radar deck (at 24m -to confirm), if not from the fore-castle deck (14m), depending on the captain's indications and the need for the primary radar. A maximum amount of effort is concentrated on and near the trackline so as not to miss any sightings there. During low-speed or stationary sampling activities the platform is treated as a quasi-fixed vantage point and 360° are scanned, considering that the probability that cetaceans may approach from behind the vessel is significantly increased.

Main parameters collected include (see datasheet for full list) when available/applicable: species, time, GPS-position, relative position of animals to ship (estimated angle and radial distance), group size estimates, group composition, diagnostic or unusual morphological features, any behavioural comments, basic air/sea conditions and some other info. A sketch of notable external features and of the sighting dynamics may be added.

Species are identified in a strictly conservative way, i.e. only when diagnostic features were confirmed, alternatively the sighting is assigned to the family or genus level. When identification is probable but not confirmed, it is classified as a "like-species" (cf. IWC usage). As a high priority, but depending on distance, it is attempted to take photographs with a Canon reflex camera with a 70-300mm zoom lens. A GPS waypoint is marked and a paper sighting data form is filled out.
A separate form is used for observer effort information, with indications of sea state, swell and ship's activity (although more detailed data from the vessel's log will be used for analysis).

OCEANOGRAPHIC CONDITIONS

1.9 Physical measurements

1.9.1 Wind

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

1.9.2 Hydrography

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).

ICHTHYOPLANKTON SAMPLING

1.10 First coverage

The distribution of egg and larva of anchovy and sardinella during the first coverage of the survey area is described in Figure xx. The figure show that the distribution of sardinella larvae was mainly in the southern part of the survey area while the anchovy was found particularly immediately south of Dakar, but with some larvae also further north and south.

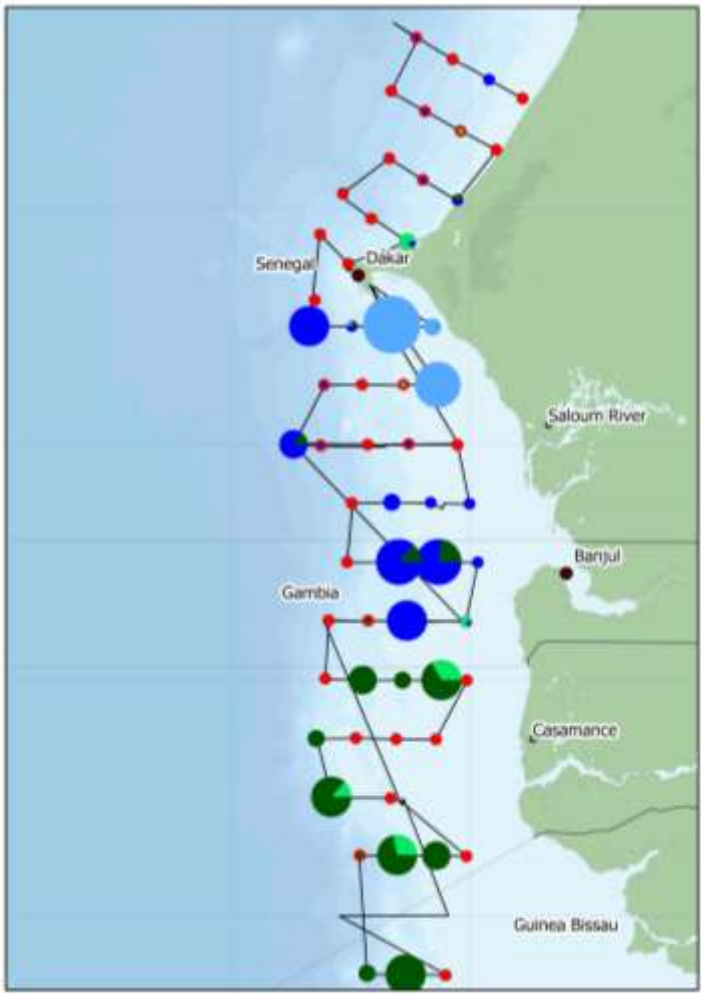


Figure xx. Horizontal distribution eggs (light colour) and larvae (dark colour), of anchovy (blue) and sardinella (green) per station. Red dots are stations without any observations.

1.11 Second coverage

The distribution of egg and larva of anchovy and sardinella during the first coverage of the survey area is described in Figure xx

Figure xx Horizontal distribution of sardine eggs and larvae.

Figure xx. Horizontal distribution of anchovy eggs and larvae

1.12 Process studies

1.12.1 Anchovy

Adult anchovy was found mixed with juvenile sardine and sardinella in relatively large schools close inshore at 20 m depth. These schools were associated with relatively cold waters and inshore of the surface chlorophyll maximum, Figure xx. Horse mackerel and adult sardinella was found on the shelf offshore of the surface chlorophyll maximum in relatively high concentrations. The cross shelf horizontal and vertical distribution of egg and larva on the transect selected south of Dakar is described in Figure XX. Anchovy eggs were found in the whole water column at the two innermost plankton stations, while anchovy larva were distributed mainly in the upper 25 m in colder more offshore waters. The oceanographic conditions described in the oceanography sections can to a large extent explain this distribution.

The size distribution of egg and larvae can be found in Figure xx.

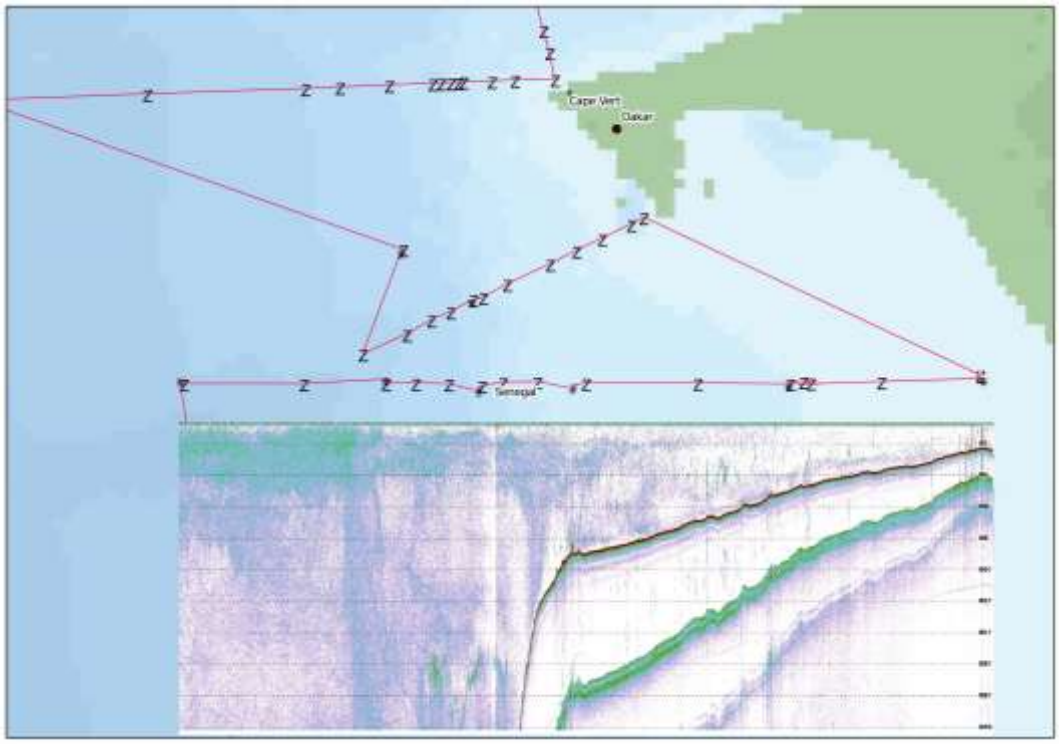


Figure xx. Acoustic recordings (38 kHz) on the transect south of Dakar

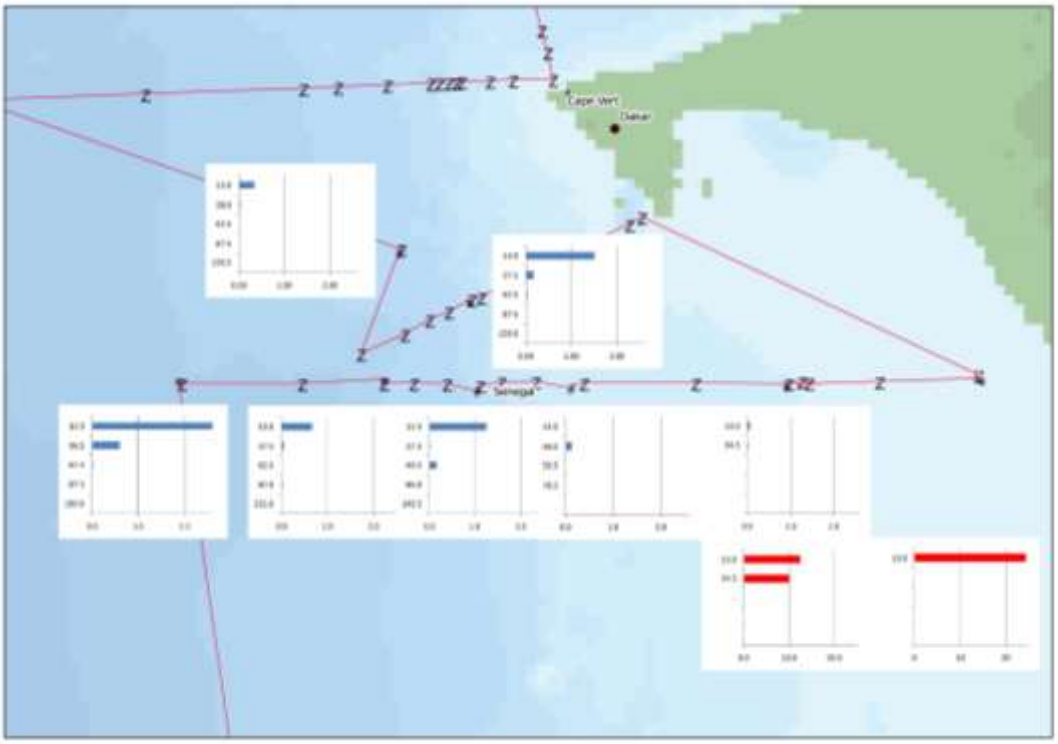
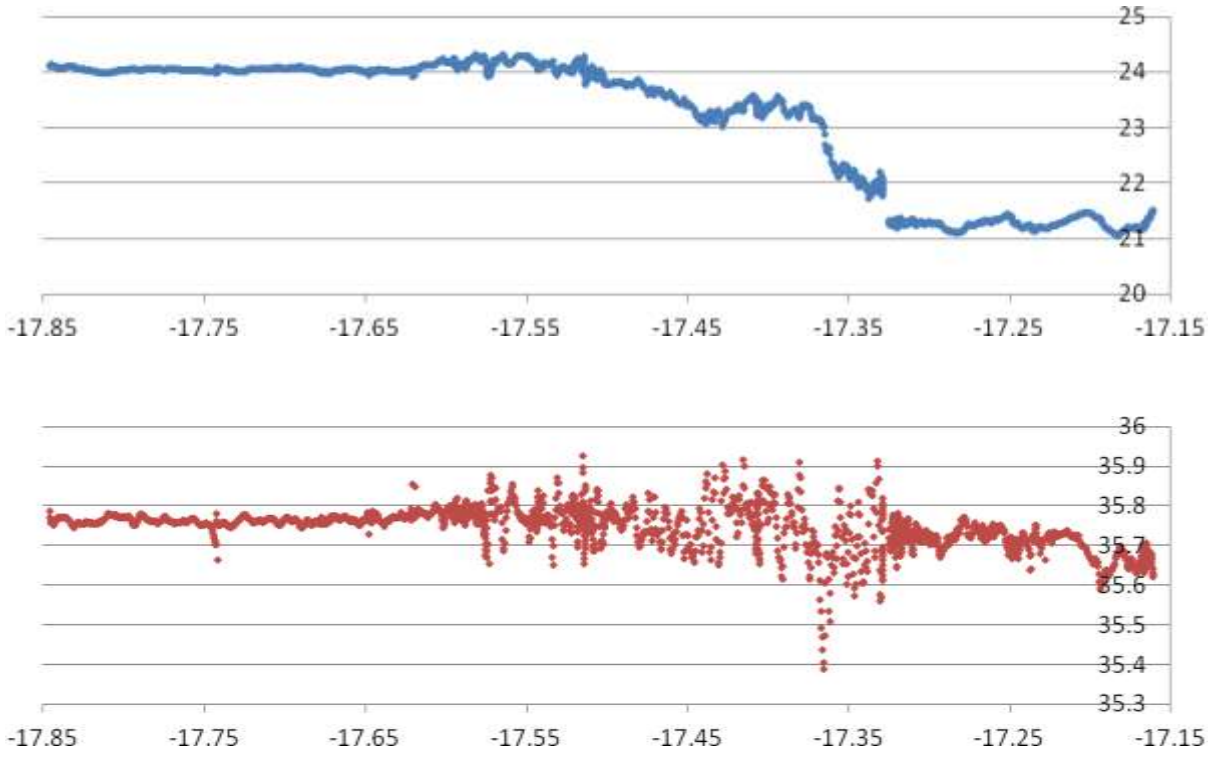
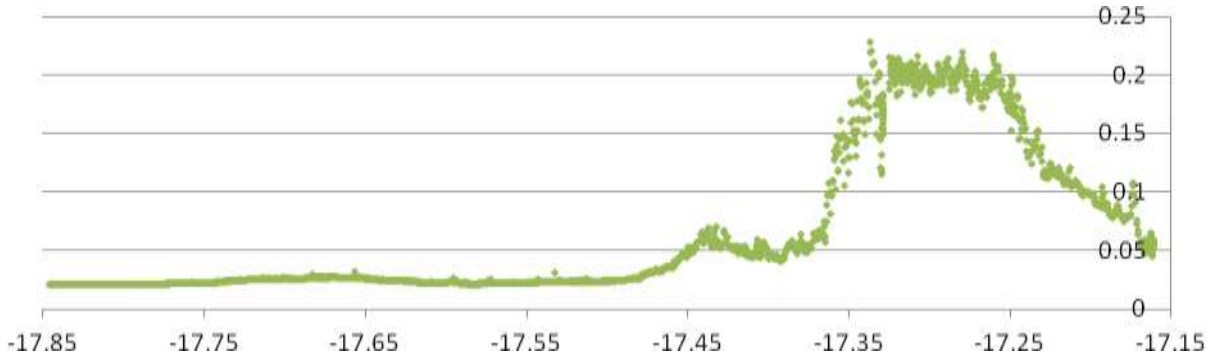


Figure xx. Horizontal and vertical distribution of anchovy eggs from Multinet stations

Figure xx. Size distribution of anchovy larvae caught in the Multinet.





Temperature, Salinity and fluorecence recorde from the thermosalinograph at 5 m depth during the transect imidiately south of Dakar.

1.12.2 Sardinella

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 22ºS, 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 ºC 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 21º30S and Tombua (Figure 13). The distribution indicated a slow northward transport except for the northernmost area.

1.12.3 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 Baia dos Tigros) 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.

1.13 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.

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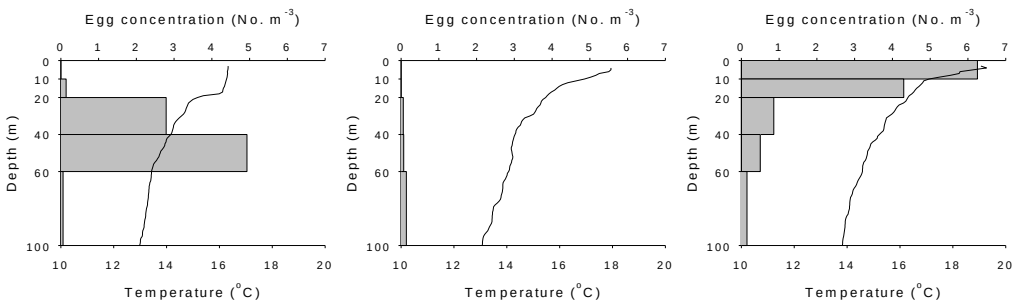

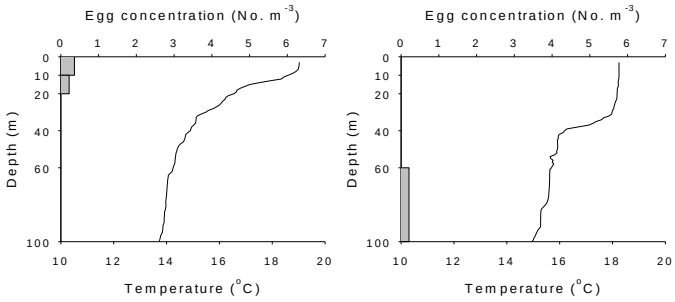

Figure 14. Vertical distribution of sardine eggs from Multinet stations and profiles of temperature.

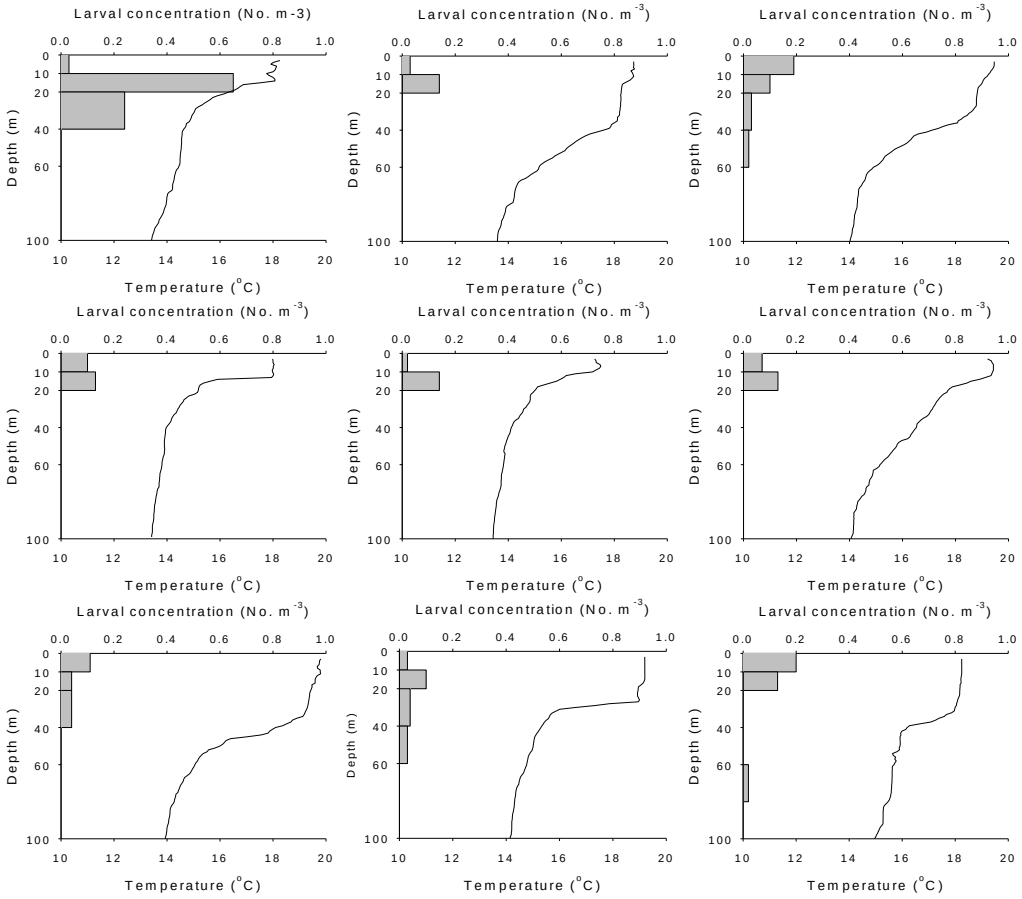

Figure 15. Vertical distribution of sardine larvae from Multinet stations during the first leg of the survey and profiles of temperature.