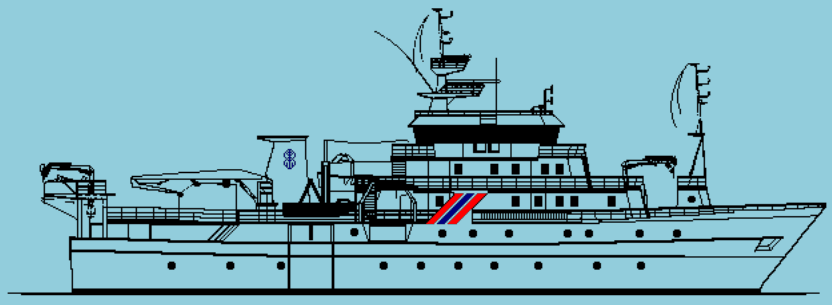

Recruitment studies on sardinella *Sardinella aurita* and *S. maderensis* in the coastal waters of Gabon, Congo and Northern Angola

24 MAY – 14 JUNE 2014

THE EAF-NANSEN PROJECT

FAO started the implementation of the project “Strengthening the Knowledge Base for and Implementing an Ecosystem Approach to Marine Fisheries in Developing Countries (EAF-Nansen GCP/INT/003/NOR)” in December 2006 with funding from the Norwegian Agency for Development Cooperation (Norad). The EAF-Nansen project is a follow-up to earlier projects/programmes in a partnership involving FAO, Norad and the Institute of Marine Research (IMR), Bergen, Norway on assessment and management of marine fishery resources in developing countries. The project works in partnership with governments and also GEF-supported Large Marine Ecosystem (LME) projects and other projects that have the potential to contribute to some components of the EAF-Nansen project.

The EAF-Nansen project offers an opportunity to coastal countries in sub-Saharan Africa, working in partnership with the project, to receive technical support from FAO for the development of national and regional frameworks for the implementation of Ecosystem Approach to Fisheries management and to acquire additional knowledge on their marine ecosystems for their use in planning and monitoring. The project contributes to building the capacity of national fisheries management administrations in ecological risk assessment methods to identify critical management issues and in the preparation, operationalization and tracking the progress of implementation of fisheries management plans consistent with the ecosystem approach to fisheries.

LE PROJET EAF-NANSEN

La FAO a initié la mise en oeuvre du projet "Renforcement de la base des connaissances pour mettre en oeuvre une approche écosystémique des pêcheries marines dans les pays en développement (EAF-Nansen GCP/INT/003/NOR)" en décembre 2006. Le projet est financé par de l'Agence norvégienne de coopération pour le développement (Norad). Le projet EAF-Nansen fait suite aux précédents projets/ programmes dans le cadre du partenariat entre la FAO, Norad et l'Institut de recherche marine (IMR) de Bergen en Norvège, sur l'évaluation et l’aménagement des ressources halieutiques dans les pays en développement. Le projet est mis en oeuvre en partenariat avec les gouvernements et en collaboration avec les projets grands écosystèmes marins (GEM) soutenus par le Fonds pour l’Environnement Mondial (FEM) et d'autres projets régionaux qui ont le potentiel de contribuer à certains éléments du projet EAF-Nansen.

Le projet EAF-Nansen offre l’opportunité aux pays côtiers de l'Afrique subsaharienne partenaires de recevoir un appui technique de la FAO pour le développement de cadres nationaux et régionaux visant une approche écosystémique de l’aménagement des pêches et la possibilité d'acquérir des connaissances complémentaires sur leurs écosystèmes marins. Ces éléments seront utilisés pour la planification et le suivi des pêcheries et de leurs écosystèmes. Le projet contribue à renforcer les capacités des administrations nationales responsables de l’aménagement des pêches en introduisant des méthodes d'évaluation des risques écologiques pour identifier les questions d’aménagement d’importance majeure ainsi que la préparation, la mise en oeuvre et le suivi des progrès de la mise en oeuvre de plans d’aménagement des ressources marines conformes à l'approche écosystémique des pêches.

Recruitment studies on sardinella *Sardinella aurita* and *S. maderensis* in the coastal waters of Gabon, Congo and Northern Angola

by

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CHAPTER 1 INTRODUCTION

Executive summary

The main stocks of the two pelagic species of sardinella (*S. maderensis* and *S. aurita*) are shared between Gabon, Congo and Angola, and investigations carried out by the EAF-Nansen project indicate for both stocks that more than 25% of the total abundance (especially juveniles and large adults) can be found off Congo-Gabon during certain periods of the year. The main part of the commercial sardinella fishery takes place in Angola, but the two species are important for the artisanal fleet in all three countries. Previous studies strongly indicate that one of the most important spawning and nursery areas for the *S. aurita* is located off Congo and Gabon south of Cape Lopez, but the mechanisms involved are poorly investigated. Proper management of the stocks need to take this into consideration. In this context it is important to be aware that this region also has very high oil related industrial activities. A large-scale spill of oil or other chemical substances during the recruitment/nursery period is assumed to have the potential of exercising strong detrimental impacts on these species.

Gabon
In Gabon, demersal species are exploited by industrial and artisanal fisheries. The artisanal fishery lands about half of the total fish production with mean annual production of around 25 000 tonnes, with 80 percent composed of demersal species. The annual production of the industrial fishery in 2008 was about 13 000–14 000 tonnes. Traditionally, gears such as purse seine and beach seine are distinguished from more individual gears such as gillnet, hand lines, long lines and cast nets.
Sardinella in Gabon are most abundant south of Cape Lopez and specifically off Mayoumba. The two species are caught by artisanal gears and do not constitute a directed fishery but a by-catch. The period with high abundances of these species corresponds with the time of arrival of cetaceans at the coast of Gabon (June to August), and surveys and available statistical data show that the species are uncommon during the rest of the year. Sardinella is not very popular on the local market and local fishermen normally only target these species for consumption by their own families. Industrial fisheries on sardinella are non-intentional and represent only 0.05% of the annual catch. No Gabonese fishing vessels have specialized in capturing sardinella, and the catches in the artisanal and industrial fishing together have according to statistics ranged between only 10 - 40 tonnes in recent years.

Congo
Small pelagic fish species are caught in Congo by the artisanal fleet, that take a significant proportion of the catch and, secondly, by a flotilla of small sardinella purse seiners located in

Pointe-Noire whose activity has changed slightly in recent years along with the arrival of the Chinese. The artisanal fishing is practiced by two communities: the national fishermen, generally ethnic Vili catching Bonga and juveniles of sardines and anchovies, and migrant fishermen mostly from Benin, the Popo, which mainly target sardinella. The Vili use quite small dugout canoes (6 m long) while the Popo use significantly larger dugout canoes (over 12 m), all with outboard motor. There are currently about 689 canoes fishing in Congo, of which 240 are of Popo and 449 of Vili type.
Currently, five different gears are used to catch the small pelagics: sardinella gill net (*S. maderensis*), gillnet for round sardinella (*S. aurita*), gillnet for Bonga (*Ethmalosa fimbriata*), beach seine and the plateau net for harvesting of juvenile sardinella and anchovies (*Engraulis encrasicolus*). The commercial sardinella fishery started in Pointe-Noire in 1956 with a single ship. The fleet consists of small seiners 16-24 m, poorly equipped and in a generally bad state of repair. The fish is kept in chilled ice water. Currently, there are nine sardinella vessels whose activity is periodic for the Chinese and permanent for local ship-owners.

Angola

The *S.aurita* and *S. maderensis* are widely distributed along the Angolan coast from Congo River to Kunene river (6º -17ºS). *S. aurita* is typically found offshore on the shelf whereas *S. maderensis* is more coastal.
Angola has by far the largest fishing sector of the three countries with a combination of large trawlers, purse seiners and small scale artisanal boats and canoes. The main catch of sardinella is performed with purse seines by a mostly semi-industrial and artisanal fleet. Generally about 90 vessels are licensed every year, and the declared catches range from 40,000 to 80,000 tons. However, a major under-reporting of data by the vessel owners is assumed.
The estimated biomass off Angola shows a cyclic fluctuating pattern from acoustic abundance surveys with the Dr. Fridtjof Nansen. This is commonly found for pelagic species, usually reflecting actual changes in abundance, often caused by changes in the environmental conditions. However, this may also be due to the surveyed populations at times being located partly outside of the survey region, for instance in areas too shallow to be surveyed. The estimated biomass has for several years, until 2012, been above 500,000 tonnes during the warm season. More recently the estimates have declined and are now about 350 000 tonnes. Of this a typical distribution of the sardinella resources is 20% in the north, 50% in the central region, and 30% in the south. The TAC (total allowable catches) assigned to these species (2008-2013) has been above 250,000 tons per year.

During this survey with the R/V Dr. Fridtjof Nansen we carried out recruitment studies on sardinella in the coastal waters of Gabon, Congo and Northern Angola. The study aimed at identifying the distribution area of sardinella eggs and larvae, to identify and describe the

oceanographic features affecting their distribution, and if possible to explain the retention and distribution mechanisms for eggs and larvae within the survey area.

The main hypothesis at the end of the survey for the spawning dynamics of *S. aurita* is that the identified spawning area north of Cabinda must be the most important in the region. Here the *S. aurita* spawn in shallow water in the eddy system caused by the northward flow of the Congo River, in fact, in the Congo River plume itself. Most probably just below the pycnocline. The hatched larva are drifting in the main current and transported northwards while they feed and grow in the nutrient-rich water masses within the current with high phytoplankton production. It is known from other surveys that large concentrations of juvenile *S. aurita* are found together with adult fish close to the coast off southern Gabon in what has been known as a favourable nursery area for sardinella. It is therefore expected (but not yet observed) that the older larvae take advantage of the undercurrent or coastal moving eddies to become transported towards the coast further north.

With respect to the spawning of *S. maderensis*, data are much sketchier and no clear spawning areas have been identified with confidence. Still, indirect data available among others from this survey (distribution of ready-to-spawn adult fish in combination with Sardinella sp. Larvae in the same area) indicate that the distribution of larvae of this species is considerably closer to the coast than our observations of *S. aurita*.

General objectives

This aim of the survey was to identify the distributions of sardinella eggs and larvae within the region between Cape Lopez in Gabon and Luanda in Angola. The horizontal and vertical distributions of the eggs and larvae were mapped, and related to mapping of water mass circulation and frontal boundaries.

Specific objectives of the survey

1. Identify the distributions of sardinella (*Sardinella aurita* and *S. maderensis*) eggs and larvae in the survey area
2. Identify oceanographic features affecting their distribution
3. If possible, explain the retention and distribution mechanisms for eggs and larvae in the survey area

Participation

The scientific members during the cruise were:

From Institute of Marine Research Norway:

Jens-Otto Krakstad (cruise leader),Tore Mørk, Inge Nymark, Espen Bagøien, Njård Gudbrandsen (to 6th June) and Tor Ensrud

From INIP, Angola:

Ivania Castro and Antonio Miguel Andre

From Direction Generale de Peche et de la Aquaculture, Gabon

Jean de Dieu Lewembe, Jean Daniel Mbega and Davy Angueko

From Direction Generale de Peche et de la Aquaculture, Congo

Claude Benoit Atsango, Jean Samba, Tite Romuald Akenze and Richard Ntse

Narrative

The vessel left Port Gentil on the 24/5 at 18:30 hours and steamed south to the start of the area of investigation immediately south of the restricted area off Cape Lopez. Transects spaced 15 NM apart were carried out from 20 m bottom-depth at the coast to 200 m bottom depth offshore occasionally extended into deeper water to map oceanographic features or check for offshore eggs and larvae. Sampling stations along the transects were spaced 10 NM apart, and on each of these stations sampling consisted of one CTD, one WP2 net to max 200 m depth, one WP2 net to 25 m depth, one phytoplankton net to 25 m and one Multinet for sampling of egg and larvae to 75 m depth. Acoustic registrations were made en route with targeted trawling on registrations to identify acoustic targets. Dedicated oceanographic transects were carried out on every forth transect (every 1° latitude) with CTD stations from 1000 m bottom-depth to the coast.

Few eggs and larvae of the target species were found in the northernmost part of the survey area. On the 29/5 at station 497 off Pte. Panga smaller concentrations of sardinella larvae were found at the outer shelf ~80 m bottom depth. At the same time we started to register adult *sardinella aurita* and *S. maderensis* on the echosounder, verified by trawl catches. This presence of larvae continued on the next transect and into Congo with increasing concentrations southwards. At station 510 at the southernmost transect in Gabon we encountered high concentrations of sardinella eggs. On the following transect in Congo it was decided to continue offshore until the concentration of larvae decreased towards nil to find the outer border of the distribution. It was also decided to repeat the last transect in Gabon using all 5 nets of the Multinet to investigate the vertical distribution of these larvae (75-40 m, 40-30 m, 30-20 m, 20-10 m, and 10 m - surface). After this transect the vessel continued with the remaining transects in Congo using only one net of the Multinet before breaking off on the 3/6 in the morning to go to Port Gentil and prepare the crew change. Immigration problems caused the crew change to take considerably more time than anticipated, and the vessel only continued the survey on the 5/6 in the afternoon. Since we ended in an area with very high

concentrations of eggs and larvae before the cruise-break, it was decided to resurvey the last transect before continuing southwards. On the 6/6 the vessel crossed into Cabinda and we managed to include two sampling transects in-between the oil platforms before moving south of the Congo River on the 7/6. The sampling continued with regular intensity in Angola, covering the whole northern region and parts of the central region until the afternoon of the 13/6, when we broke off at Cabo Sao Braz (-10°S) and returned to Luanda. During the survey south of Congo River, adult sardinella were regularly found in low densities inshore, but larvae concentrations were generally very low and no eggs were encountered.

Survey effort

The survey effort per region is given in Table 1.1 while cruise tracks with bottom trawls, pelagic trawls, and hydrographic stations are shown in Figures 1.1 and 1.2.

Table 1.1 Number of hydrographic (CTD) plankton (PL) pelagic trawl (PT) and bottom trawl (BT) and benthos sampling stations as well as the distance covered (NM) during the survey by sub-areas.

Regions:	Gabon	Congo	Angola
BT Station:	1	0	2
PT Station:	4	4	8
CTD Station:	79	43	81
Plankton hauls*:	225	137	253

*Total number of different nets. Most stations had a combination of 3 nets

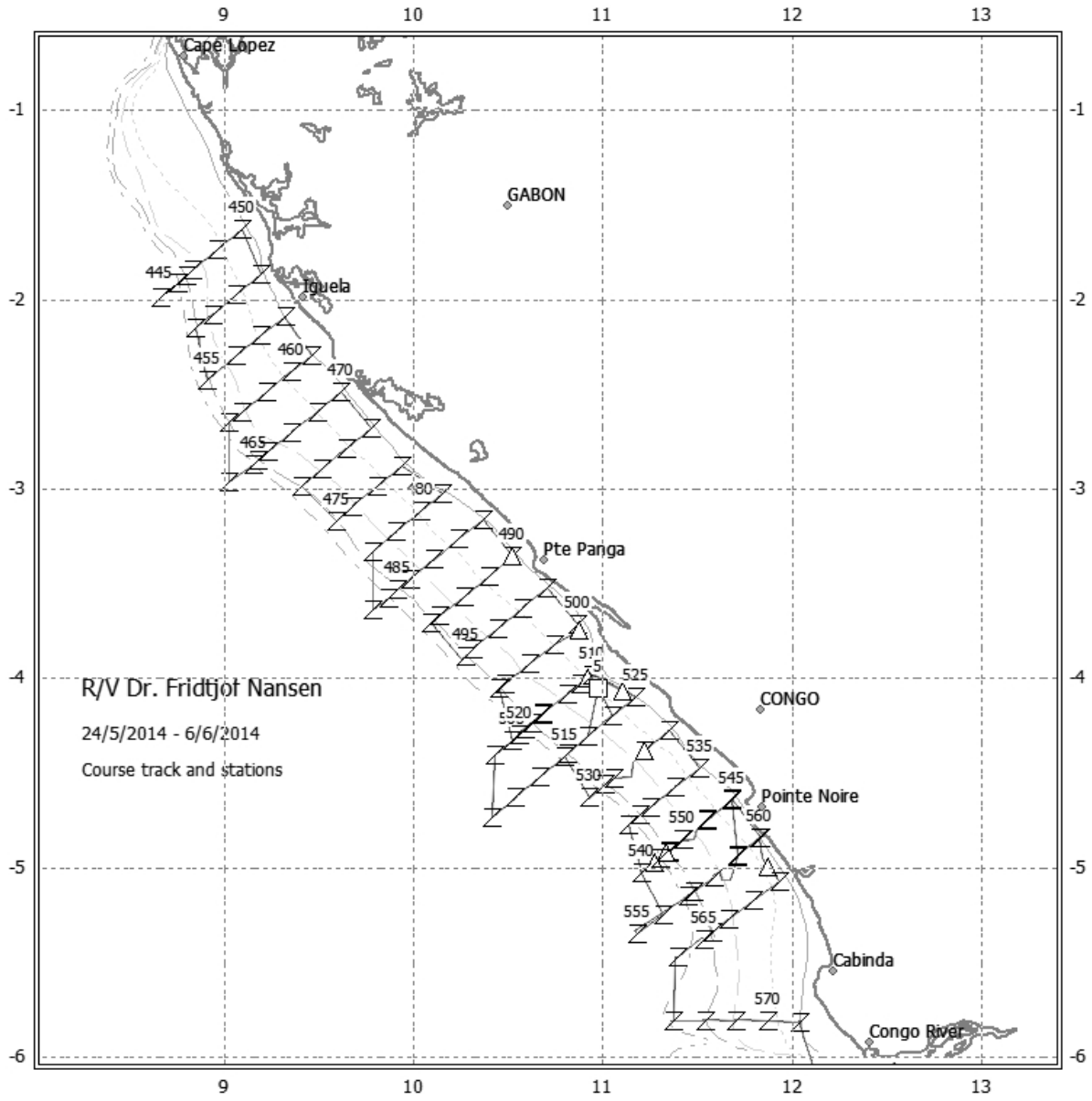


Figure 1.1. Course track Gabon-Congo. Demersal (□) and pelagic (Δ) trawl stations and hydrographic (Z) stations. Plankton was generally sampled on every hydrographic station. Depth contours are indicated.

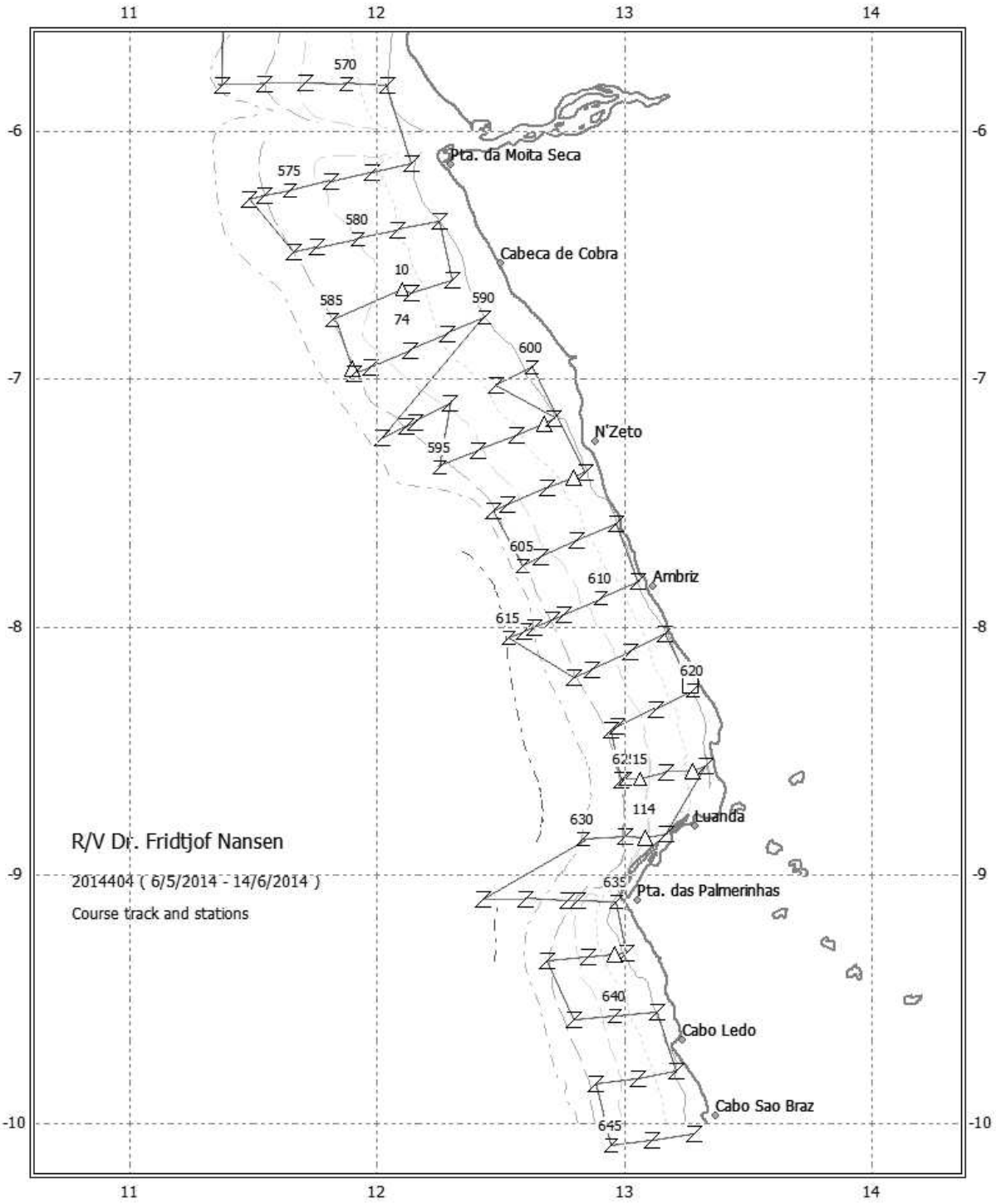


Figure 1.2. Course track Angola. Demersal (□) and pelagic (Δ) trawl stations and hydrographic (Z) stations. Plankton was generally sampled on every hydrographic station. Depth contours are indicated.

CHAPTER 2 METHODS

Meteorological observations

Wind direction and speed, air temperature, air pressure, relative humidity, and sea surface temperature (5 m depth) were logged automatically every 60 second with a DNMI weather station.

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 SBE 43 oxygen sensor. Real time logging and plotting was made 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 (12 units á 10 liters) attached to a CTD-mounted rosette were used to collect seawater at predefined depths (see below). For validation of the salinity (conductivity) measurements of the CTD, the salinity of seawater collected by Niskin-bottles at various depths was analyzed using a Portasal salinometer (mod. 8410A) onboard the vessel. The results could be confirmed to the first decimal on most depths. The average deviation compared to the Portasal salinometer was 0.03 ‰ (0.01 ‰ if the 5 m sample is let out) The CTD was not stopped in the water column prior to closing the Niskin bottles, so no special effort was made to stabilize neither the salinity nor the oxygen. The result of the test is listed in Table 2.1 and Figure 2.2. To validate the oxygen-measurements from the CTD-mounted sensor, concentrations of dissolved oxygen in the seawater-samples collected with the Niskin-bottles were analyzed in the ship laboratory. Twelve samples from CTD station 539 were analysed. The depth range was 5- 500 m and the average offset on the Oxygen sensor was -1,68% when compared to winkler. The results of the test are listed in Table 2.1 and Figure 2.1. The analyses were made according to the Winkler redox titration method, following the procedures of Hagebø (2008).

Also attached to the CTD was an uncalibrated Chelsea Mk III Aquatracka fluorometer which measures *in situ* fluorescence on relative scale. Unfortunately, after reaching Point Noire this fluorometer no longer functioned due to problems with the power supply. Hence, fluorescence measurements could not be made with this instrument for the region further south.

Table 2.1 Oxygen from winkler and CTD, salinity from Portasal and CTD

			Oxygen				Salinity			
Station	Bottle	Depth	WINKLER	Ctd	Dev	% Dev	Portasal	CTD	Dev	% Dev
539	10	501,36	2.165	2.171	0.006	0.27	34.671	34.6789	-0.008	-0.02
	12	400,22	1.656	1.637	-0.019	-1.12	34.751	34.7633	-0.012	-0.04
	14	299,79	0.767	0.715	-0.053	-6.85	34.995	34.9809	0.014	0.04
	15	201,47	1.503	1.460	-0.043	-2.86	35.611	35.5402	0.071	0.20
	37	148,81	1.733	1.673	-0.060	-3.46	35.595	35.692	-0.097	-0.27
	38	100,34	2.412	2.368	-0.045	-1.85	35.849	35.8537	-0.005	-0.01
	39	75,35	3.055	2.973	-0.082	-2.69	35.989	35.965	0.024	0.07
	40	49,58	3.161	3.096	-0.065	-2.04	36.026	36.0468	-0.021	-0.06
	41	30,66	3.462	3.390	-0.072	-2.08	36.12	36.0552	0.065	0.18
	42	20,38	3.588	3.512	-0.076	-2.12	36.074	36.0157	0.058	0.16
	43	10,77	3.708	3.785	0.077	2.08	36.007	35.9332	0.074	0.21
	4	5,20	4.006	4.107	0.100	2.50	35.989	35.7554	0.234	0.65

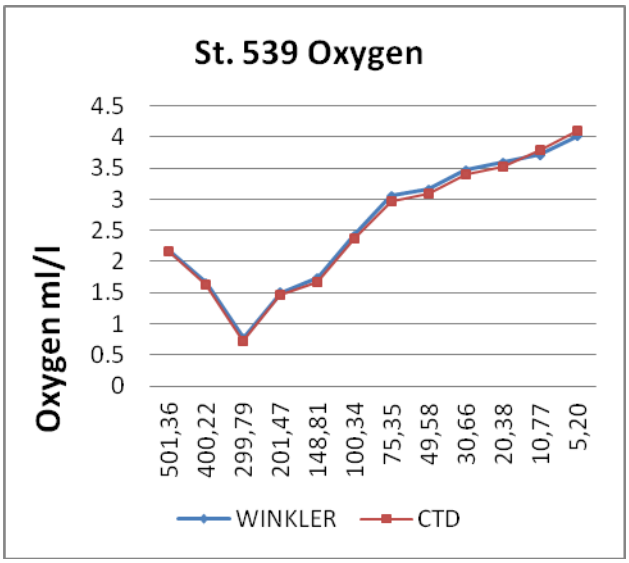


Figure 2.1 Oxygen from winkler and CTD

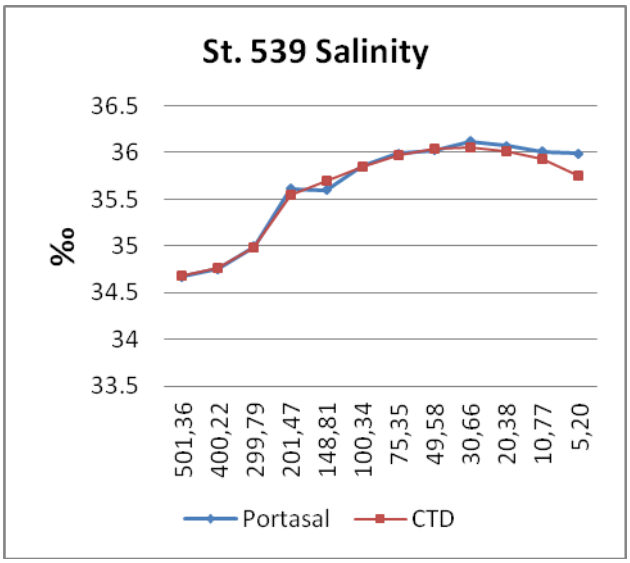


Figure 2.2 Salinity from portasal and CTD

Thermosalinograph

The SBE 21 Seacat thermosalinograph was running continuously during the survey, measuring sea surface salinity along with relative temperature (5 m depth) every 10 seconds. An attached in-line factory-calibrated Turner designs C3 measured *in situ* levels of chlorophyll *a* -and turbidity.

Current speed and direction measurements (ADCP)

A hull-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.

Chlorophyll

Chlorophyll *a* is a plant pigment, which in oceanography typically is used as an indirect measure for phytoplankton biomass. Seawater samples for analysis of chlorophyll *a* and phaeopigment concentrations were taken at the plankton stations. The samples were collected at predefined depths from rosette-mounted Niskin bottles attached to the CTD. Surface-samples from a manually lowered bucket were also collected. Seawater samples (263 ml) were collected from the standardized depths 5, 10, 20, 30, 50, 75, 100, 150, 200, 300, 400 and 500 m, with bottom-depth restricting the number of samples collected from a given station. The seawater samples were filtered on Munktell glass-fibre filters (GF/C, 25 mm diameter) using a custom-made filtration system. During the cruise, the filter-samples were stored at ~ -18°C in the dark for subsequent analysis on shore. After the cruise, the pigment samples were transported to the laboratory in a cooling-box with ice during which the pigment-samples were held dark. The ice was shifted once during the transport. Note that the sample-temperature must be assumed to have increased during the transportation to the lab, although the ice was not melted when the samples were received at their destination. The chlorophyll samples were analysed in the IMR laboratory in Norway within 30. Sep 2014. The pigments were extracted with 90% acetone in darkness over night, and the extracts centrifuged and analysed using a Turner Design fluorometer model 10 AU calibrated with pure chlorophyll *a* (Sigma Inc) (Jeffrey and Humphrey, 1975). Fluorescence was measured before and after acidification by a drop of 5% HCl, and concentrations of chlorophyll *a* and phaeorbides estimated according to Holm-Hansen *et al*. (1965). As part of the post-analysis quality control, the within-station depth profiles for chlorophyll as well as the chlorophyll/phaeophytin ratios were evaluated. This revealed some values that were believed to be incorrect, and for that reason were excluded from the dataset here presented.

Phytoplankton sampling

At each plankton-station, qualitative phytoplankton samples were collected with a net (35 cm in diameter and mesh-size of 10 μm), hauled vertically at a speed of ca. 0.1 ms^{-1} from the depth of 25m to the surface. The samples were preserved with 2 ml 20% formalin on dark 100 ml glass bottles to allow for subsequent taxonomic analyses on shore.

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 of 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 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 hauls were made oblique, and the typical towing speed of the net was about 1.4 ± 0.2 m s^{-1} (average ± standard deviation).

For the large-scale survey, only the first net of the Multinet was used, covering almost the entire water-column in areas with bottom-depths less than 75 m, and ranging from 75 m to the surface in deeper areas.

For process studies in selected target areas, up to 5 nets were used to obtain vertically stratified plankton-samples. The number of nets employed at any given station depended on the bottom depth. The following standardized sampling-depths were used: 75-40, 40-30, 30-20, 20-10, and 10-0 m.

Once the Multinet was back onboard after a haul, the depth-stratified samples represented by each net were collected. First, all fish larvae visible with “the naked eye” were removed from the total sample, and transferred onto Petri-dishes where they were examined under stereomicroscope. Larvae of the species *Sardinella spp.* were identified using the key of Olivar and Fortuño (1991), and their standard lengths measured. In most cases the individuals were also photographed for documentation purposes. The fish larvae of these two species were then preserved in 96 % ethanol and/or 4% borax buffered formaldehyde. Likewise, fish larvae belonging to other species were also preserved with ethanol or formaldehyde.

When all the visible fish larvae had been removed from the Multinet sample, a known fraction of the remaining sample that permitted the enumeration of eggs was examined under stereomicroscope. The fractionating of the sample was made by use of a Motoda plankton splitter (Motoda 1959). The principle of this procedure is to split a homogenised sample into two “equal” parts, which again can be split further depending on the sample size. Fish eggs were sought identified and counted, along with any small fish larvae that were overlooked in

the initial scan based on the “naked eye” (see above). Moreover, the egg diameters, their embryos as well as the lipid globules were measured. Note that larvae and eggs belonging to the two *Sardinella* species were not separated but grouped together as an entity.

At all plankton-stations during the large-scale survey, the WP2 plankton-net (56 cm in diameter, mesh-size 180 µm) (Fraser 1966, Anonymous 1968) was applied to sample mesozooplankton. Two hauls were made with the WP2 net at each station. The first, from 200 m (or near the bottom in shallower areas) to the surface, and the second from 25 m to the surface. All WP2-hauls were made vertically with a velocity of ~ 0.5 m s^{-1}. Once a sample was on deck, it was split into two equal parts by use of the Motoda plankton-splitter (Motoda 1959). One half was preserved with borax-buffered formalin resulting in a 4% final concentration to allow for subsequent taxonomic identification of zooplankton on shore. The other half of the sample – unpreserved - was sequentially sieved through three filters to obtain the zooplankton biomass representing the size-fractions >2000 µm, 2000-1000 µm, and 1000-180 µm. All visible jellyfish (or remains of such) were removed from the samples and their volume measured before size-fractioning. The biomass samples were stored on pre-weighed 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 biomass samples were thereafter kept frozen at -18°C for subsequent weighing of dry-weight (following a second drying period) in the laboratory of IMR (Norway). During the weighing process, samples with some degree of greenish colour that indicates inclusion of plant residue – phytoplankton or from other potential sources – were identified and noted. When all zooplankton biomass data thereafter were processed, the results for a few samples were excluded from the dataset presented in this report due to possible confounding of tray numbers used for the biomass samples.

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 (sardinella) 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. Length, weight, sex, gonad stage and gonad weight were collected from the first randomly selected 30 individuals of target species. Maturity stages were classified according to the scale given in Annex III.

Single beam acoustic sampling

Acoustic equipment

Acoustic data were recorded using a Simrad ER60 scientific echo sounder equipped with keel-mounted transducers at nominal operating frequencies of 18, 38, 120 and 200 kHz. All transceivers were calibrated close to Kyun Phi Lar, in the southern part of Myanmar on the 14th of December 2013 and again in June 2014 during the pelagic survey of Angola (following this). No major deviation was detected between these calibrations.

The technical specifications and operational settings of the echo sounder used during the survey are given in Annex V.

Allocation of acoustic energy to species group

The acoustic data were scrutinized using the LSSS version 1.6.1. Back scatters were displayed at 38 kHz. The mean 5 nautical miles (NM) area backscattering coefficient s_A (m^2/NM^2) was allocated to a predefined set of species groups on the basis of established echogram features. Ground truthing and estimation of mean length and weight were accomplished by means of targeted pelagic and demersal trawling. The complete records of fishing stations and catches are shown in Annex I while the target groups used during the survey for acoustic classification can be found in Annex IV.

The following target strength (TS) function was applied to convert s_A-values (mean integrator value for a given area) to number of fish by category:

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

or in the form

$$C_F = 1.26 \cdot 10^6 \cdot L^{-2} \quad (2)$$

where L is the total length and C_F is the reciprocal back scattering strength or the so-called fish conversion factor. Generally in order to split and convert the allocated s_A-values (m^2/NM^2) to fish densities (number per length group per NM^2) the following formula was used

$$N_i = A \cdot s_A \cdot \frac{p_i}{\sum_{i=1}^{n} \frac{p_i}{C_{Fi}}} \quad (3)$$

where: N_i = number of fish in length group i
A = area (NM^2) of fish concentration
s_A = mean integrator value (echo density) in area A (m^2/NM^2)
p_i = proportion of fish in length group i in samples from the area
C_{Fi} = fish conversion factor for length group i

Further the traditional method is to sum the number per length group (N_i) to obtain the total number of fish:

$$N = \sum_{i=1}^{n} N_i \quad (4)$$

The length distribution of a given species within an area is computed by simple addition of the length frequencies obtained in the pelagic trawl samples within the area. In the case of co-occurrence of target species the s_A value is split in accordance with length distribution and catch rate in numbers in the trawl catches. Biomass per length group (B_i) is estimated by applying measured weights by length (W_i) when available or theoretical weights (calculated by using condition factors) multiplied with number of fish in the same length group (N_i). The total biomass in each area is obtained by summing the biomass of each length group:

$$B = \sum_{i=1}^{n} N_i \overline{W}_i \qquad (5)$$

The number and biomass per length group in each concentration are then added to obtain totals for each region.

However the combination of low s_A value recorded few PEL1 and PEL2 in the bottom trawl catch and few pelagic trawls made the splitting by length groups unreliable. Therefore a theoretic mean length of 23 cm was used to convert the s_A values by stratum (Equation 3) to number of fish. Equation 5 was used to convert the number of fish in the defined average length class (23 cm) to total estimated biomasses of PEL1 and PEL2.

A description of the fishing gears used acoustic instruments and their standard settings is given in Annex V.

CHAPTER 3 OCEANOGRAPHIC CONDITIONS

Horizontal distribution

Horizontal distribution of sea surface temperature (SST), sea surface salinity (SSS), sea surface chlorophyll and turbidity was derived from the vessel thermosalinograph 5 m below sea surface. The maps are separated in two regions, Southern Gabon and Congo to Cabinda, and Congo River to Luanda. The temperature data from the thermosalinograph gives slightly higher values than real data due to a heating in the vessel pipes systems. However, the large number of data points (>100 000 recordings) from this instrument (compared with CTD data) makes it interesting to show the data due to the higher dynamics that can be observed.

The most prominent feature affecting surface distribution of water masses in the Gabon-Congo region during this part of the year is the Congo River, which has a northward direction typically following the shelf margin until it deflects from the coast around Cape Lopez. The surface plots (Figure 3.1) derived from the thermosalinograph data show very strong dynamics in the Congo-Gabon region. Temperature ranged between 22.3-28.5°C, being lowest in the southern part of Congo and towards Congo River. Relatively cooler waters were also observed inshore in southern Gabon. Salinity ranged between 37 and ~24 although even lower values were observed in the vicinity of the Congo River mouth. The highest salinity was recorded off Gabon, while a very high variability was observed south of 4°S due to the effect of the Congo River. Chlorophyll concentrations recorded by the sensor mounted on the thermosalinograph ranged between 1.36 to 0.04 µg/l. Off Gabon, the highest concentrations were found along the coast in a small band while further south, off Congo, the situation was more dynamic and highest chlorophyll concentrations were found in a band from the coast and offshore around 5 °S, with high concentrations offshore also further north (4°-4°30’S). Turbidity (typical range 0.04-0.4 NTU Nephelometric Turbidity Units) showed a very regular pattern with increasing concentrations southwards towards Congo River.

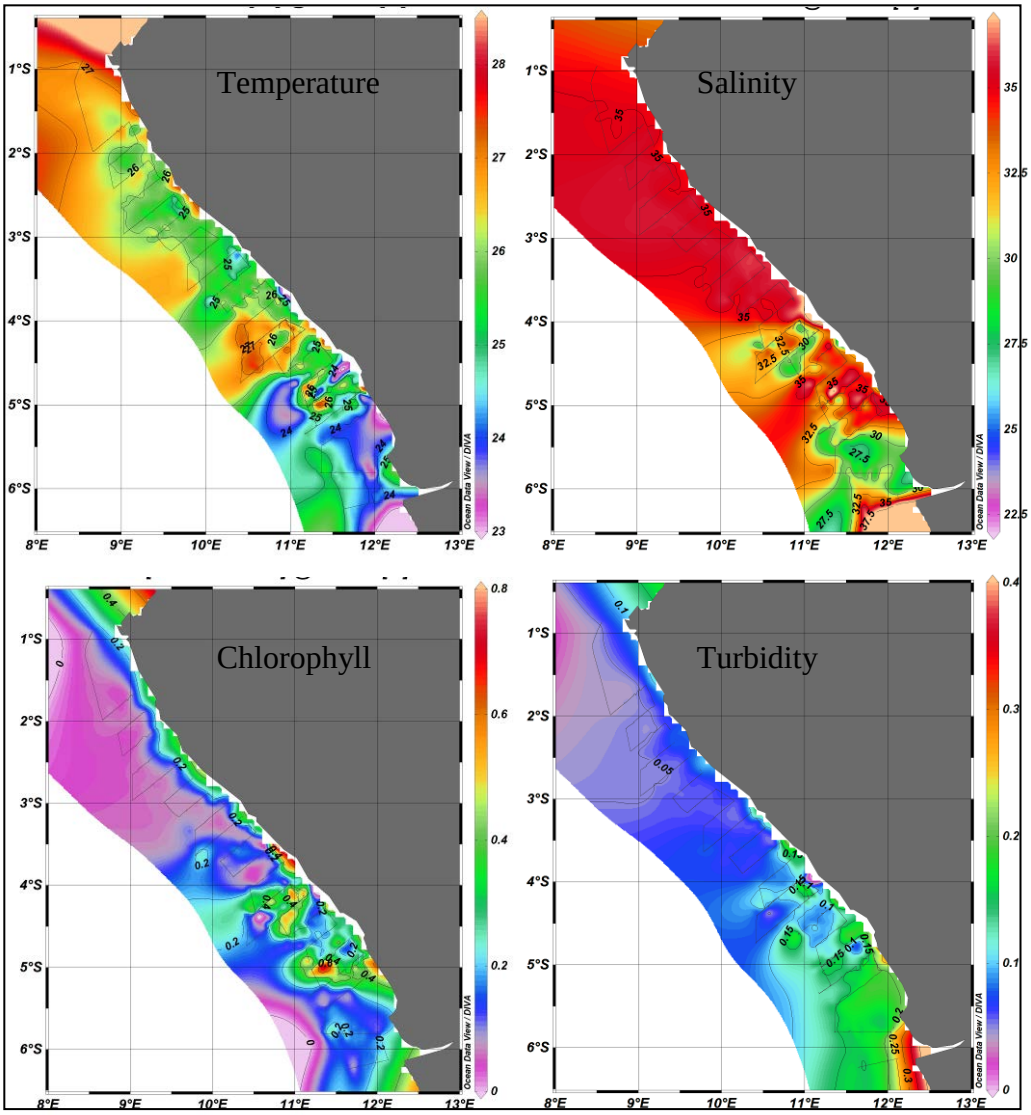


Figure 3.1 Sea surface distributions of temperature, salinity, chlorophyll and turbidity recorded by the thermosalinograph in Gabon - Congo.

South of Congo River (Figure 3.2) sea surface temperatures ranged between 21.3-26.6°C and were generally stable across large parts of the region. The highest temperatures were observed offshore while the lowest temperatures were observed inshore especially in the region off Luanda. SSS ranged between 25.9 and 36.9. Low recordings and a strong boundary was observed in the border region to the Congo River. The rest of the region had relatively stable salinity values with decreasing salinity southwards with the exception of the region off Luanda where higher salinity corresponded with lower water temperature. The chlorophyll concentrations ranged between 0.04 and 0.46 µg/l and were typically much lower than in the region further north. Slightly elevated values were found in the region around Ambriz and off Luanda. The turbidity (range between 0.13-0.37 NTU, Nephelometric Turbidity Units)

showed low levels across the whole region with the exception of the northern border to the Congo River and inshore close to the coast from 9°S and further south.

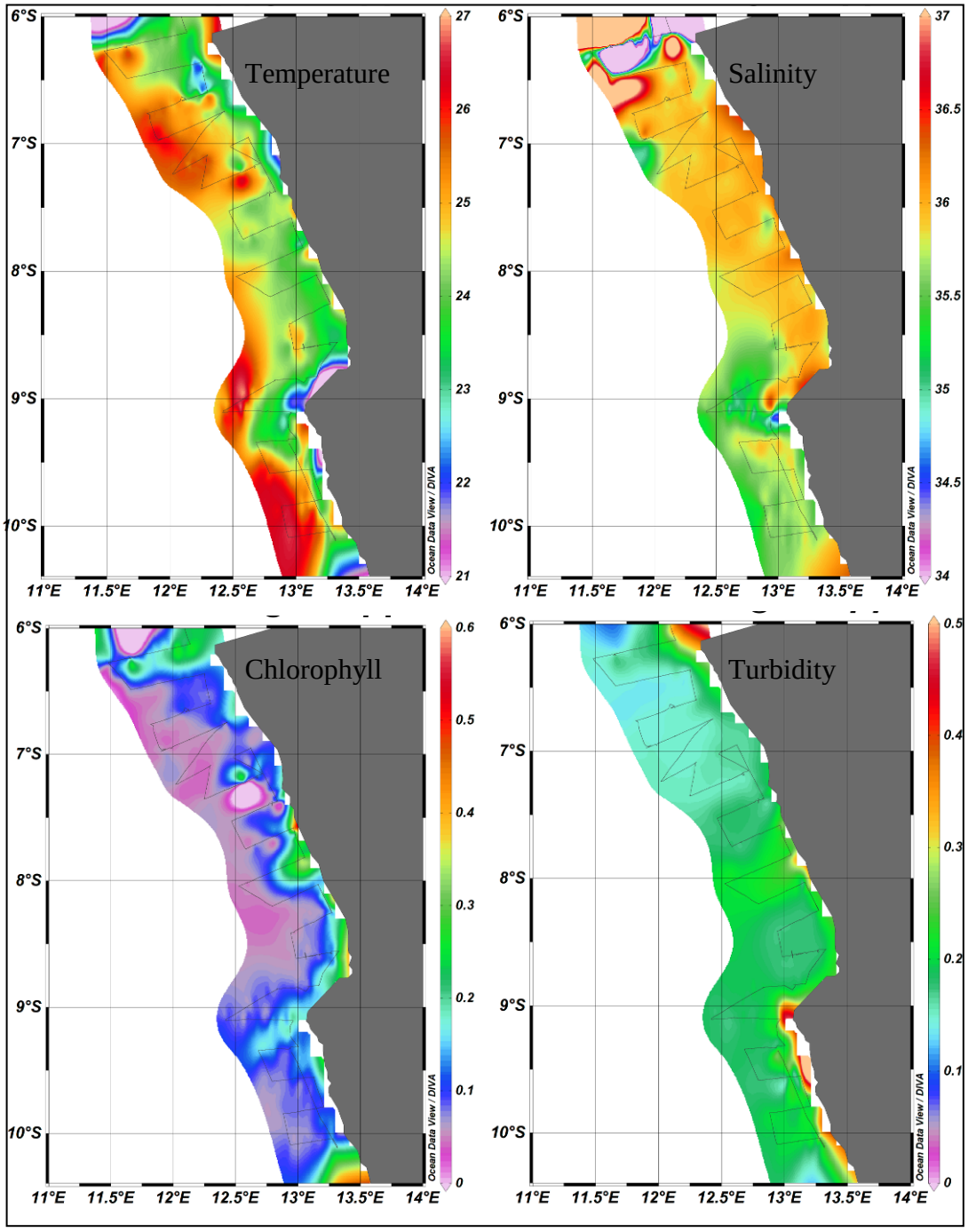


Figure 3.2 Sea surface distributions of temperature, salinity, chlorophyll and turbidity recorded by the thermosalinograph in Angola from Congo River. Note different z scale than in Figure 3.1

Vertical distribution

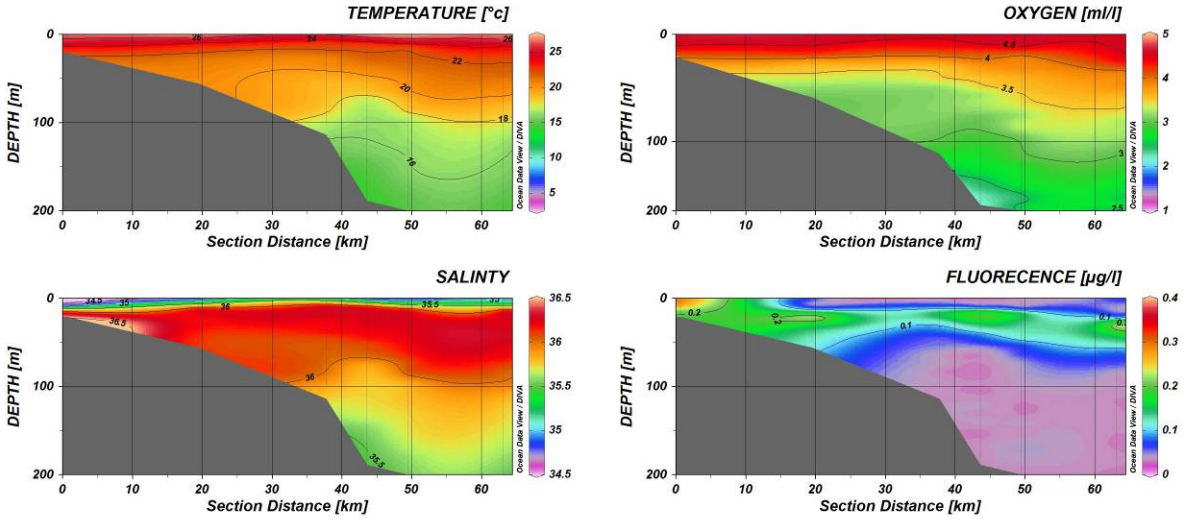
Vertical distributions of temperature, salinity, oxygen and fluorescence are described from environmental transects conducted from the coast at bottom-depths of 20 m to 1000 m bottom depth offshore separated by 1° Latitude (Figure 3.3). CTD casts were made from the surface to approximately 5 m from the bottom. The plots depict the distribution of the environmental parameters in the upper 200 m as this depth region is the most important for this study. Technical problems with the power supply of the CTD-attached fluorometer that arose outside Point Noire prevented measurements with this instrument for the rest of the survey. Note, however, that chlorophyll samples for laboratory analysis were collected from the CTD water-bottles during the entire cruise (presented in a separate chapter below).

Between Olindè and Iguèla temperature in the surface layers were >26°C and relatively stable across shelf with well mixed conditions in the upper 25 m. The salinity plot shows a thin layer of lower salinity water at the surface (<34.5), slightly deeper in the coastal zone and overlaying relatively high salinity waters of 36.5, and a strong salinity gradient in the upper 10 m. Salinity was otherwise very stable in the upper 100 m, decreasing slightly in deeper waters. Oxygen levels were high at the surface, decreasing towards deeper waters, reaching 2.5 ml/l at 200 m depth. The fluorescence maximum was found inshore in the surface layer corresponding to the most pronounced salinity gradient. Further offshore the fluorescence maximum was found at around 50 m depth. At the next environmental transect off Sette Cama, the observations are similar to further north, although the high salinity subsurface water masses were lifting and reached the surface at the innermost part of the shelf, with even higher fluorescence concentrations in this area compared to further north.
At the third oceanographic transect north of Pte. Panga, surface temperatures had decreased to around 24-25°C and there is an indication of a lifting of the thermocline at the shelf break. This is also visible in the salinity profile. The oxygen profile shows well oxygenated surface waters and a more rapidly declining oxygen profile offshore compared with further north. An oxygen minimum of ~1.0 ml/l can be found at 260 m depth (not shown). Fluorescence levels were high in the upper 50 m with maximums inshore at the surface and an offshore sub-surface at around 25 m depth (both levels around 0.3) separated with an area of *lower fluorescence* on the central shelf.
North of Point Noire along the forth oceanographic transect, much less saline water masses were present across shelf compared with further north, the lowest salinity in the surface waters were found on the shelf break (salinity ~28) with increasing salinities both inshore and offshore. This layer was about 10-15 m thick, overlaying water masses with salinities >36.5 forming a very strong salinity gradient separating water masses with very different densities. The other striking features along this transect is the high oxygen content in the surface waters on the shelf and the corresponding very high fluorescence levels with a maximum in the

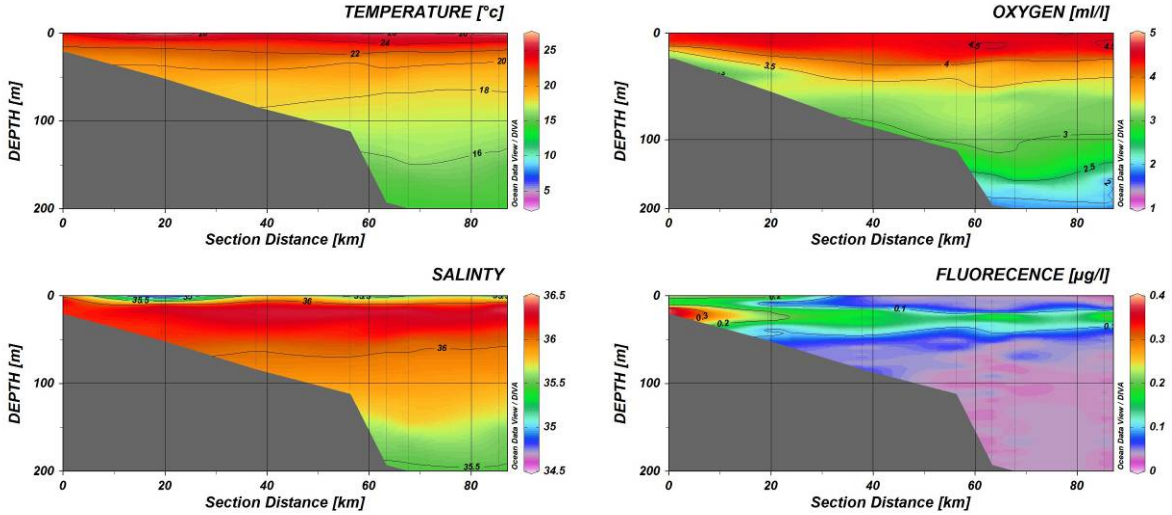
surface around 0.7 over the mid-shelf (both values outside figure scale), and another peak around 30-40 m depth close to the coast indicating very high primary production.
The fifth transect in Congo, immediately north of the border to Cabinda does not show fluorescence due to the faulty sensor. The section shows the high salinity water masses coming to the surface inshore along the coast with corresponding reduction in temperature. This must probably be described as a localised current driven upwelling caused by the strong Congo River flow, and is relatively permanent this time of the year. Offshore from about the shelf break there is still a strong separation between the high and low salinity water masses and increasing depth of the low salinity surface layer originating from the Congo River.

In Angola four cross shelf transects were carried out during the survey. These were at Congo River, N'Zeto, Ambriz and Pta. Das Palmerinhas. At the Congo River transect surface water masses were influenced by the low salinity waters from the river and the strong pycnocline separating this from the relatively high salinity water masses below. These sub surface water masses reached the surface inshore. Surface temperatures were generally around 23-24°C decreasing to 14°C at 200 m depth. Oxygen concentrations were around 4.5-4.1 ml/l in the surface, decreasing to 1.3 ml/l at 200 m depth. Further south at N'Zeto and Ambriz the effect of Congo River is not observed. Water masses were typically very stable with warm, saline and well-oxygenated surface waters, a pycnocline at around 25 m depth, and gradually declining parameters at deeper depths. The conditions at Pta. Das Palmerinhas were similar to that further north, but with the notable exception of lower surface salinity values overlaying higher values (10-25 m depth) and cooler SST inshore compared to further north. Oxygen concentrations were generally high in the surface, declining to <1 ml/l at 200 m depth.

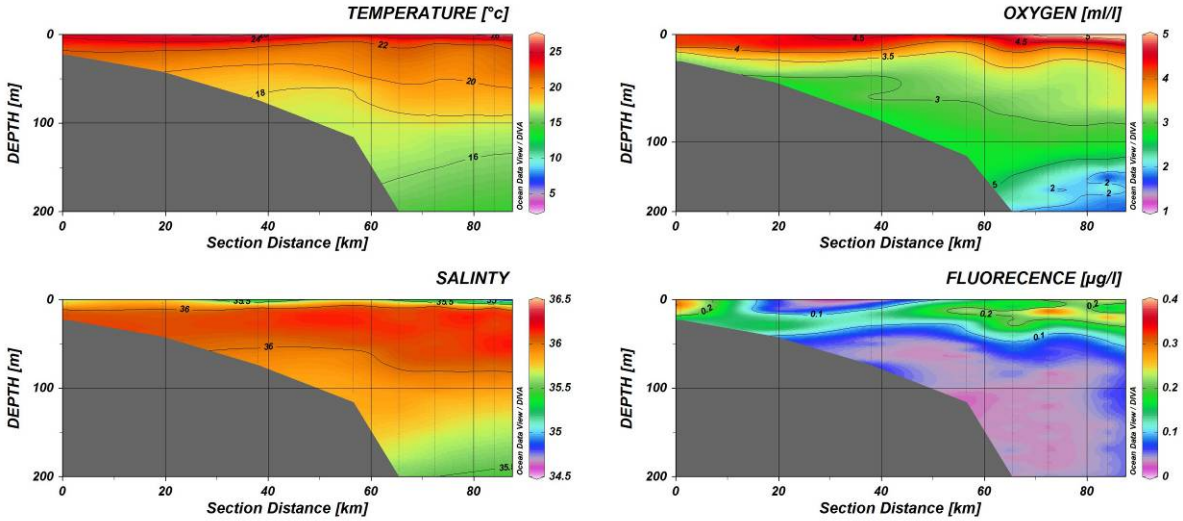
a) South of Olinde



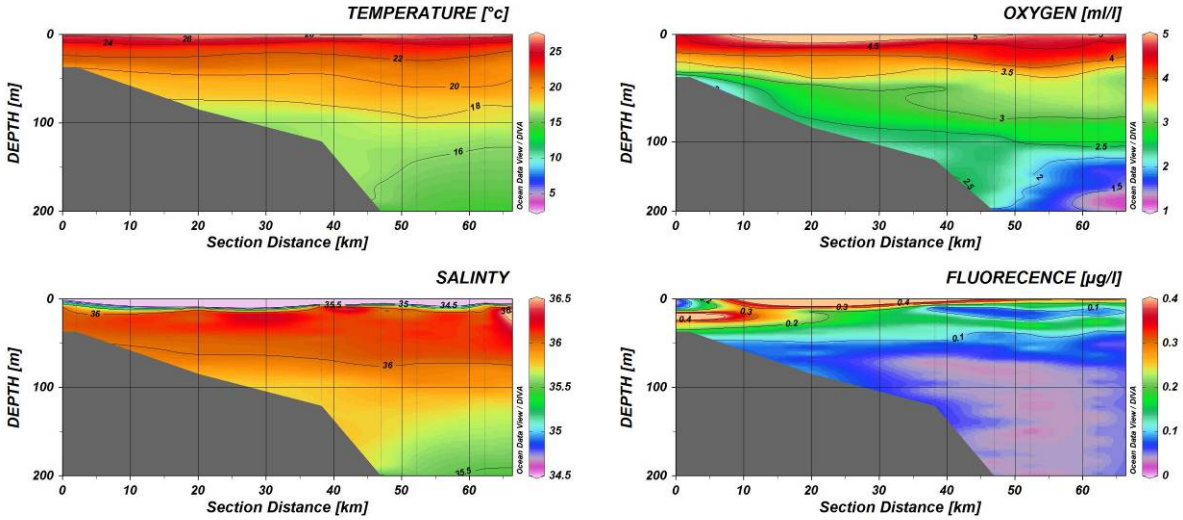
b) Sette Cama



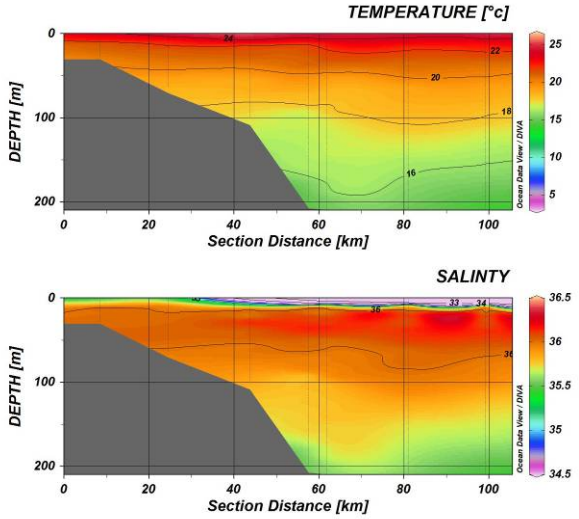
c) Pte. Panga

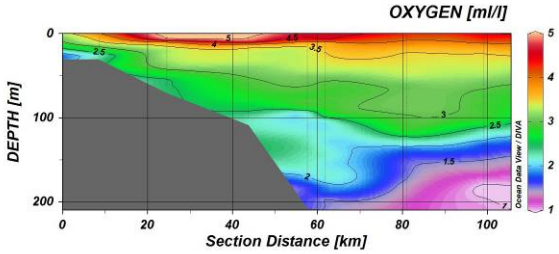


d) North of Point Noire

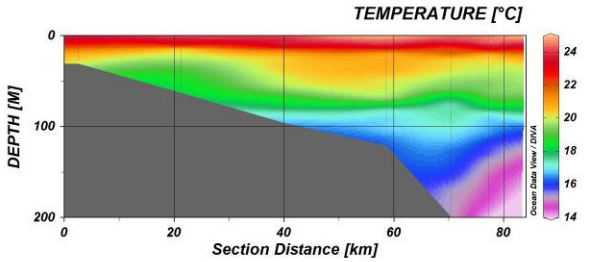


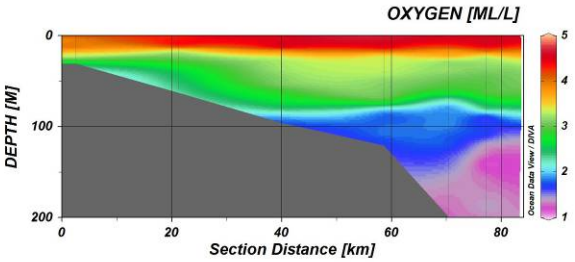
e) Border to Cabinda

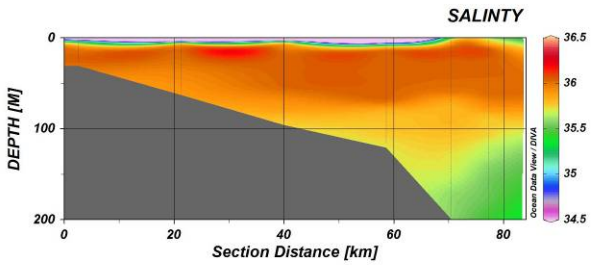




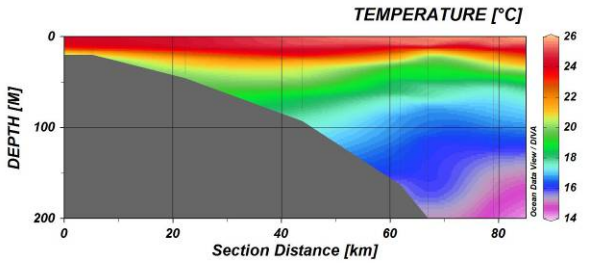
f) Congo River

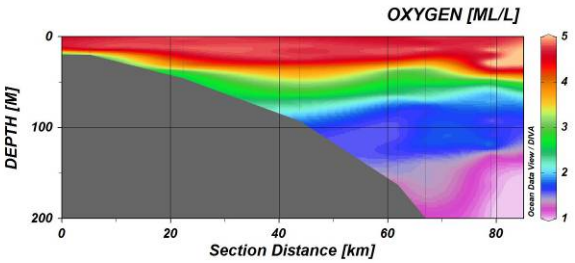


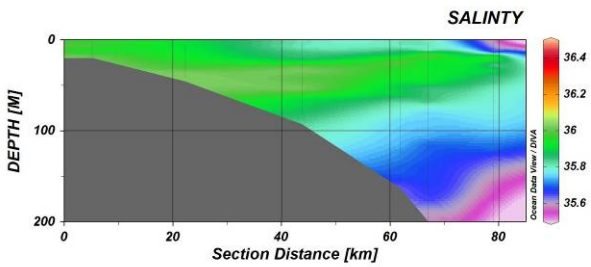




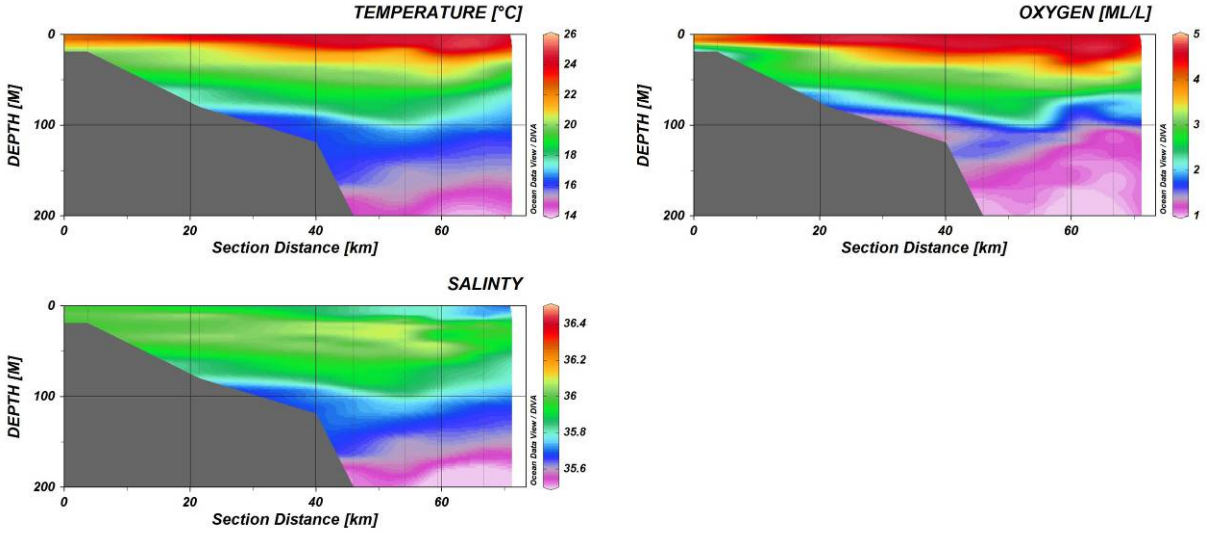
g) N'Zeto







h) Ambriz



i) Pta. Das Palmerinhas

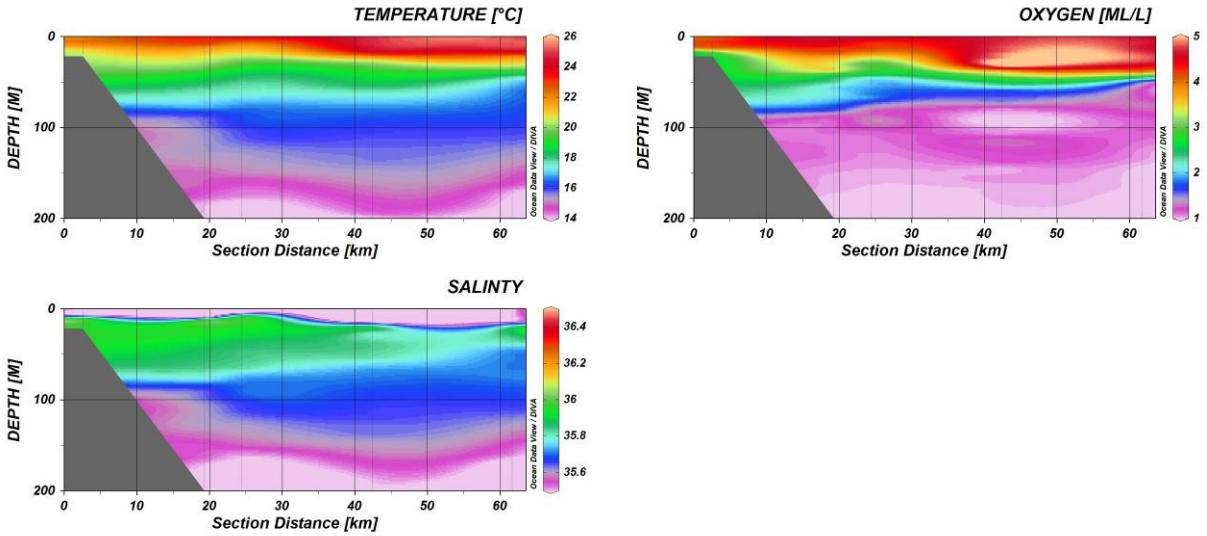


Figure 3.3. Vertical distributions of temperature, salinity, oxygen and relative fluorescence across the shelf at: South of Olinde a), Sette Cama b) Pte. Panga c), North of Point Noir d), border to Cabinda e), Congo River f), N'Zeto g), Ambriz h) and Pta. Das Palmerinhas i).

CHAPTER 4 CHLOROPHYLL AND ZOOPLANKTON BIOMASSES

Chlorophyll *a*

Concentrations of chlorophyll *a* based on the laboratory analyses of sea-water samples collected at depth of 5 m were comparatively high in the region outside Point Noir (Congo) as well as near the coast in the area north of Luanda (Angola) (Fig. 4.1). At depth of 10 m, the latitudinal differences were less pronounced, but a generally stronger pattern of decreasing concentrations with increasing cross-shelf distance from land can be observed for the whole study region (Fig. 4.1). For sampling-depth of 20 m, the concentrations tended to be more similar along the latitudinal range within the study region, and the concentrations were more homogeneous with respect to distance from shore. When considering all stations and including all depths, the levels ranged between 0 and 5.2 mg chl.*a* m^{-3}.

Vertical distributions of chlorophyll revealed some interesting patterns (not considering the shallowest stations). In the northern part of the study area (Gabon), for stations with intermediate bottom-depths (few samples were collected deeper than 100m in the northern part of the survey-region), a subsurface maximum at about 10-20m was typical. In strong contrast, in the area outside of Congo, it was more common with concentrations increasing from depth towards the surface, at times with the profiles displaying a very shallow sub-surface maximum. Yet again, further south, in the region outside of Angola, a subsurface maximum at about 10-30 m seemed typical. In all three areas, below the subsurface maxima when present, the concentrations had generally become very low when approaching a depth of 100 m, and were near zero at even greater depths. There were, however, exceptions to these somewhat subjectively described patterns within each of the different regions. Moreover, it should be expected that stations located at different distances from the coast and hence with different bottom-depths vary somewhat regarding vertical profiles – although we have not taken this into consideration in the present report. A few selected examples illustrating some very different patterns observed are given in Fig. 4.2.

We do not discard the possibility of some of the chlorophyll measured in samples from certain areas representing not only marine phytoplankton, but perhaps some residue from other plant sources as well. A few zooplankton samples collected with the WP2-net were observed to include considerable amounts of some unidentified green-brownish material, which was assumed to be of plant origin. When inspecting this green-brownish material under the microscope onboard, we were not able to determine if it stemmed from phytoplankton or might have some other origin (described below). Looking closer at the fixed samples collected from the phytoplankton net might provide useful information about this.

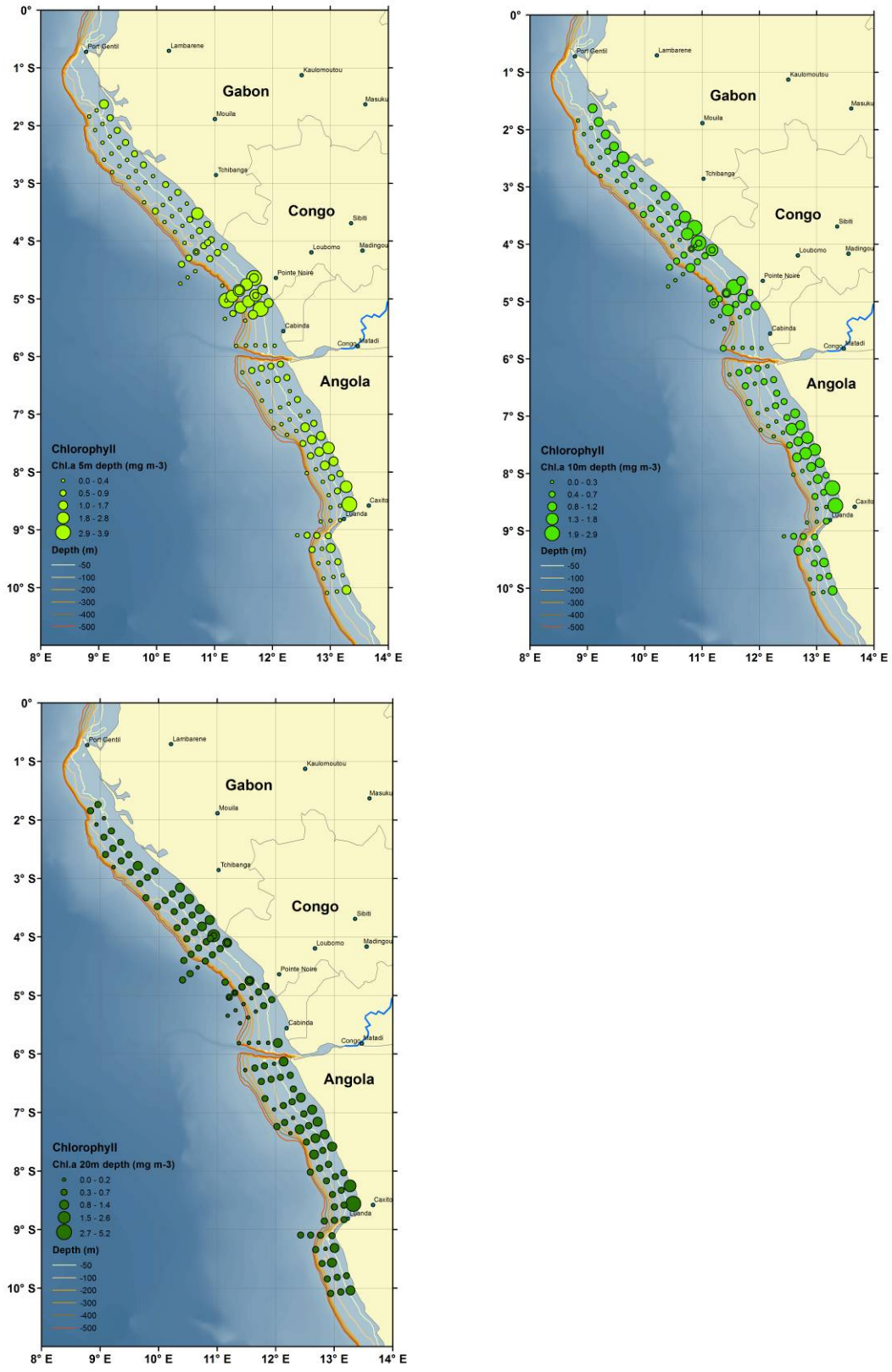
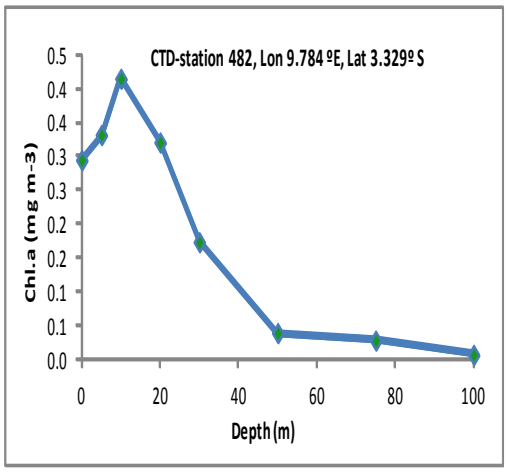
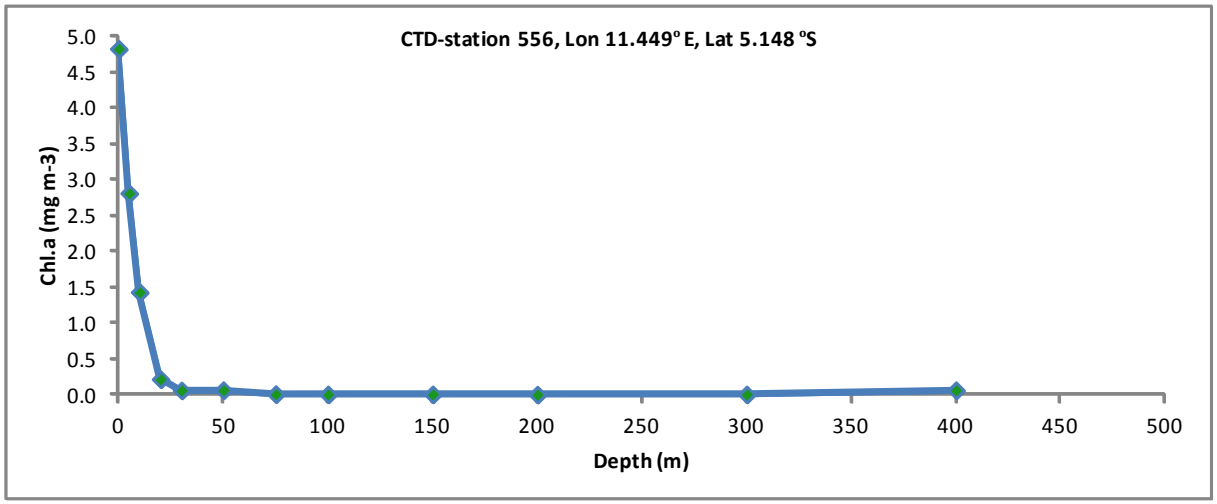


Figure 4.1. Chlorophyll *a* concentrations (mg m^{-3}) at the selected sampling-depths of 5 m (upper left), 10 m (upper right) and 20 m (lower left). Figure legends show concentrations as bubble-size, while bottom-depths are indicated by coloured lines. Some bubbles overlap due to very proximate sampling stations. Note different scales for bubble-sizes among the figures.





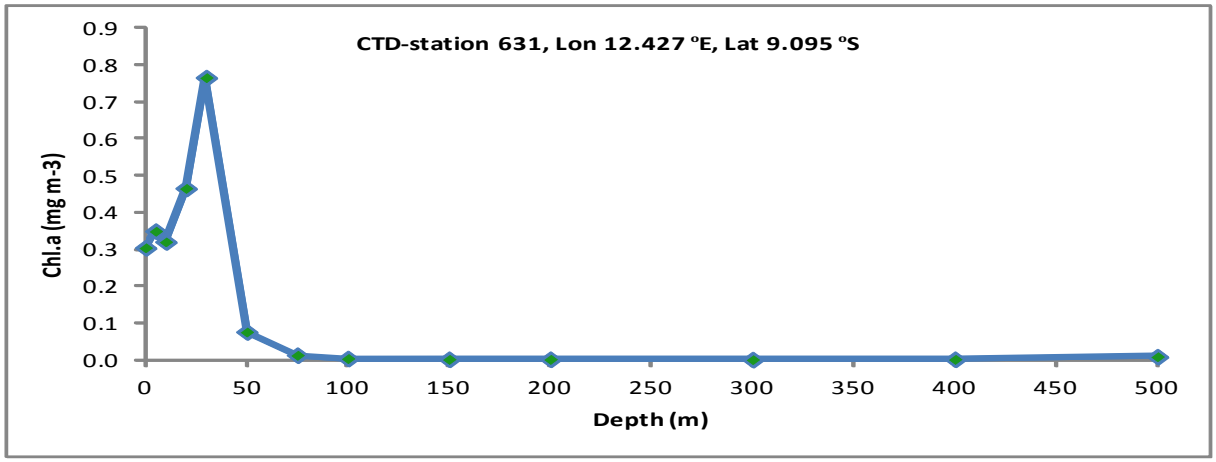


Figure 4.2. Some subjectively selected examples demonstrating very different vertical distributions of chlorophyll *a* (mg m^{-3}). Note varying scales for chlorophyll concentrations and depth among the figures. These examples are selected to visualize some markedly different patterns, which in addition to area-specific features also may be subject to natural variability among within-region profiles as well as varying distances from the coast and thus bottom-depths. Hence, the exact vertical patterns in these particular examples should not be considered as generally representative for the region where they were sampled.

Zooplankton biomasses

When comparing the zooplankton biomasses sampled from only the uppermost 25m with those representing the whole water-column (though only above depth of 200 m), the results were found to be rather similar – both regarding the biomass values and horizontal patterns. Still, the biomasses for the deeper WP2s were as a rule somewhat higher than for the samples representing only the 25-0m stratum. Due the overall similarity, we present only the biomass results for the upper 25m in this report (Fig. 4.3). For the uppermost 0-25m depth-stratum, the total biomass (sum of all three size-fractions) ranged between 0.7 and 15 g dry-weight per square meter surface, with an average of 2.2 g DW m^{-2}.

The most notable pattern observed was the cluster of stations about in the middle of the latitudinal range of the study area – off Congo – with biomasses typically being higher than at stations both further north and south (Fig. 4.3). In this same area, it also seems that the weight-proportion of the smallest size-fraction (0.18-1 mm) to the total biomass (including all size-fractions; 0.18-1 mm, 1-2 mm, and > 2mm) often was somewhat higher than elsewhere (Fig. 4.3). However, as described above in the chlorophyll chapter we observed that several samples contained a green-brownish unidentified material – assumed to be some type of plant residue – that we for practical reasons were not able to separate from the zooplankton or eliminate from the samples. Such stations were identified during the weighing process and are indicated with red in Fig. 4.3 (lower panel). The main location of these stations was outside of Congo, though also in the very northern part of the survey area (Gabon). This green-brownish material was included in the zooplankton samples, and particularly in the smallest size-fraction. Hence, the zooplankton biomasses here reported for these particular samples will not only represent zooplankton. To what extent this material contributed to the total biomass for the affected samples is not clear, but at least for some stations is obviously dominated the weight for the smallest size-fraction. Considering the location of many of these particular samples (se Fig. 4.3), it seems reasonable to believe that the apparently higher zooplankton biomasses outside of Congo to some degree may be a result of this artifact. This assumed plant residue, however, may have two opposing effects; it will increase the sample-weight and may therefore lead to overestimation of the zooplankton biomass, but on the other hand it may also cause the plankton net to clog and thereby lead to reduced zooplankton catches. For this reason we are hesitant to conclude that there was more zooplankton in the upper waters outside Congo than elsewhere. Separate studies would be needed to elucidate this issue.

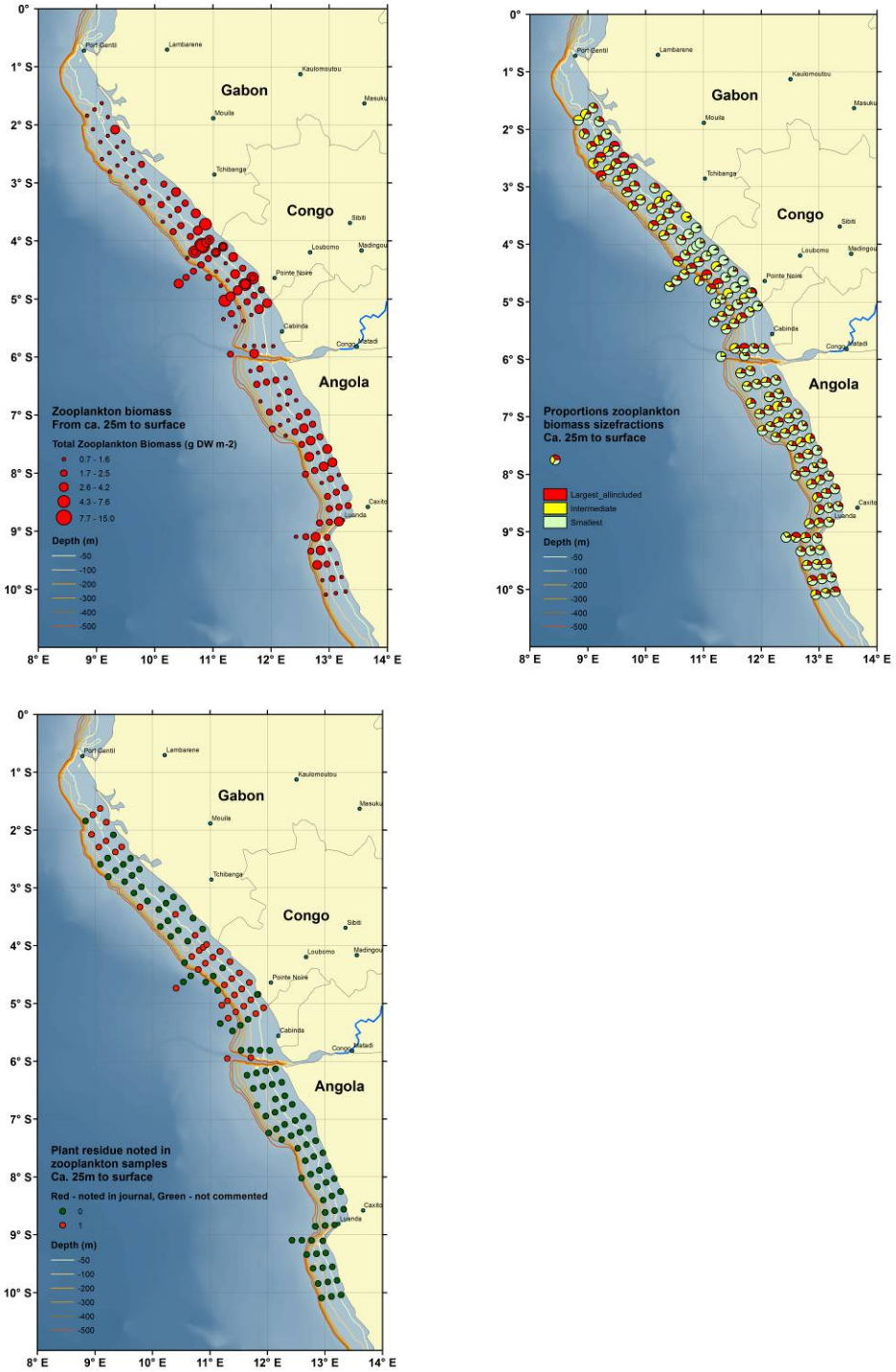


Fig. 4.3. Zooplankton biomasses in uppermost 25m of water-column. Total biomass is shown in upper left panel (but see comments in the text above regarding a possible bias), weight-proportions of different size-classes corresponding to size-fractioning filters (0.18-1 mm in green, 1-2 mm in yellow, and > 2mm in red) are shown in upper right panel, whereas stations where notable contents of greenish residue assuming to represent phytoplankton or other plant material are indicated with red in lower left figure.

CHAPTER 5 SARDINELLA DISTRIBUTION AND ABUNDANCE

Adult sardinella

Acoustic recordings of pelagic species were made regularly during the entire survey and trawl samples were taken at regular intervals to verify the species composition, to collect length frequency information for *Sardinella*, and to obtain biological information including length, weight, sex, maturity stage and gonad weight of approximately thirty randomly selected individuals from each trawl. Annex III gives the maturity scale used for the staging of individuals

Gabon and Congo

Figure 5.1a illustrates the distribution within the region surveyed. Two low density areas of sardinella were found near the coast in Gabon while the main distribution was found south of Pte. Panga (Mayomba). In the northern part of this distribution area the sardinella was closer to the coast, while further south in Congo the distribution continued offshore off the shelf (and in one instance further than our cruise lines). Highest densities were found on the shelf in the southern part of Congo. Most of the Cabinda region was not possible to survey due to the oil industry in the area. However, one transect conducted north of Congo river indicates that the distribution was discontinued from somewhere inside this region.

The *S. aurita* in the region consisted only of one cohort with large individuals, the length distribution showed a modal peak around 29 cm (Figure 5.2a), while the *S. maderensis* was smaller and had a wider size-distribution, with modal peaks at 9, 12 and 19 cm (Figure 5.2b).

Summarised information of sex, maturity stage and average length for fish caught in Gabon and Congo can be found in Table 5.1. The *S. aurita* showed a dominance of fish in maturity stage four (fish ready to spawn, but not yet running stage), while a number were caught "running" (stage 5). In other words, most of the fish caught were preparing to spawn and none were found in stage six "post spawning / recovering". On the other hand the *S. maderensis* found in the region showed a dominance of smaller immature fish and mature fish in maturity stage 2. No fish were found in stage 4 and only 1 fish was in stage five (running).

The total estimated biomass of sardinella for the region was 236 000 tonnes. Of this *S. aurita* was the dominant species with 196 000 tonnes, representing around 83% of the total biomass, while *S. maderensis* contributed with 17% (40 000 tonnes). The species composition was similar to previous years (Table 5.2). The abundance in Gabon was relatively low and approximately 16 % of the total sardinella biomass was found there. Of this 28 000 tones was *S. aurita* while 10 000 tonnes was *S. maderensis*. The sardinella in Congo and Gabon is not regularly covered, but several previous biomass estimates are in the same range and with

similar size distribution as this. The estimate for 2014 is among the highest in the time series, and the population of *S. aurita* consisted mainly of fish with lengths of around 30 cm. It should however be noted that the transect spacing on our cruise was 15 NM, which means that this is a less precise estimate than the dedicated pelagic surveys conducted in Angola where transect spacing is about 7 NM.

Angola

No sardinella were found on the transects immediately north and south of the Congo River, but small registrations were made close to the coast south of this, continuing southwards between the coast and 50 m bottom-depth from Congo River to Cabo Sao Braz. The density was generally low but with larger abundance in some areas, off N`Zeto, between Ambriz and Luanda, at Pta. das Palmerinhas and at Cabo Sao Braz at the southern border of the survey area. Most likely the distribution continued south of this point. The two sardinella species were found mixed in the region.

The *S. aurita* in the region consisted of several cohorts. One can observe one modal peak at 16 cm, one at 21 cm and there are probably also one or two older cohorts with a modal peak around 28 cm. (Figure 4.2c). The size distribution of *S. maderensis* shows one juvenile cohort around 8 cm, one modal peak at 18 cm and possibly another modal peak around 22 cm (Figure 5.2d).

Table 5.2 shows summarised information for sex, maturity stage and average length for the sardinella caught in Angola. The *S. aurita* investigated showed a large number of immature fish. Of the adult fish observed most were in maturity stage 2 and some in maturity stage three. Only one fish was classified to each of maturity stages four and five, respectively. It is therefore very likely that most of the sardinella larvae caught with the Multinet off the coast of Angola was not *S. aurita*. *S. maderensis* found in Angola showed a wider range of maturity stages than *S. aurita*. There was also for this specie a dominance of immature fish, and adult fish of stage two. However, slightly more fish with maturity stage four were found (7% of the total number of *S. maderensis* investigated). No fish in stage five were found.

The total estimated biomass of sardinella in Angola was 174 000 tonnes. Of this 89 000 tonnes was *S. aurita* (51%), while 85 000 (49%) was *S. maderensis*. Usually the surveys in Angola divide the area into three different strata. Only the northern region (Congo river-Pta das Palmerinhas) was covered completely during this survey. In that region 61 000 tonnes of *S. aurita* and 52 000 tonnes of *S. maderensis* were estimated. The acoustic abundance estimation of sardinella in Angola is usually covered during two pelagic abundance surveys with more detailed coverage's than during this survey. Hence, the estimate reported here does not enter any time series for sardinella abundance, but is relevant to compare with the observations made in Congo and Gabon and also with the denser coverage that will be carried out during the traditional pelagic survey that was carried out immediately after this.

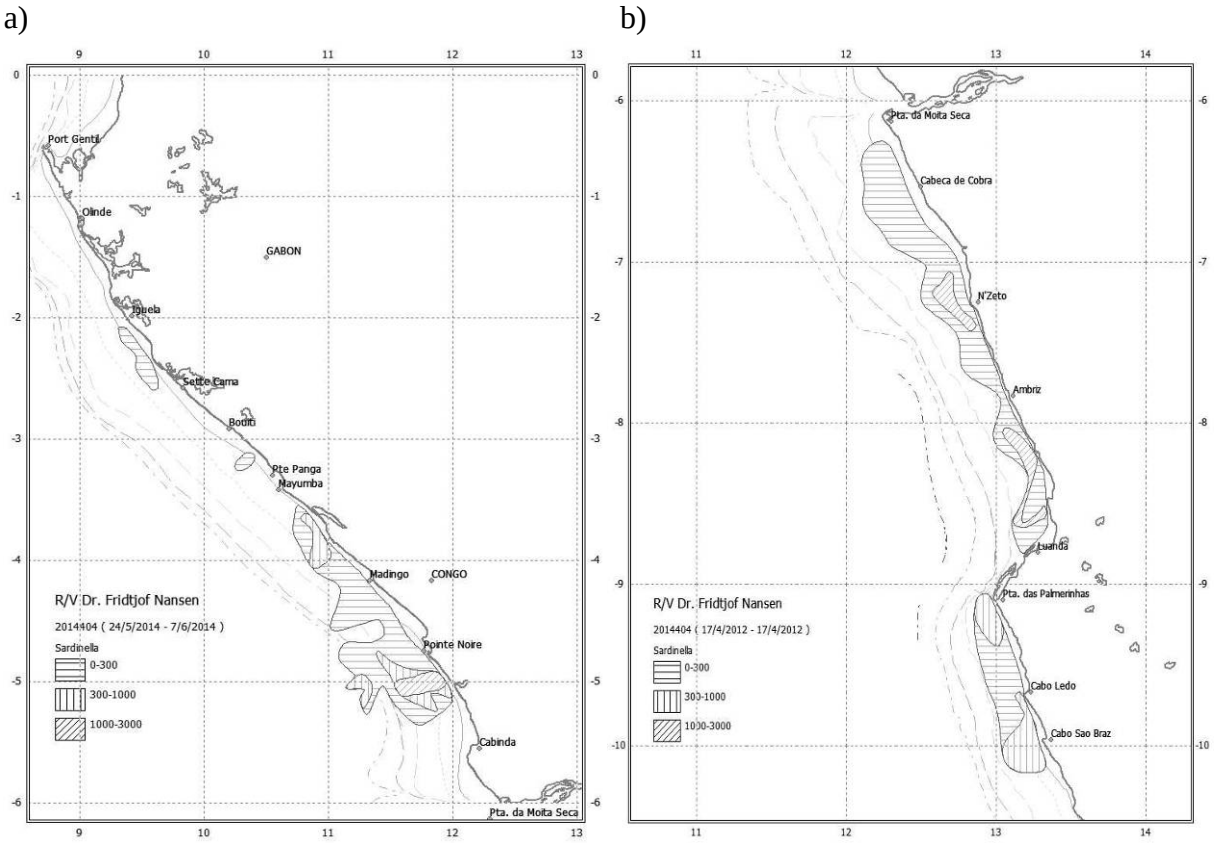


Figure 5.1. Distribution of acoustic recordings of sardinella in a) Gabon and Congo and b) Angola to Cabo Sao Braz

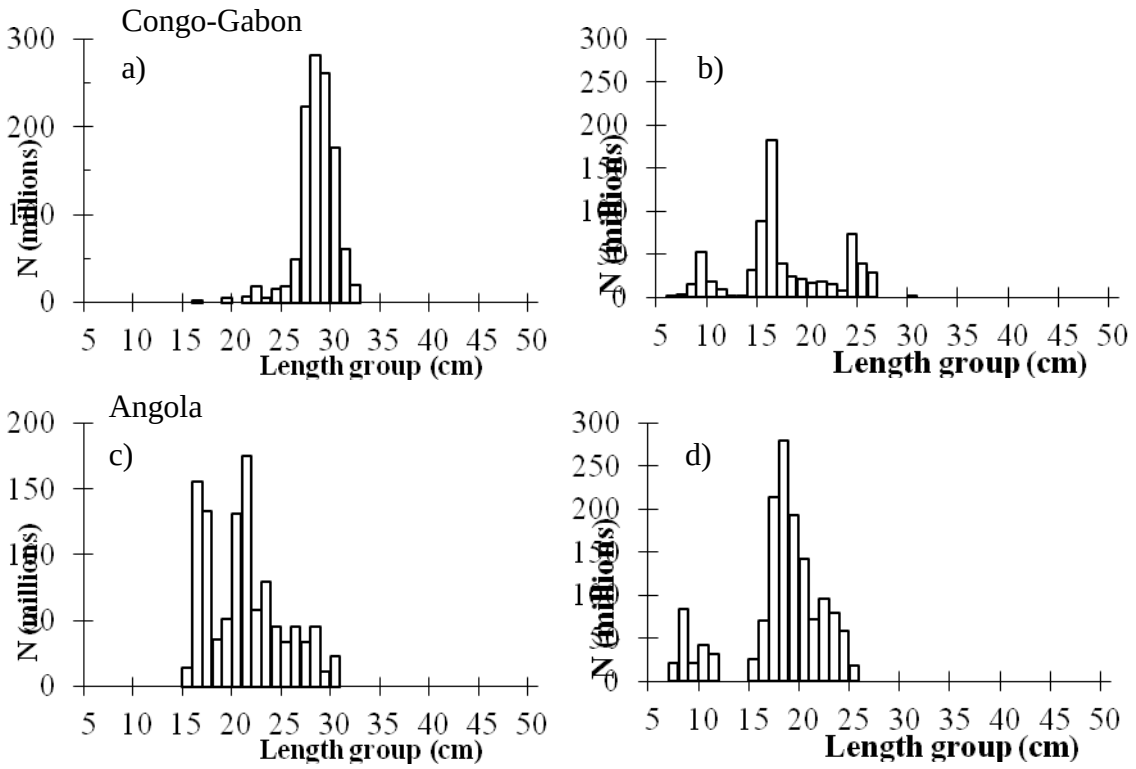


Figure 5.2 Size distribution of *S. aurita* (a&c) and *S. maderensis* (b&d) caught in Congo-Gabon, and Angola

Table 5.1. Sex, maturity stage and average length of the sardinella caught in Gabon and Congo

species	*S. aurita*								*S. maderensis*									
maturity	2	3		4		5		Total	0	1		2		3		4	5	Total
sex	F	F	M	F	M	F	M	-	J	F	M	F	M	F	M	-	M	
Count	5	24	17	41	55	13	7	162	31	15	13	9	8	1	1	-	1	79
Avg. L	28.2	28.8	27.8	28.0	28.1	28.4	30.6	28.3	13.5	19.2	19.5	21.4	22.3	26.5	24.5	-	19.5	17.8

Table 5.2. Sex, maturity stage and average length of the sardinella caught in Angola

species	*S. aurita*									*S. maderensis*									
maturity	0	1	2		3		4	5	Total	0	1	2		3		4		5	Total
sex	J	-	F	M	F	M	M	F	-	J	-	F	M	F	M	F	M	-	-
count	79	0	32	10	11	5	1	1	168	83	0	42	19	8	6	6	4	0	139
avg. L	19.2	-	22.7	24.9	22.2	28.2	30.0	25.5	19.1	16.2	-	20.7	22.3	22.9	24.0	23.4	24.8	-	21.1

Horizontal Distribution of sardinella egg and larvae

The distributions of sardinella eggs and larvae during the survey area were based on the Multinet samples. These were visually scrutinised first in a counting chamber and then under the binocular, and eggs and larvae of sardinella were identified and counted. The eggs and larvae were generally found in the uppermost 25 m of the water column and the filtered water volume of all Multinet stations was therefore standardised calculating the volume filtered from this depth to the surface when the nets were taken from greater depths, assuming that no eggs or larvae was found deeper than 25 m.

Gabon-Congo

The horizontal distributions of sardinella eggs and larvae are described in Figure 5.3. Figure 5.3a shows that the main concentrations off eggs were found off southern Congo at the border with Cabinda. The station with the highest egg concentration (PL279) was situated off the shelf break at a bottom depth of 1000 m. This area was also characterised by a thin layer (7 m) of low salinity surface water originating from the Congo River overlaying high salinity waters, and with strong fluorescence measured at 5 m depth with the thermosalinograph. The egg concentration measured at the station was 500 eggs/m^3. Lower egg-concentrations were found in vicinity of this station in all directions, but the concentrations decreased rapidly and the high concentration of eggs was confined to a relatively small area.

Sardinella larvae were distributed over a much wider area. These were typically found north towards Mayomba at the border between Gabon and Congo and with the southern border of distribution just south of the main egg concentration. The main surface current direction in the region was northwards, and the highest larvae concentrations were found about 60 NM north

of the main egg concentrations and slightly inshore, over the shelf break, at 119 m depth. There was a tendency that the highest larvae concentration followed the shelf with declining densities on each side of the maximum (Figure 5.3 and 5.4).

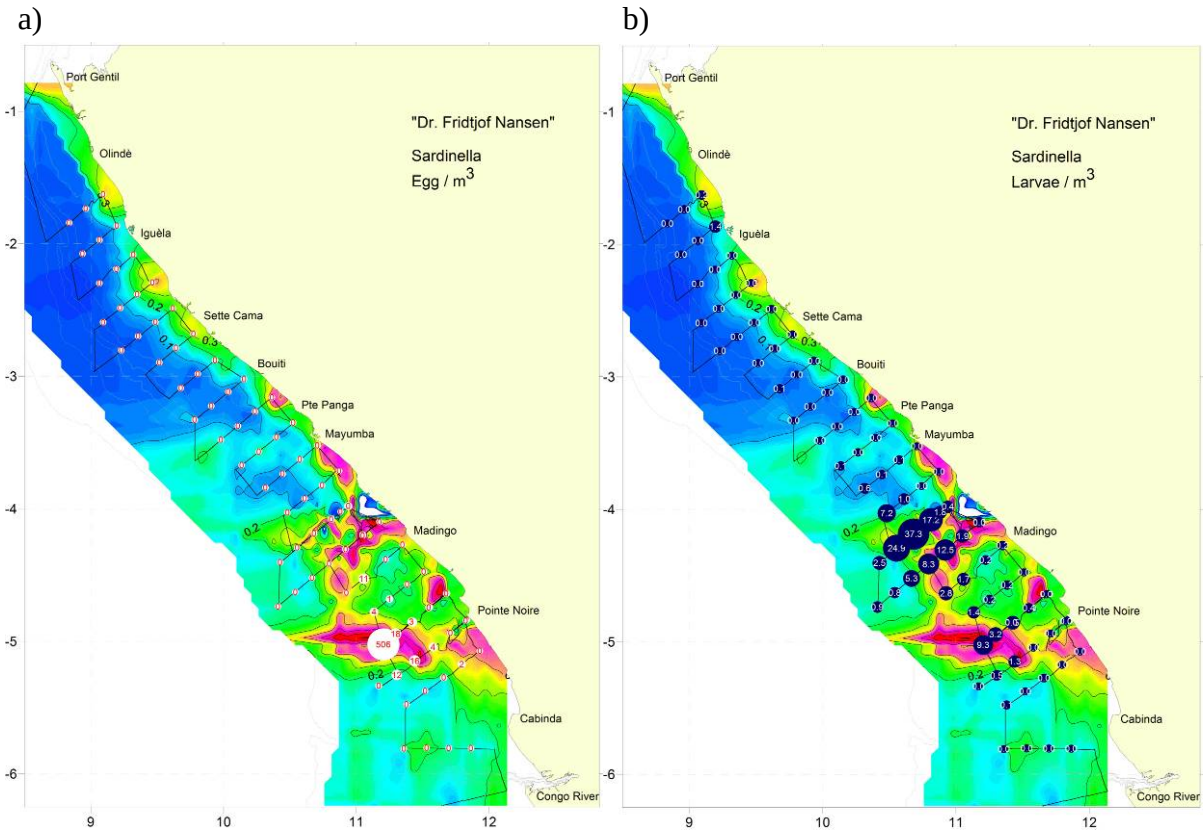


Figure 5.3. Horizontal distribution of number of sardinella eggs/m^3 calculated from the upper 25 m (white dots with red number) and number of larvae/m^3 (blue dots with white number) per station in Congo and Gabon. The map is overlayed a map of sea surface fluorescence from the thermosalinograph.

A north-south gradient in larval size was also observed (Figure 5.5), where the smallest larvae were found at the same stations as the eggs. On these stations, eggs were hatching under the binoculars during counting and identification and the larvae found were mainly yolk-sac larvae. Further northwards from the main egg concentration the larval size increased gradually. The largest larvae were found in Gabon more than 120 NM away from the main spawning between Sette Cama and Pte. Panga, although in low concentrations. Clear relations between bottom-depth and larval size were also observed throughout most of the region during our survey. The larvae were typically largest offshore and then declined in size towards the coast (Figure 5.4 and 5.5). Based on earlier observations with Dr. Fridtjof Nansen in the region, the main nursery for juvenile sardinella was expected to be the inner shelf of southern Gabon, and the larvae should most probably end up in that region. It therefore seems difficult to explain for the moment why the largest larvae were found offshore. However,

there is an incomplete understanding of the Congo River currents and undercurrents in the area, and further investigation of these may provide a better understanding.

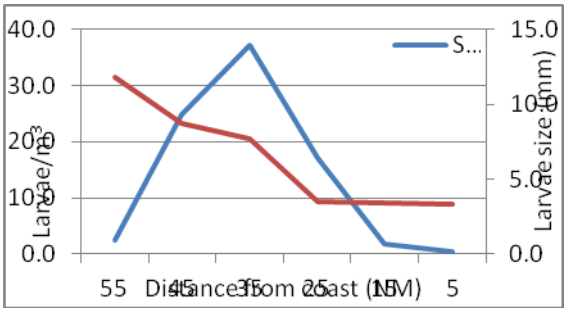


Figure 5.4 Cross shelf distribution of sardinella larvae (per m^3) and their size distribution (mm) along a transect carried out in southern Gabon on the border with Congo.

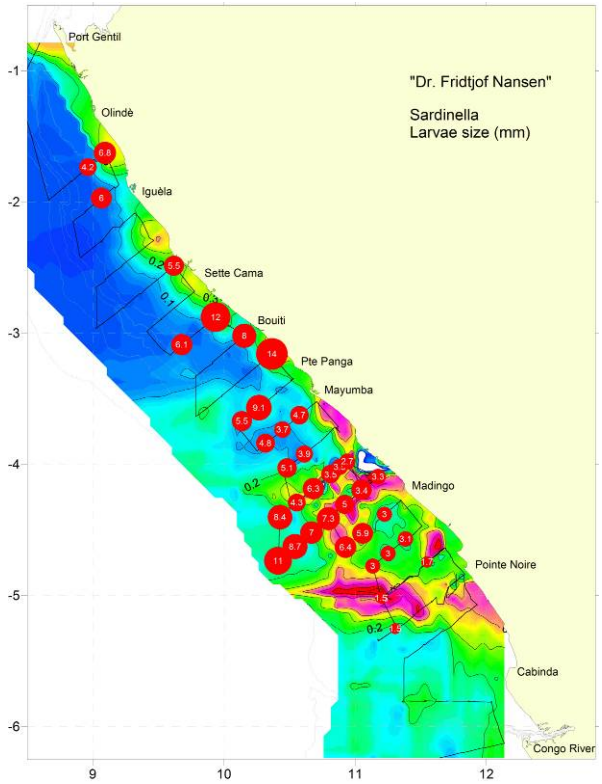


Figure 5.5. Horizontal distribution of average larvae size per station where sardinella was found. The map is overlayed a map of sea surface fluorescence from the thermosalinograph.

Angola

In Angola no sardinella eggs were observed at all, and considerably fewer sardinella larvae were found compared to further north (Figure 5.6a). The larvae were found in two areas, north of N'Zeto and in a much larger area between Ambriz, across Pta. Das Palmerinhas until Cabo Ledo. The larvae were typically observed with increasing density towards the coast and with the exception of Pta das Palmerinhas, where the shelf break is very close to the coast, no stations with larvae were found off the shelf break. The size distribution of the larvae (Figure

5.6b) shows that the larvae size had a much smaller size range than further north. Most larvae found were between 5-10 mm with the exception of some larvae found off Ambriz that were 3.9 mm. Although the numbers of observations are low, there are some indications of increasing larval size with distance from the coast.

It is not possible to distinguish between the larval stages of *S. aurita* and *S. maderensis* visually. It is however suspected that the larvae encountered in Angola belong to *S. maderensis* based on the positions of the observations and expected difference in spawning behaviour between the two species. *S. maderensis* being a more inshore coastally distributed species than *S. aurita*. However, the larvae are kept on ethanol and it is possible to do genetic analyses to answer this with certainty.

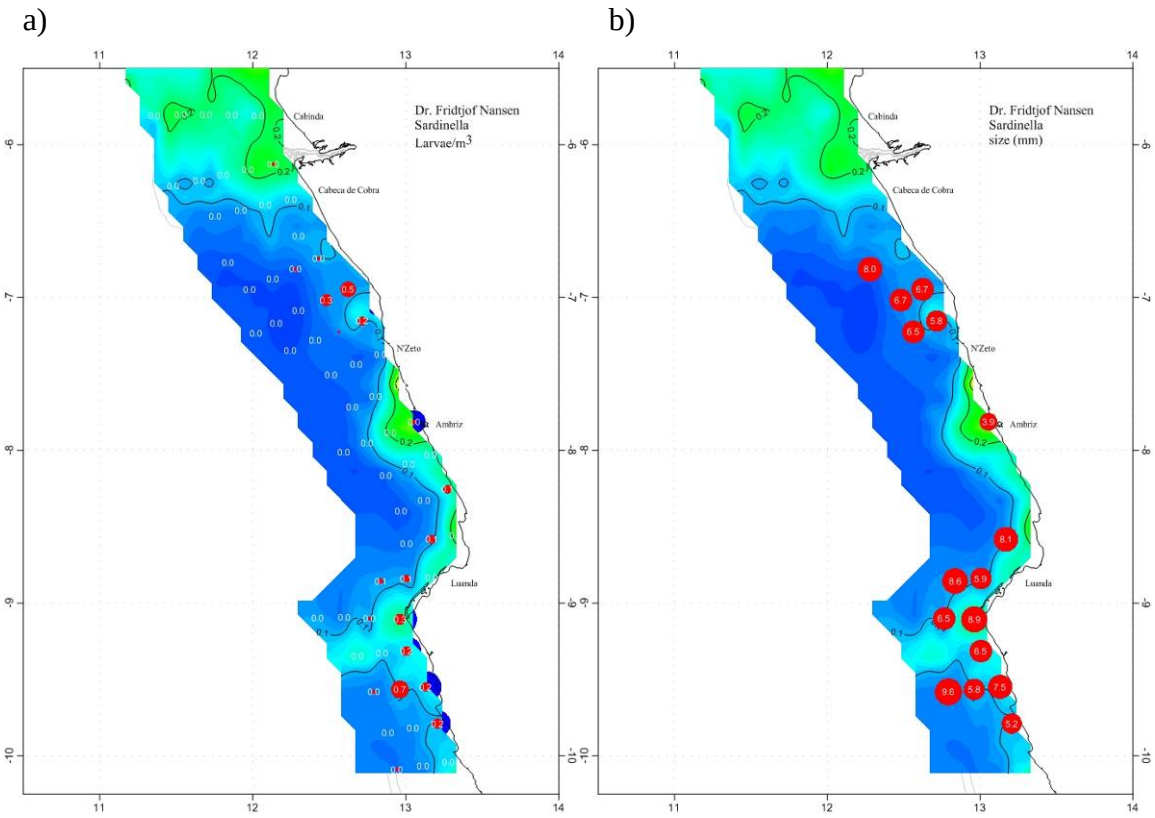


Figure 5.6. Horizontal distribution of number of sardinella larvae/m^3 calculated from the upper 25 m (red dots with white number) per station a) and average larvae size per station b) in Angola. The map is overlayed a map of sea surface fluorescence from the thermosalinograph.

Vertical distribution of eggs and larvae

Studies on vertical distributions of sardinella eggs and larvae (Figure 5.7) were conducted on a dedicated transect during 31. May - 1. June in the border area between Congo and Gabon along a 40 nm long transect. The area had relatively high concentrations of sardinella larvae, but eggs were only found on one station (two eggs of poor condition at PL218, bottom depth = 83 m). Relatively high egg-concentrations were observed on the innermost station one day earlier (station PL175), and this was one reason for why this transect was selected for this study. It is reasonable to assume that the eggs have positive buoyancy as most other pelagic fish eggs, and that they would therefore ascend towards the surface in the salinity profiles experienced during the survey.

The larval distributions showed highest concentrations in the surface waters, more specifically in the uppermost ten meters (Figure 5.7) above the salinity maximum, in water masses with relatively high fluorescence and above the thermocline (not shown). Very few larvae were found in deeper waters, and those found were in poor condition possibly indicating that these were dead or dying animals sinking. The highest concentrations of larvae (around 36.1 larvae/m^3) were found immediately inshore of the shelf edge (bottom depth = 119 m), and the station with the second highest abundance was 10 nm further offshore (bottom depth = 702 m). On both sides of these high-value stations, the larvae concentrations decreased rapidly.

The size distributions of larvae along this transect show a clear trend, with the largest larvae found offshore at the deepest station (mean size= 8.4 mm), intermediate-sized larvae at the middle of the transect on the station with highest larval abundance (mean size= 6.3 mm), while the innermost station (where relatively high egg concentrations were found the previous day) showed a mean larval size of around 3.4 mm.

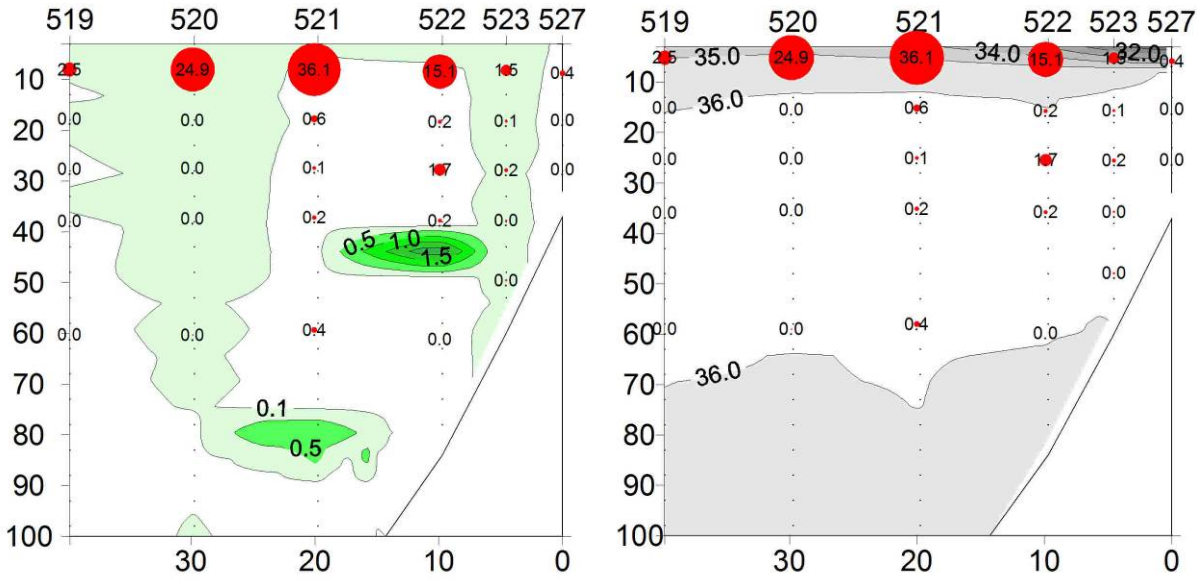


Figure 5.7. Vertical distribution of sardinella larvae (ind. per m^3) overlayed vertical profiles of fluorescence on relative scale (left panel) and salinity (right panel) as measured by the CTD. Numbers on the top of the figures give station numbers.

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ANNEX I Fishing Stations

R/V Dr. Fridtjof Nansen SURVEY:2014404 STATION: 1
DATE :29/05/14 GEAR TYPE: PT NO: 7 POSITION:Lat S 3°21.10
start stop duration Lon E 10°31.30
TIME :00:20:11 00:36:00 15.8 (min) Purpose : 1
LOG : 2838.98 2839.92 0.9 Region : 3300
FDEPTH: 18 23 Gear cond.: 1
BDEPTH: 23 26 Validity : 3
Towing dir: 0° Wire out : 56 m Speed : 3.6 kn
Sorted : 0 Total catch: 51.07 Catch/hour: 193.70

SPECIES	CATCH/HOUR weight	CATCH/HOUR numbers	% OF TOT. C	SAMP
Sardinella maderensis	127.62	3190	65.89	1
Sphyraena guachancho	42.93	155	22.16	
Brachydeuterus auritus	8.34	269	4.31	
Ilisha africana	4.17	224	2.15	
Pomadasys rogeri	3.34	95	1.72	
Selene dorsalis	2.62	61	1.35	
Pomadasys jubelini	1.74	8	0.90	
Chloroscombrus chrysurus	1.52	42	0.78	
Pomadasys incisus	0.64	8	0.33	
Pseudupeneus prayensis	0.30	322	0.16	
Penaeus notialis	0.30	322	0.16	
Galeoides decadactylus	0.15	8	0.08	
Sepia officinalis	0.00	11	0.00	
Trichiurus lepturus	0.00	4	0.00	
Total	193.70		100.00	

R/V Dr. Fridtjof Nansen SURVEY:2014404 STATION: 2
DATE :29/05/14 GEAR TYPE: PT NO: 7 POSITION:Lat S 3°44.73
start stop duration Lon E 10°52.40
TIME :19:03:32 19:36:04 32.5 (min) Purpose : 1
LOG : 2950.30 2952.63 2.3 Region : 3300
FDEPTH: 10 10 Gear cond.: 0
BDEPTH: 28 30 Validity : 0
Towing dir: 0° Wire out : 100 m Speed : 4.3 kn
Sorted : 38 Total catch: 49.84 Catch/hour: 91.93

SPECIES	CATCH/HOUR weight	CATCH/HOUR numbers	% OF TOT. C	SAMP
Sardinella aurita	52.01	273	56.58	2
Ilisha africana	16.91	522	18.40	4
Sphyraena guachancho	7.58	65	8.25	0
Stromateus fiatola	5.74	13	6.24	0
Brachydeuterus auritus	3.95	0	4.29	0
Hemicaranx bicolor	1.64	11	1.79	0
Selene dorsalis	1.29	22	1.40	0
Chloroscombrus chrysurus	1.03	11	1.12	0
Trachurus trecae	0.76	6	0.82	0
Sardinella maderensis	0.52	24	0.56	3
Cypselurus oligolepis	0.48	2	0.52	0
Trichiurus lepturus	0.02	2	0.02	0
Total	91.93		100.00	

R/V Dr. Fridtjof Nansen SURVEY:2014404 STATION: 3
DATE :30/05/14 GEAR TYPE: PT NO: 7 POSITION:Lat S 4°3.94
start stop duration Lon E 11°6.50
TIME :13:36:16 14:17:36 41.3 (min) Purpose : 1
LOG : 3051.76 3053.93 2.2 Region : 3400
FDEPTH: 10 10 Gear cond.: 0
BDEPTH: 24 24 Validity : 0
Towing dir: 0° Wire out : 100 m Speed : 3.1 kn
Sorted : 0 Total catch: 251.73 Catch/hour: 365.44

SPECIES	CATCH/HOUR weight	CATCH/HOUR numbers	% OF TOT. C	SAMP
Chloroscombrus chrysurus	280.69	1125	76.81	
Sardinella maderensis	48.63	891	13.31	6
Sphyraena guachancho	19.21	94	5.26	
Sardinella aurita	10.63	77	2.91	5
Stromateus fiatola	3.89	9	1.06	
Scomberomorus tritor	1.86	1	0.51	
Ariomma bondi	0.51	1	0.14	
Total	365.41		99.99	

R/V Dr. Fridtjof Nansen SURVEY:2014404 STATION: 4
DATE :01/06/14 GEAR TYPE: PT NO: 1 POSITION:Lat S 3°59.98
start stop duration Lon E 10°55.25
TIME :02:18:37 02:50:49 32.2 (min) Purpose : 1
LOG : 3200.98 3203.01 2.0 Region : 3300
FDEPTH: 17 18 Gear cond.: 0
BDEPTH: 45 56 Validity : 0
Towing dir: 0° Wire out : 75 m Speed : 3.8 kn
Sorted : 0 Total catch: 1.45 Catch/hour: 2.70

SPECIES	CATCH/HOUR weight	CATCH/HOUR numbers	% OF TOT. C	SAMP
Brachydeuterus auritus	0.99	67	36.55	
Sphyraena guachancho	0.50	9	18.62	
Stromateus fiatola	0.48	4	17.93	
Penaeus notialis	0.30	13	11.03	
Trichiurus lepturus	0.26	35	9.66	
Ilisha africana	0.13	6	4.83	
Trachurus trecae	0.04	2	1.38	
Total	2.70		100.00	

R/V Dr. Fridtjof Nansen SURVEY:2014404 STATION: 5
DATE :01/06/14 GEAR TYPE: BT NO: 26 POSITION:Lat S 4°3.11
start stop duration Lon E 10°58.36
TIME :13:31:56 14:51:37 79.7 (min) Purpose : 1
LOG : 3266.28 3270.41 4.1 Region : 3300
FDEPTH: 47 47 Gear cond.: 0
BDEPTH: 47 47 Validity : 0
Towing dir: 0° Wire out : 130 m Speed : 3.1 kn
Sorted : 0 Total catch: 500.00 Catch/hour: 376.51

SPECIES	CATCH/HOUR weight	CATCH/HOUR numbers	% OF TOT. C	SAMP
Miscellaneous fishes	376.51	0	100.00	
Total	376.51		100.00	

R/V Dr. Fridtjof Nansen SURVEY:2014404 STATION: 6
DATE :02/06/14 GEAR TYPE: PT NO: 1 POSITION:Lat S 4°22.83
start stop duration Lon E 11°13.32
TIME :03:24:25 03:37:37 13.2 (min) Purpose : 1
LOG : 3343.03 3343.80 0.8 Region : 3300
FDEPTH: 15 17 Gear cond.: 0
BDEPTH: 71 74 Validity : 0
Towing dir: 0° Wire out : 95 m Speed : 3.5 kn
Sorted : 41 Total catch: 203.65 Catch/hour: 925.68

SPECIES	CATCH/HOUR weight	CATCH/HOUR numbers	% OF TOT. C	SAMP
Sardinella aurita	886.36	5364	95.75	7
Trachurus trecae	28.64	205	3.09	
Trichiurus lepturus	4.55	159	0.49	
Scomber japonicus	3.41	23	0.37	
Selene dorsalis	2.73	45	0.29	
Total	925.68		100.00	

R/V Dr. Fridtjof Nansen SURVEY:2014404 STATION: 7
DATE :02/06/14 GEAR TYPE: PT NO: 4 POSITION:Lat S 4°58.34
start stop duration Lon E 11°16.55
TIME :18:29:36 19:01:18 31.7 (min) Purpose : 1
LOG : 3426.93 3428.76 1.8 Region : 3400
FDEPTH: 0 0 Gear cond.: 0
BDEPTH: 666 614 Validity : 0
Towing dir: 0° Wire out : 110 m Speed : 3.5 kn
Sorted : 0 Total catch: 766.99 Catch/hour: 1451.72

SPECIES	CATCH/HOUR weight	CATCH/HOUR numbers	% OF TOT. C	SAMP
Sardinella aurita	1395.14	5684	96.10	8
Carcharhinus galapagensis	33.12	2	2.28	
Trichiurus lepturus	11.92	159	0.82	
MYCTOPHIDAE	7.55	3259	0.52	
Melanostomias sp.	2.38	199	0.16	
Plesionika martia	1.59	2385	0.11	
Total	1451.72		100.00	

R/V Dr. Fridtjof Nansen SURVEY:2014404 STATION: 8
DATE :05/06/14 GEAR TYPE: PT NO: 4 POSITION:Lat S 4°55.12
start stop duration Lon E 11°20.33
TIME :22:30:43 23:04:41 34.0 (min) Purpose : 1
LOG : 3634.57 3636.68 2.1 Region : 3400
FDEPTH: 0 0 Gear cond.: 0
BDEPTH: 294 401 Validity : 0
Towing dir: 0° Wire out : 110 m Speed : 3.7 kn
Sorted : 0 Total catch: 55.31 Catch/hour: 97.69

SPECIES	CATCH/HOUR weight	CATCH/HOUR numbers	% OF TOT. C	SAMP
Sardinella aurita	67.29	378	68.88	9
Trichiurus lepturus	9.68	389	9.91	
Penaeus notialis	6.09	2914	6.24	
Sarda sarda	6.02	4	6.17	
MYCTOPHIDAE	5.30	2271	5.42	
Auxis thazard thazard	1.64	4	1.68	
Pteroscion peli	1.02	106	1.05	
Diaphus dumerili	0.46	55	0.47	
Tylosurus crocodilus crocodil.	0.18	19	0.18	
Total	97.69		100.00	

R/V Dr. Fridtjof Nansen SURVEY:2014404 STATION: 9
DATE :06/06/14 GEAR TYPE: PT NO: 4 POSITION:Lat S 4°59.86
start stop duration Lon E 11°52.43
TIME :20:12:16 20:32:36 20.3 (min) Purpose : 1
LOG : 3753.47 3754.67 1.2 Region : 3400
FDEPTH: 5 5 Gear cond.: 0
BDEPTH: 39 41 Validity : 0
Towing dir: 0° Wire out : 110 m Speed : 3.5 kn
Sorted : 70 Total catch: 2290.60 Catch/hour: 6756.93

SPECIES	CATCH/HOUR weight	CATCH/HOUR numbers	% OF TOT. C	SAMP
Sardinella aurita	5296.81	24735	78.39	10
Sardinella maderensis	1058.41	16587	15.66	11
Chloroscombrus orqueta	174.48	3932	2.58	
Brachydeuterus auritus	72.86	2782	1.08	
Sphyraena guachancho	44.10	97	0.65	
Stromateus fiatola	39.32	97	0.58	
Trachurus trecae	26.84	192	0.40	
Selene dorsalis	26.84	97	0.40	
Ilisha africana	17.26	575	0.26	
Total	6756.93		100.00	

R/V Dr. Fridtjof Nansen SURVEY:2014404 STATION: 10
DATE :08/06/14 GEAR TYPE: PT NO: 1 POSITION:Lat S 6°38.19
start stop duration Lon E 12°6.24
TIME :13:59:20 13:59:31 0.2 (min) Purpose : 1
LOG : 4019.72 4019.73 0.0 Region : 4000
FDEPTH: 25 40 Gear cond.: 0
BDEPTH: 74 74 Validity : 0
Towing dir: 0° Wire out : 120 m Speed : 4.9 kn
Sorted : 0 Total catch: 0.00 Catch/hour: 0.00

SPECIES	CATCH/HOUR weight	CATCH/HOUR numbers	% OF TOT. C	SAMP
N O C A T C H	0.00	0	0.00	

R/V Dr. Fridtjof Nansen SURVEY:2014404 STATION: 11
DATE :08/06/14 GEAR TYPE: PT NO: 4 POSITION:Lat S 6°57.50
start stop duration Lon E 11°54.06
TIME :19:52:46 20:23:22 30.6 (min) Purpose : 1
LOG : 4053.01 4054.88 1.9 Region : 4000
FDEPTH: 0 0 Gear cond.: 0
BDEPTH: 192 127 Validity : 0
Towing dir: 0° Wire out : 120 m Speed : 3.6 kn
Sorted : 0 Total catch: 16.23 Catch/hour: 31.82

SPECIES	CATCH/HOUR weight	CATCH/HOUR numbers	% OF TOT. C	SAMP
Trichiurus lepturus	28.16	43	88.48	
Sarda sarda	1.43	2	4.50	
MYCTOPHIDAE	1.18	139	3.70	
Trachurus trecae	0.37	12	1.17	
Synagrops microlepis	0.31	20	0.99	
Dosidicus gigas	0.20	55	0.62	
Saurida brasiliensis	0.12	14	0.37	
Selene dorsalis	0.06	78	0.18	
Total	31.82		100.00	

R/V Dr. Fridtjof Nansen SURVEY:2014404 STATION: 12
DATE :09/06/14 GEAR TYPE: PT NO: 4 POSITION:Lat S 7°10.67
start stop duration Lon E 12°40.57
TIME :18:13:51 18:38:28 24.6 (min) Purpose : 1
LOG : 4199.13 4200.56 1.4 Region : 4000
FDEPTH: 5 5 Gear cond.: 0
BDEPTH: 35 37 Validity : 0
Towing dir: 0° Wire out : 110 m Speed : 3.5 kn
Sorted : 74 Total catch: 1738.77 Catch/hour: 4237.46

SPECIES	CATCH/HOUR weight	CATCH/HOUR numbers	% OF TOT. C	SAMP
Sardinella aurita	2539.94	64028	59.94	13
Brachydeuterus auritus	762.84	1833	18.00	
Sardinella maderensis	501.69	9851	11.84	12
Sphyraena guachancho	184.41	624	4.35	
Chloroscombrus chrysurus	103.09	802	2.43	
Stromateus fiatola	69.87	173	1.65	
Ilisha africana	36.65	860	0.86	
Trachurus trecae	18.33	458	0.43	
Caranx rhonchus	12.04	173	0.28	
Selene dorsalis	5.73	58	0.14	
Galeoides decadactylus	2.88	58	0.07	
Total	4237.46		100.00	

R/V Dr. Fridtjof Nansen SURVEY:2014404 STATION: 13
DATE :10/06/14 GEAR TYPE: PT NO: 1 POSITION:Lat S 7°23.87
start stop duration Lon E 12°47.58
TIME :03:57:06 04:14:24 17.3 (min) Purpose : 1
LOG : 4266.39 4267.38 1.0 Region : 4000
FDEPTH: 5 5 Gear cond.: 0
BDEPTH: 40 40 Validity : 0
Towing dir: 0° Wire out : 110 m Speed : 3.4 kn
Sorted : 34 Total catch: 792.81 Catch/hour: 2749.63

SPECIES	CATCH/HOUR weight	CATCH/HOUR numbers	% OF TOT. C	SAMP
Sardinella maderensis	2313.29	25287	84.13	14
Chloroscombrus chrysurus	323.86	3749	11.78	
Sardinella aurita	68.60	1595	2.49	15
Trachurus trecae	24.73	558	0.90	
Selene dorsalis	19.14	160	0.70	
Total	2749.63		100.00	

R/V Dr. Fridtjof Nansen SURVEY:2014404 STATION: 14
DATE :11/06/14 GEAR TYPE: BT NO: 26 POSITION:Lat S 8°14.07
start stop duration Lon E 13°15.88
TIME :07:33:21 08:04:37 31.3 (min) Purpose : 1
LOG : 4440.66 4442.67 2.0 Region : 4000
FDEPTH: 23 24 Gear cond.: 0
BDEPTH: 23 24 Validity : 0
Towing dir: 0° Wire out : 110 m Speed : 3.8 kn
Sorted : 155 Total catch: 372.97 Catch/hour: 715.65

SPECIES	CATCH/HOUR weight	CATCH/HOUR numbers	% OF TOT. C	SAMP
Galeoides decadactylus	216.48	1520	30.25	
Pseudotolithus typus	104.00	345	14.53	
Pteroscion peli	92.01	1736	12.86	
Ilisha africana	91.74	4914	12.82	
Brachydeuterus auritus	78.94	2168	11.03	
Pomadasys rogeri	26.81	27	3.75	
Cynoglossus cadenati	13.95	33	1.95	
Trichiurus lepturus	13.58	90	1.90	
Dicologoglossa cuneata	13.12	102	1.83	
Pomadasys jubelini	12.89	59	1.80	
Lagocephalus laevigatus	12.17	10	1.70	
Chloroscombrus chrysurus	7.46	272	1.04	
Pomadasys incisus	6.95	50	0.97	
Eucinostomus melanopterus	6.68	102	0.93	
Pentanemus quinquarius	4.93	115	0.69	
Drepane africana	3.42	10	0.48	
Selene dorsalis	3.36	88	0.47	
Sphyraena guachancho	2.21	19	0.31	
Penaeus notialis	2.07	36	0.29	
TORPEDINIDAE	1.80	10	0.25	
Parapenaeopsis atlantica	0.96	349	0.13	
Raja miraletus	0.10	13	0.01	
Octopus vulgaris	0.05	23	0.01	
Total	715.65		100.00	

R/V Dr. Fridtjof Nansen SURVEY:2014404 STATION: 15
DATE :11/06/14 GEAR TYPE: PT NO: 1 POSITION:Lat S 8°36.75
start stop duration Lon E 13°3.88
TIME :16:24:41 17:04:52 40.2 (min) Purpose : 1
LOG : 4489.69 4491.83 2.1 Region : 4000
FDEPTH: 85 95 Gear cond.: 0
BDEPTH: 114 116 Validity : 0
Towing dir: 0° Wire out : 250 m Speed : 3.2 kn
Sorted : 0 Total catch: 56.50 Catch/hour: 84.37

SPECIES	CATCH/HOUR weight	CATCH/HOUR numbers	% OF TOT. C	SAMP
Brachydeuterus auritus	71.68	587	84.96	
Sarda sarda	12.69	13	15.04	
Total	84.37		100.00	

R/V Dr. Fridtjof Nansen SURVEY:2014404 STATION: 16
DATE :11/06/14 GEAR TYPE: PT NO: 1 POSITION:Lat S 8°34.64
start stop duration Lon E 13°16.33
TIME :20:49:01 21:11:04 22.1 (min) Purpose : 1
LOG : 4515.24 4516.41 1.2 Region : 4000
FDEPTH: 5 0 Gear cond.: 0
BDEPTH: 45 48 Validity : 0
Towing dir: 0° Wire out : 110 m Speed : 3.2 kn
Sorted : 0 Total catch: 1518.51 Catch/hour: 4132.00

SPECIES	CATCH/HOUR weight	CATCH/HOUR numbers	% OF TOT. C	SAMP
Sardinella maderensis	2068.57	30000	50.06	17
Sardinella aurita	1828.57	11943	44.25	16
Trachurus trecae	130.86	3486	3.17	
Selene dorsalis	39.43	857	0.95	
Ilisha africana	29.14	457	0.71	
Sphyraena guachancho	12.57	57	0.30	
Brachydeuterus auritus	9.14	171	0.22	
Scomber japonicus	8.00	57	0.19	
Lichia amia	5.71	57	0.14	
Total	4132.00		100.00	

R/V Dr. Fridtjof Nansen SURVEY:2014404 STATION: 17
DATE :12/06/14 GEAR TYPE: PT NO: 1 POSITION:Lat S 8°50.76
start stop duration Lon E 13°5.14
TIME :01:47:37 02:16:33 28.9 (min) Purpose : 1
LOG : 4547.44 4549.05 1.6 Region : 4000
FDEPTH: 40 0 Gear cond.: 0
BDEPTH: 108 109 Validity : 0
Towing dir: 0° Wire out : 120 m Speed : 3.3 kn
Sorted : 0 Total catch: 25.85 Catch/hour: 53.63

SPECIES	CATCH/HOUR weight	CATCH/HOUR numbers	% OF TOT. C	SAMP
Brachydeuterus auritus	46.80	349	87.27	
Lagocephalus laevigatus	3.82	4	7.12	
Trachurus trecae	1.87	52	3.48	18
Engraulis encrasicolus	0.85	166	1.59	
Trichiurus lepturus	0.27	8	0.50	
Selene dorsalis	0.02	10	0.04	
Total	53.63		100.00	

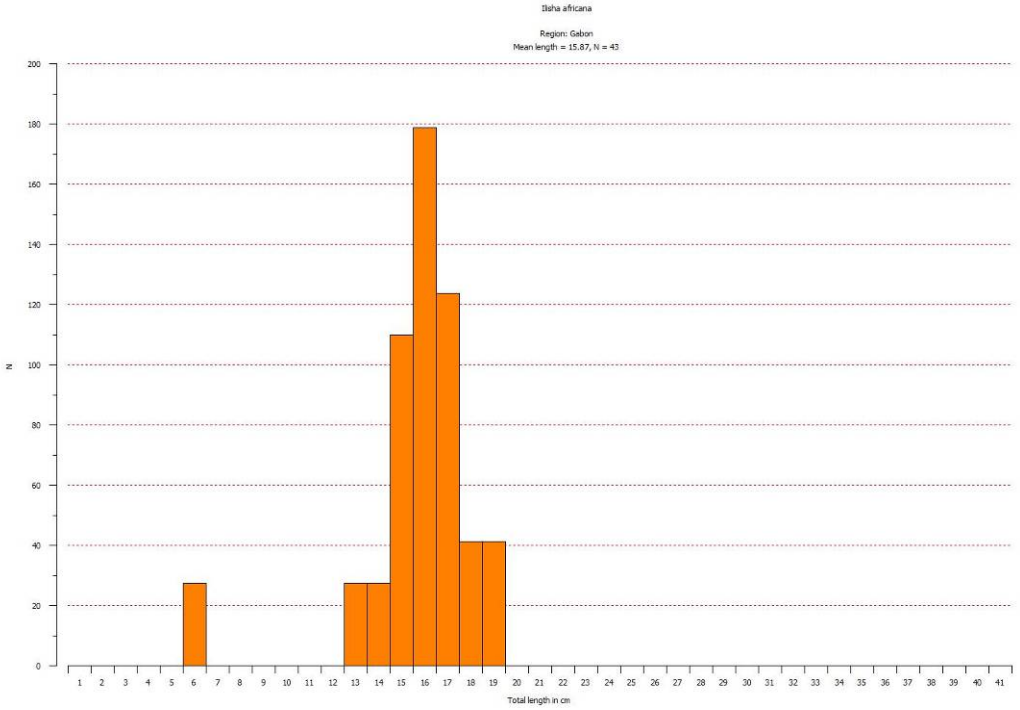
R/V Dr. Fridtjof Nansen SURVEY:2014404 STATION: 18
DATE :12/06/14 GEAR TYPE: PT NO: 1 POSITION:Lat S 9°18.94
start stop duration Lon E 12°57.65
TIME :18:19:32 18:51:14 31.7 (min) Purpose : 1
LOG : 4645.59 4647.13 1.5 Region : 4000
FDEPTH: 0 0 Gear cond.: 0
BDEPTH: 35 47 Validity : 0
Towing dir: 0° Wire out : 110 m Speed : 2.9 kn
Sorted : 64 Total catch: 540.66 Catch/hour: 1023.33

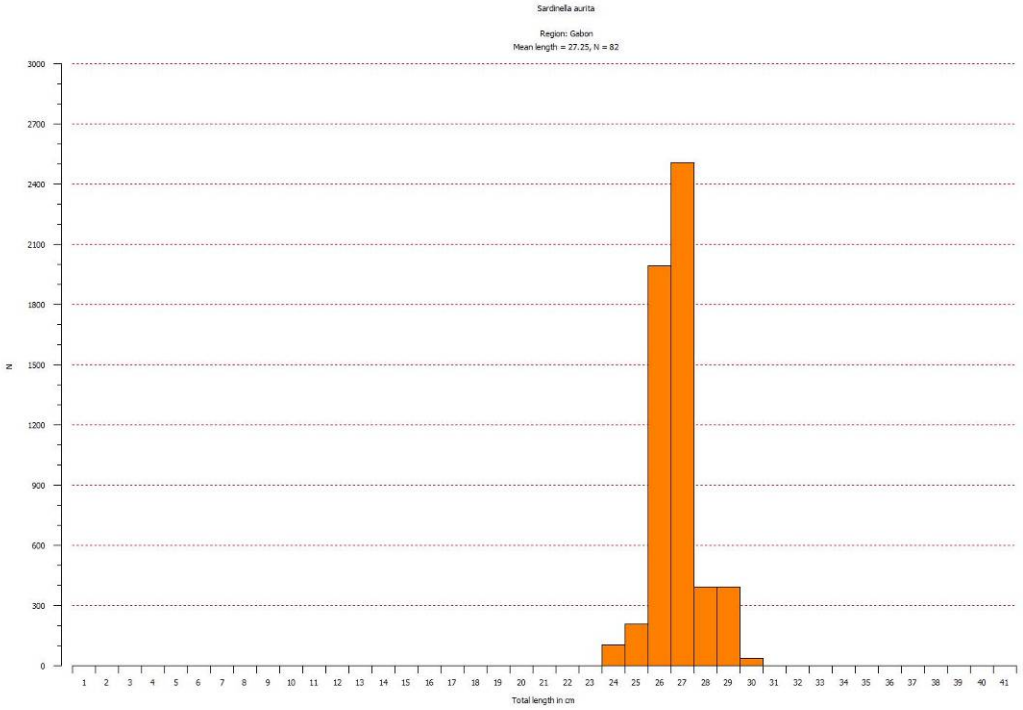
SPECIES	CATCH/HOUR weight	CATCH/HOUR numbers	% OF TOT. C	SAMP
Sardinella aurita	440.50	6114	43.05	19
Brachydeuterus auritus	233.28	3604	22.80	
Sardinella maderensis	122.91	1544	12.01	20
Chloroscombrus chrysurus	98.95	901	9.67	
Sphyraena guachancho	54.04	161	5.28	
Trachurus trecae	28.32	483	2.77	
Selene dorsalis	20.54	500	2.01	
Ilisha africana	11.91	225	1.16	
Selar crumenophthalmus	5.32	17	0.52	
Trichiurus lepturus	3.86	49	0.38	
Galeoides decadactylus	3.71	32	0.36	
Total	1023.33		100.00	

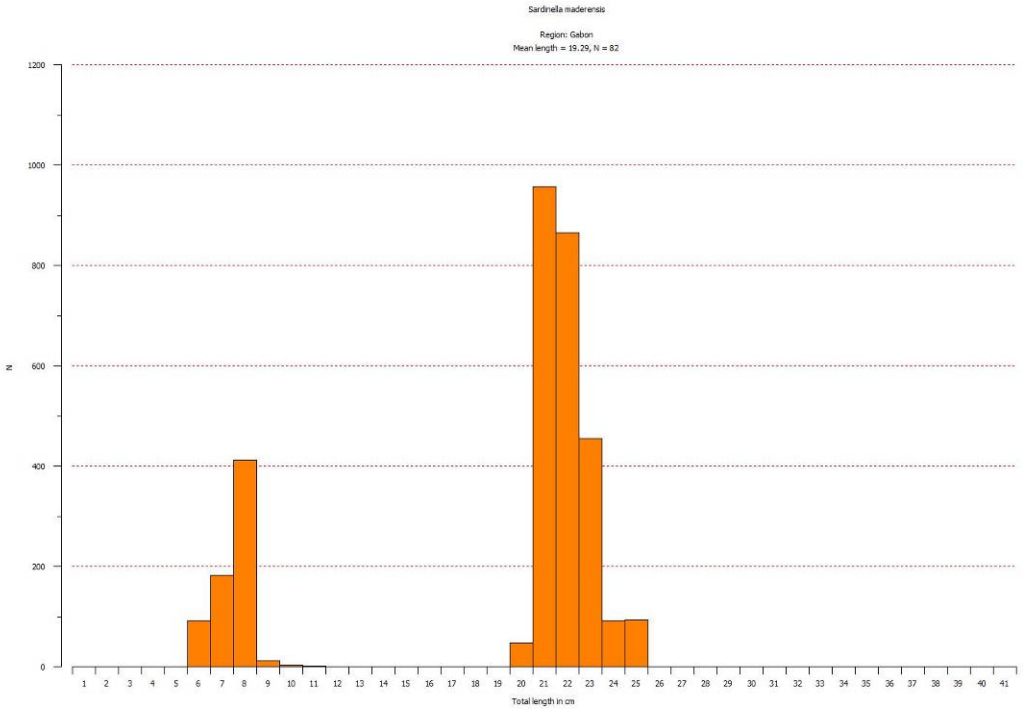
R/V Dr. Fridtjof Nansen SURVEY:2014404 STATION: 19
DATE :13/06/14 GEAR TYPE: BT NO: 26 POSITION:Lat S 10°3.61
start stop duration Lon E 13°17.52
TIME :14:55:17 15:31:19 36.0 (min) Purpose : 1
LOG : 4773.68 4775.90 2.2 Region : 4000
FDEPTH: 22 24 Gear cond.: 0
BDEPTH: 22 24 Validity : 0
Towing dir: 0° Wire out : 110 m Speed : 3.7 kn
Sorted : 0 Total catch: 1296.35 Catch/hour: 2158.78

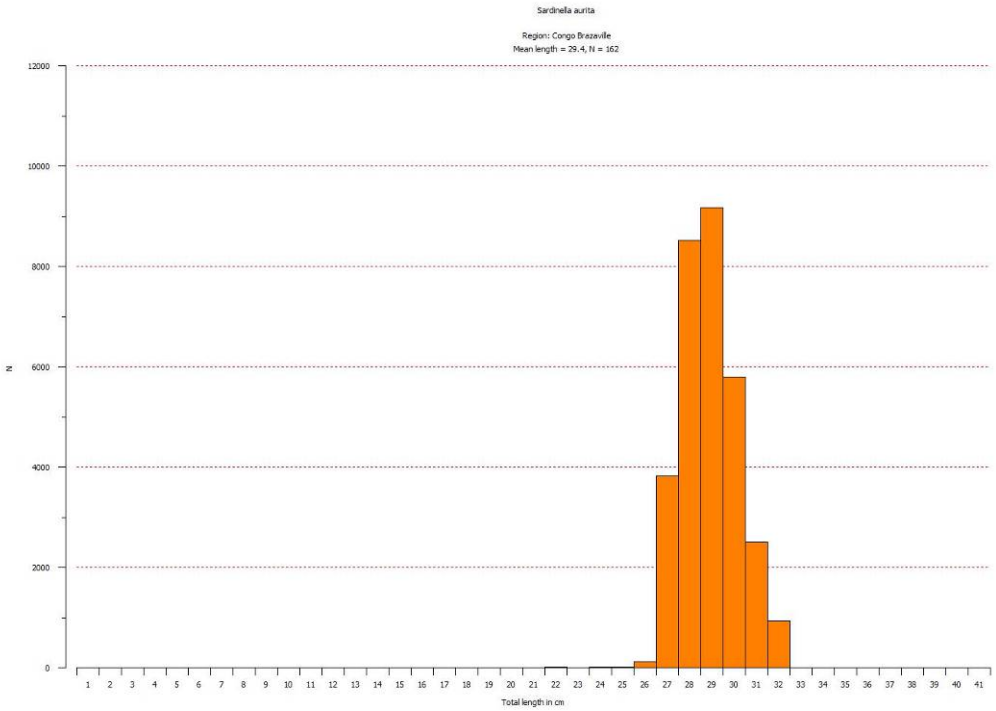
SPECIES	CATCH/HOUR weight	CATCH/HOUR numbers	% OF TOT. C	SAMP
Brachydeuterus auritus	798.80	17915	37.00	
Ilisha africana	278.27	6010	12.89	
Selene dorsalis	167.09	3710	7.74	
Trachurus trecae	139.77	1775	6.47	23
Galeoides decadactylus	131.12	1116	6.07	
Tarpon atlanticus	116.57	2	5.40	
Pteroscion peli	113.59	3369	5.26	
Sardinella aurita	94.02	1024	4.36	21
Pseudotolithus typus	84.76	386	3.93	
Chloroscombrus chrysurus	48.96	546	2.27	
Dicologoglossa cuneata	46.89	92	2.17	
Sardinella maderensis	42.13	1229	1.95	22
Arius parkii	41.47	113	1.92	
Pomadasys rogeri	31.42	318	1.46	
Penaeus notialis	7.74	1639	0.36	
Pomadasys jubelini	6.83	23	0.32	
Trichiurus lepturus	2.73	113	0.13	
Zanobatus shoenleinii **	2.73	23	0.13	
Pentanemus quinquarius	1.60	23	0.07	
Gymnura micrura	1.37	23	0.06	
Pegusa lascaris	0.92	23	0.04	
Total	2158.78		100.00	

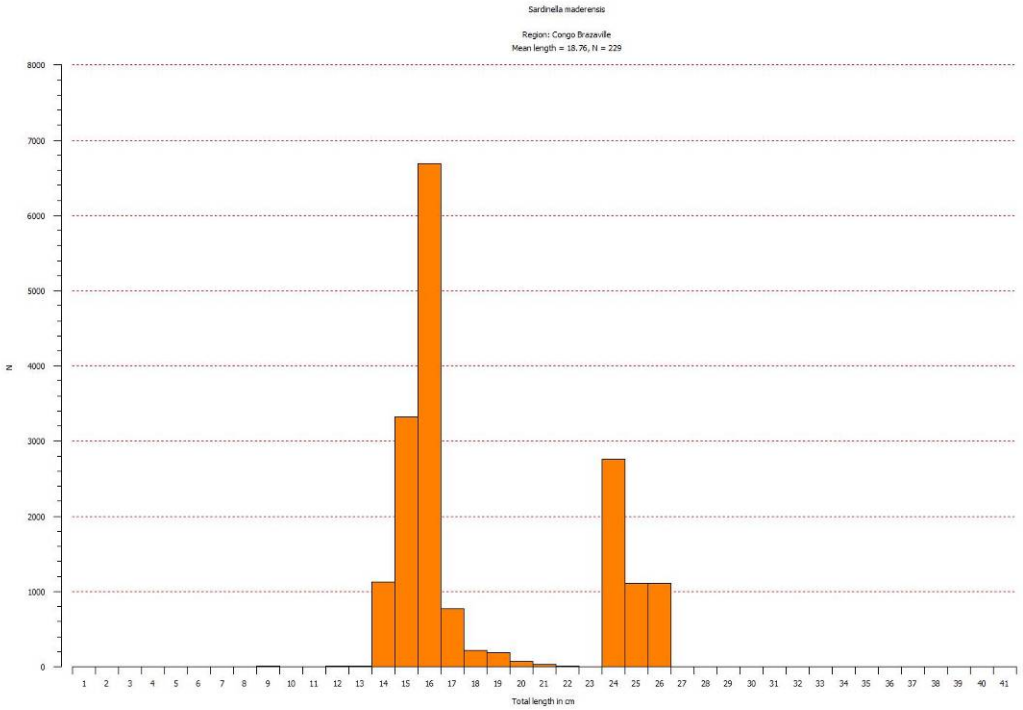
ANNEX II Length frequencies of main species

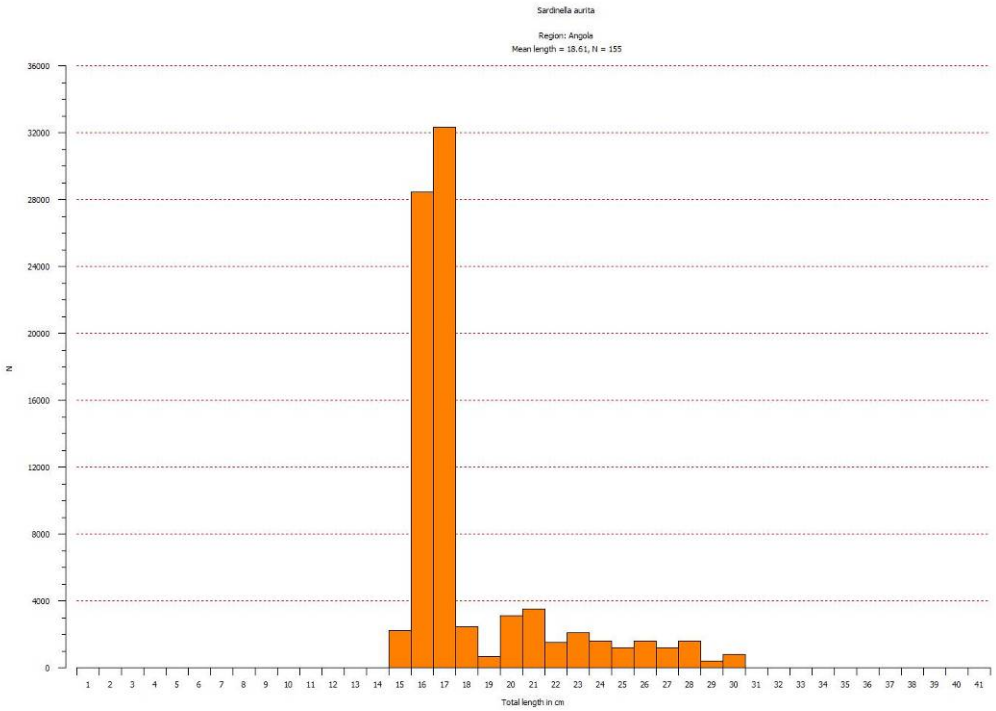


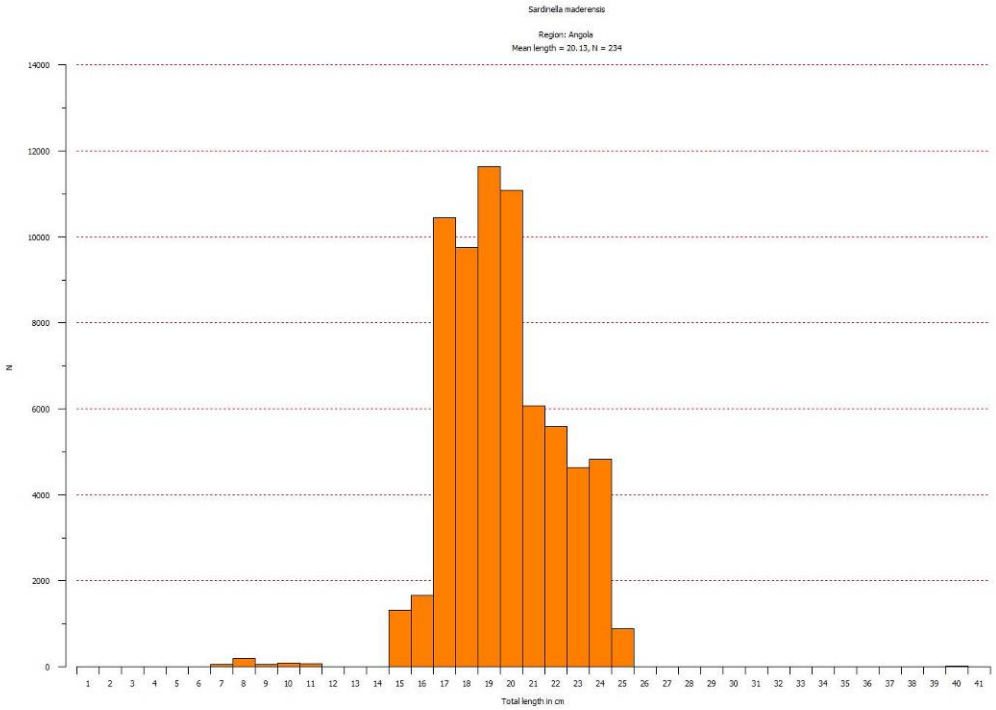


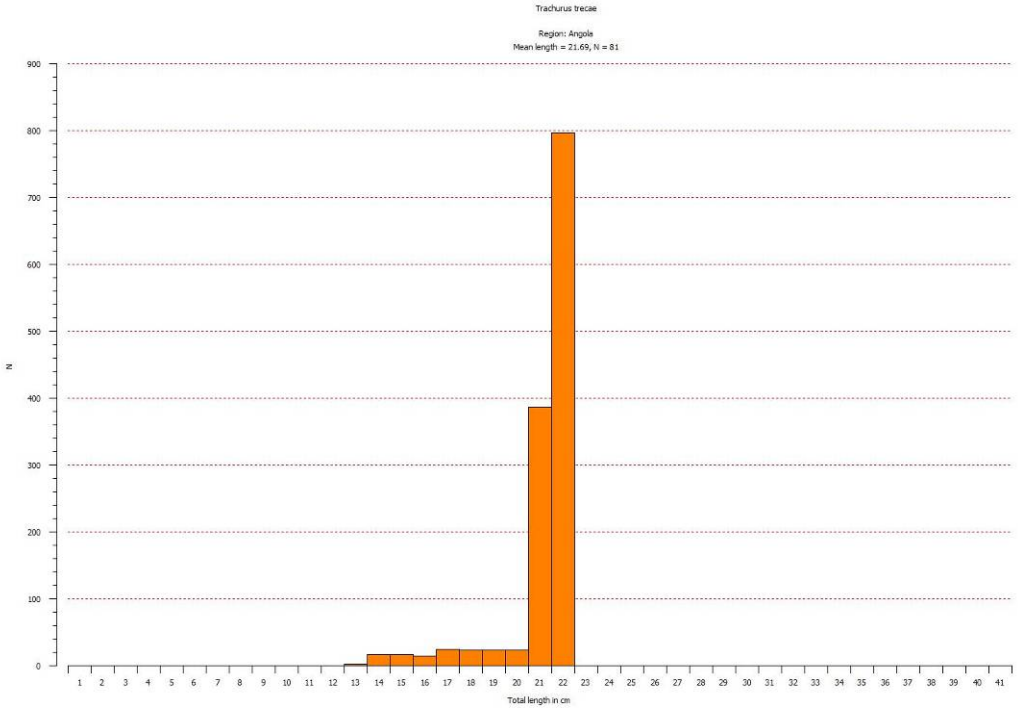

Sardinella maderensis
Region: Gabon
Mean length = 19.29, N = 82
N
Total length in cm


Sardinella aurita
Region: Congo Brazaville
Mean length = 29.4, N = 162
N
Total length in cm


Sardinella maderensis
Region: Congo Brazaville
Mean length = 18.76, N = 229
N
Total length in cm


Sardinella aurita
Region: Angola
Mean length = 18.61, N = 155
N
Total length in cm


Sardinella maderensis
Region: Angola
Mean length = 20.13, N = 234
N
Total length in cm


Trachurus trecae
Region: Angola
Mean length = 21.69, N = 81
N
Total length in cm

ANNEX III M**aturity stages for horse mackerel and sardinella**

Stage	**Maturity stage**	**Description**
I	Immature	Small gonads, do not occupy more than 1/3 of abdominal cavity length. Ovary pinkish; testis whitish. Ovary not visible to naked eye
II	Maturing virgin and recovering spent	The gonads begin to develop, increasing substantially in size; about ½ length of the abdominal cavity. Gonads more opaque, small points visible to the naked eye (oocytes at the beginning of vitelogenese).The gonads in rest/recovery more flaccid with some more conspicuous blood than the gonads in development.

III	Mature. Before pre-spawning	At the beginning, oocytes more conspicuous giving the gonad a granular aspect. Ovary yellow-orange, testis creamy. Visible sperm in testis if open. Gonads quite swollen in the beginning of the reproduction period. Gonads that have spawned once lose consistency, but opaque oocytes present, and sperm in testis if cut. At the end of the stage is possible to find some translucent oocytes. Gonads occupy about 2/3 of abdominal cavity.
IV	Mature Pre-spawning	The gonads occupy about 2/3 of abdominal cavity. Ovaries orange in colour with visible blood vessels. Most oocytes translucent, testis creamy, flat and brilliant texture. The gonads stop flowing oocytes and sperm flows at low pressure.
V	Mature. In spawning	The gonads occupy about 2/3 or less of abdominal cavity. Ovaries orange in colour with the conspicuous blood vessels, blood stained mainly in one end. Most oocytes translucent; testis creamy, flat and brilliant texture. The gonads stop flowing oocytes and sperm flows at low pressure. Pink stains at the end of gonad.
VI	Post-spawning	The gonads decrease in size and occupy about ½ or less, of abdominal cavity. Gonads flaccid and bloody. Ovary can contain remaining oocytes that were not emitted. Testis may have sperm remaining in the seminal duct. Pinkish areas in the whole extension of the gonad.

ANNEX IV Allocation of acoustic densities to species groups.

Note that for the groups sardinella, horse mackerel, big-eye grunt and pilchard all encountered species are listed, while only examples are listed for the remaining groups.

Group	Taxon	Species
Sardinella	*Sardinella* sp.	*S. aurita*
		S. maderensis
Horse mackerel	*Trachurus* sp.	*T. trecae*
		T. trachurus capensis
Pilchard	Sardinops	*S. ocellatus*
Big-eye grunt		*Brachydeuterus auritus*
Pelagic species 1	Clupeiformes[1]	*Ilisha africana*
		Etrumeus whiteheadi
		Engraulis encrasicolus
Pelagic species 2	Carangidae[2]	*Selene dorsalis*
		Chloroscombrus chrysurus
		Decapterus rhonchus
		Seriola carpenteri
	Scombridae	*Auxis thazard*
		Sarda sarda
		Scomber japonicus
	Sphyraenidae	*Sphyraena guachancho*
	Others	*Trichiurus lepturus*
		Lepidopus caudatus
Other demersal species	Sparidae[3]	*Dentex angolensis*
		D. macrophthalmus
		D. congoensis
		D. canariensis
		D. barnardi
		Pagellus bellottii
		Sparus caeruleostictus
		S. pagrus africanus
	Other taxii	*Saurida brasiliensis*
		Arioma bondi
		Pomadasys incisus
		Galeoides decadactylus
Mesopelagic species	Myctophidae$_3$	*Diaphus dumerili*
	Other mesopelagic fish	*Trachinocephalus myops*
Plankton	Calanoidae	*Calanus* sp.
	Euphausiidae	*Meganyctiphanes sp.*
	Other plankton	

[1] other than *Sardinops* sp.; [2] other than *Trachurus* sp.; [3] main taxon in group.

ANNEX V Instruments and fishing gear used

The Simrad ER-60/18, 38, and 120 kHz scientific sounder was run during the survey for fish observation and bottom conditions. Standard sphere calibrations were carried out in Kyunn Phi Lar, Myanmar, 14.12.2013 using 64 and 60 mm diameter copper spheres and 38.1 mm tungsten carbide sphere for 18, 38, 120 and 200 kHz, respectively. The details of the settings of the 38 kHz echo sounder where as follows:

Transceiver-2 menu (38 kHz)

Transducer depth	5.50 m
Absorption coefficient (variable with conditions)	9.5 dB/km
Pulse length	medium (1,024ms)
Bandwidth	2.43 kHz
Max power	2000 Watt
2-way beam angle	-20,6dB
Gain	26.13 dB
SA correction	-0.71 dB
Angle sensitivity	21.9
3 dB beam width	6.75º along ship
	6.95º athwart ship
Along ship offset	0.11º
Athwart ship offset	0.05º

Bottom detection menu

Minimum level	-45 dB

Fishing gear

The vessel has two different sized "Åkrahamn" pelagic trawls and one "Gisund super bottom trawl". Trawls were used for identification of acoustic targets only.

The bottom trawl has a headline of 31 m, footrope 47 m and 20 mm mesh size in the cod end with an inner net of 10 mm mesh size. The trawl height was about 4.5 m and distance between wings during towing about 21 m. The sweeps are 40 m long. The trawl is equipped with a 12" rubber bobbins gear. New doors are 'Thyborøn' combi type, 7.41 m^2, 1720 kg. These have been in use onboard since 19.02.08.

The SCANMAR system was used on all trawl hauls. This equipment consists of sensors, a hydrophone, a receiver, a display unit and a battery charger. Communication between sensors and ship is based on acoustic transmission. The doors are fitted with sensors to provide information on their distance, and the trawl was equipped with a trawl eye that provides information about the trawl opening. A catch sensor on the cod-end indicated the size of the catch.