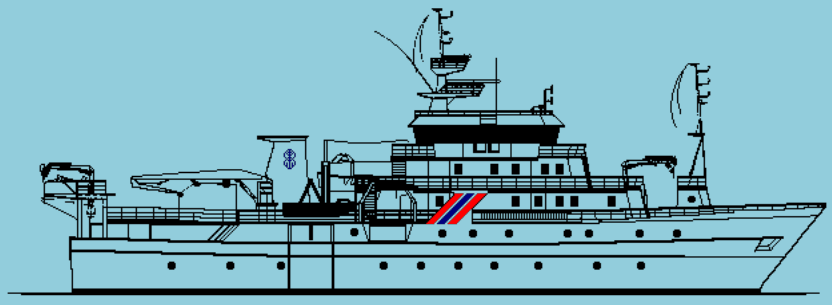

Recruitment studies on Sardinella, *Sardinella aurita* and *S. maderensis,* in the coastal waters of Gabon and Republic of the Congo

25 April – 6 May 2016

2016

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 is 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 and Republic of the Congo

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, Republic of the Congo and Angola, and investigations carried out by the EAF-Nansen project indicate for both stocks that more than 25% of the total abundance within this region (especially juveniles and large adults) can be found off Republic of the 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 Republic of the Congo and Gabon south of Cape Lopez, but the detailed distribution of larvae and retention mechanisms involved are poorly investigated. This information is critical to avoid negative impacts on these critical habitats and for understanding the possible impacts of climate change on stock abundance. In this context it is important to be aware that this region also has very high oil related industrial activities. A large-scale oil spill or of other chemicals during the recruitment/nursery period is assumed to have potentially 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.

Sardinellas 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.

Republic of the Congo

Small pelagic fish species are caught in Republic of the 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 (2014) about 689 canoes fishing in Republic of the 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.

General objectives

This aim of the survey was, as during the 2014 survey, 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

The previous egg and larvae survey in this region established the identified spawning area north of Cabinda as the most important in the region for *S. aurita* during this time of the year, and identified that the spawning was found in the Congo River plume, probably just below the pycnocline. The hatched larvae were 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. The present survey confirmed these observations. 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 that the older larvae take advantage of the undercurrent or coastal moving eddies to become transported towards the coast further north.

Participation

The scientific members during the cruise were:

From Institute of Marine Research Norway:

Jens-Otto Krakstad (cruise leader), Tore Mørk, Øystein Skagseth, Inge Nymark, Espen Bagøien and Tor Ensrud

From INIP, Angola:

Domingas N'saku and Geraldina De Assunção Salvador José

From Direction Générale des Pêches et de l`Aquaculture, Gabon

Jean de Dieu Lewembe, Jean Herve Mve Beh, Jean Noel Bibang Bi Nguema and Gratienne Ndinga Epse Manfoumbi

From Direction Générale de la Pêche et de l`Aquaculture, Republic of the Congo

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

Narrative

The vessel left Pointe Noire in Republic of the Congo on the 26th April in the afternoon and after bunkering at sea the next morning the vessel continued northward to the start of the area of investigation immediately south of the restricted area off Cape Lopez in Gabon. 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 and one Multinet for sampling of egg and larvae to 75 m depth or the bottom if shallower. Acoustic registrations were made on 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. On the 3/5 the vessel crossed the border into Republic of the Congo and continued the survey in Congolese waters. Unfortunately, a severe engine problems was experienced in the morning on the 4/5. Consequently, the survey had to be aborted. The vessel thereafter came in to Pointe Noire on the 6/5 in the morning and all scientists were offloaded.

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 Figure 1.1.

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.

		Republic of the Congo
Regions	Gabon	Brazzaville
Date	26/04/16 - 03/05/16	03/05/16 - 04/05/16
Distance Travelled (NM)	746.2	117.73
PT Stations	8	1
CTD Stations	65	5
Plankton Stations*	156	11

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

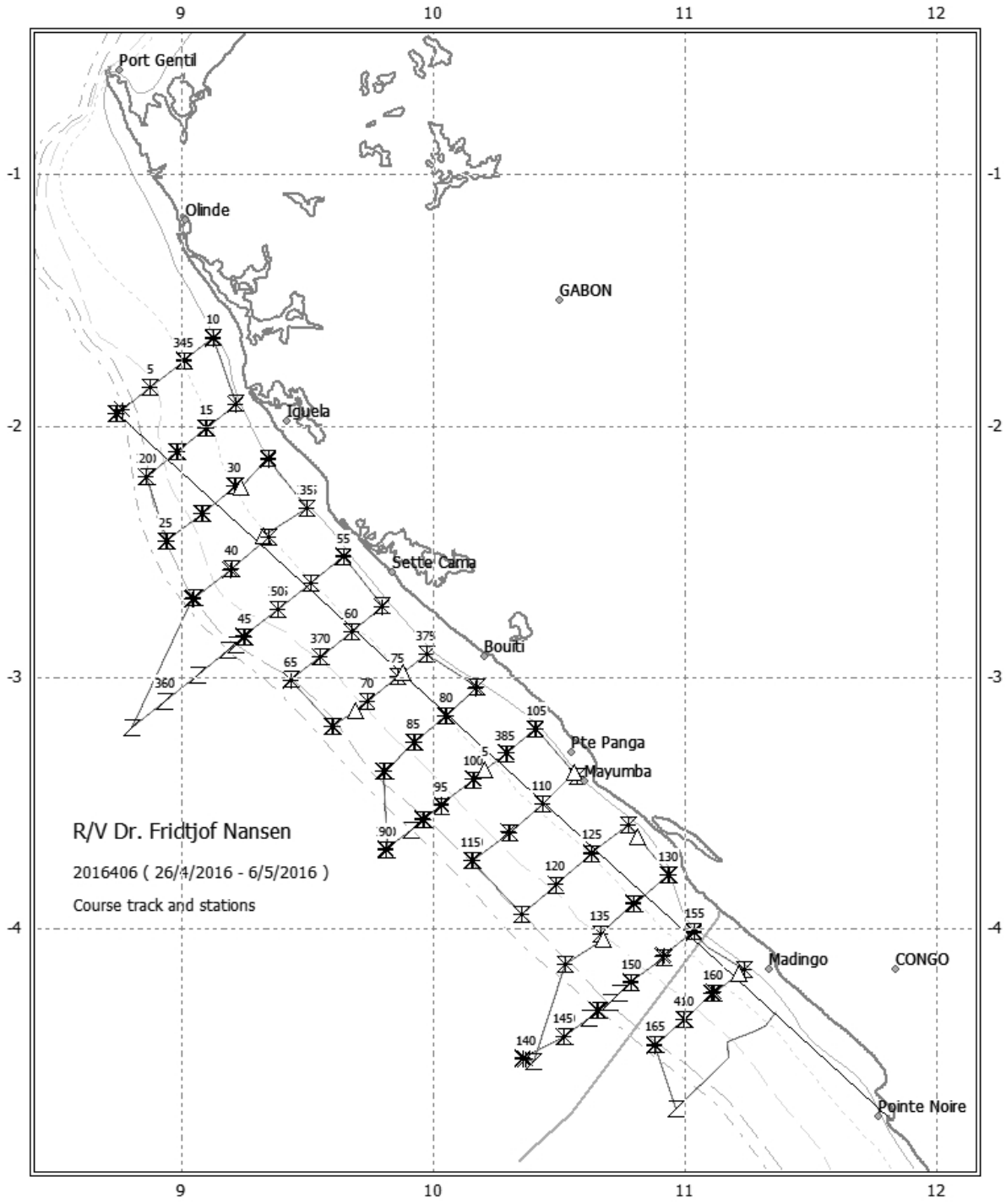


Figure 1.1. Course track Gabon-Republic of the Congo. Pelagic (Δ) trawl stations, hydrographic (Z) stations and plankton (×) stations. Depth contours are indicated.

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 WIMDA meteorological sensor.

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 2400 m.

Niskin water-bottles (12 units á 10 L) attached to a CTD-mounted rosette were used to collect seawater at predefined depths (see below). The CTD was not stopped in the water column prior to closing the Niskin bottles, so no special effort was made to pinpoint the exact depths of the seawater samples that were used both for salinity and oxygen validation.

For validation of the salinity (conductivity) measurements of the CTD, the salinity of seawater at station 399 collected by Niskin-bottles at 12 depths between ca. 5 and 2400 m was analysed using a Portasal salinometer (mod. 8410A) on board the vessel (Figure 2.1). The salinity-readings of the sensor were confirmed to the 2. decimal in 8 cases, to the 1. decimal in two cases, while the 1. decimal differed for the 2 remaining cases (Table 2.1).

To validate the oxygen-measurements from the CTD-mounted sensor, concentrations of dissolved oxygen in the seawater-samples collected with the Niskin-bottles were analysed in the ship laboratory by Winkler red-ox titration. The method is based om Winkler (1888), but modified for enhanced precision (e.g. Carpenter 1965, Murray et al. 1968, Strickland AND Parsons 1968, Culberson et al. 1991). The present version of the method is described by Grasshoff et al. (1983). Twelve samples collected between ca. 5 and 2400 m at station 399 were analysed, and in one case the sample was over-titrated and therefore excluded (Figure 2.2). The average difference between the results of the oxygen sensor and the Winkler titration was 0.23 mL/L, with the Winkler results always being higher that the CTD sensor (Figure 2.2 and Table 2.2).

Also, attached to the CTD was an uncalibrated Chelsea Mk III Aquatracka fluorometer which measures in situ fluorescence on relative scale.

Table 2.1 Salinity from CTD-sensor vs. Portasal measurements of collected water at station 399.

Bottle	Depth (m)	Salinity CTD	Salinity Portasal	Diff Salinity CTD vs. Portasal	% Diff
1	2393.6	34.948	34.964	-0.016	-0.045
2	1996.6	34.967	34.983	-0.016	-0.047
3	1599.7	34.961	34.956	0.005	0.015
4	1201.7	34.798	34.792	0.006	0.018
5	803.2	34.533	34.530	0.003	0.009
6	406.0	34.757	34.753	0.004	0.012
7	105.2	35.863	35.866	-0.003	-0.008
8	52.1	36.290	36.281	0.008	0.023
9	31.4	35.948	35.846	0.102	0.283
10	20.4	35.594	35.586	0.008	0.022
11	11.6	35.452	35.209	0.243	0.684
12	5.0	32.832	32.832	0.000	0.001

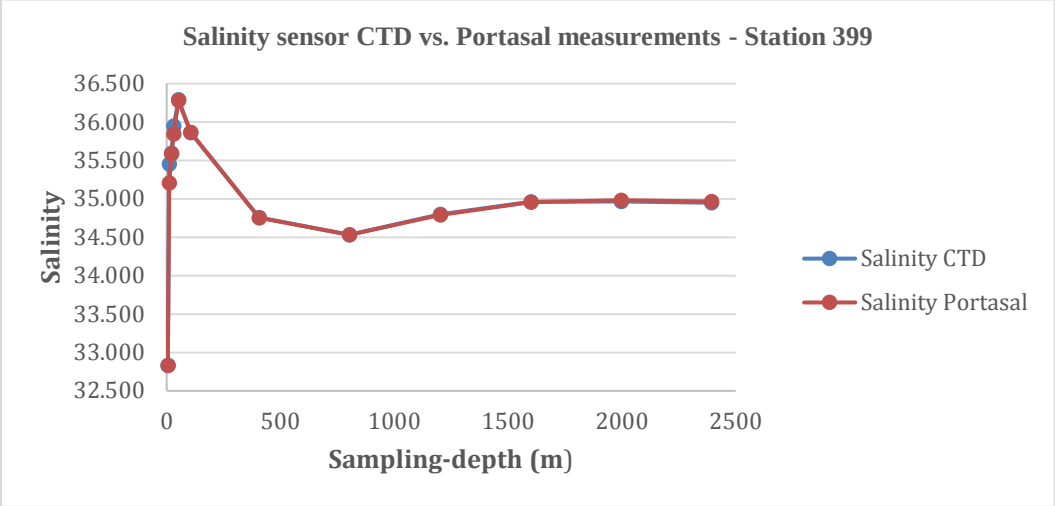


Figure 2.1 **Salinity from CTD-sensor vs Portasal measurements of water collected at St. 399.**

Table 2.2 Oxygen from oxygen sensor versus Winkler titration at station 399.

Bottle	Depth (m)	Oxygen sensor (mL/L)	Oxygen titration (mL/L)	Diff O1-O2	% Diff
1	2393.6	5.121	5.462	-0.341	6.2
2	1996.6	5.154	-	-	-
3	1599.7	4.837	5.098	-0.261	5.1
4	1201.7	3.813	4.016	-0.202	5.0
5	803.2	2.716	2.943	-0.228	7.7
6	406.0	1.446	1.614	-0.168	10.4
7	105.2	2.649	2.842	-0.193	6.8
8	52.1	3.520	3.712	-0.192	5.2
9	31.4	3.690	3.837	-0.147	3.8
10	20.4	3.783	4.065	-0.281	6.9
11	11.6	4.211	4.484	-0.273	6.1
12	5.0	4.594	4.833	-0.240	5.0

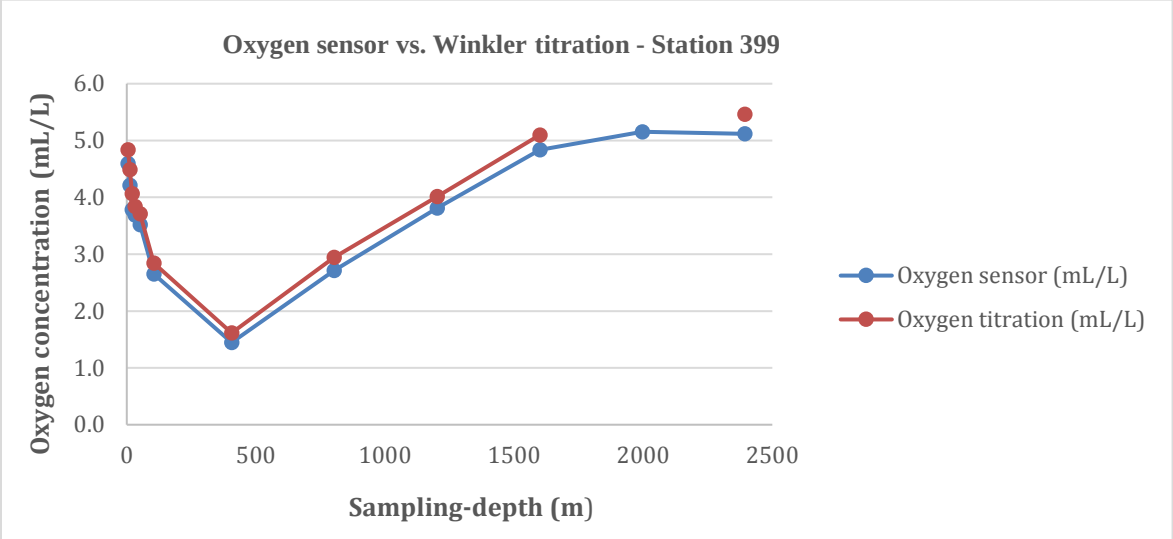


Figure 2.2 Oxygen from CTD-sensor vs. Winkler titration of samples collected at St. 399.

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 152 kHz. The system was run in narrow band mode and data were averaged in 8 m vertical bins.

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 collected at predefined depths with rosette-mounted Niskin bottles attached to the CTD at the plankton stations. In addition, surface-samples were collected manually by bucket. Seawater samples (263 ml) were collected from the standardized depths 0, 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 in the IMR laboratory in Norway. 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). Interference from phaeopigments was corrected for by measuring the amount of pigments once again, after having

added a weak acid (10% HCl). The method of determining the amount of chlorophyll *a* and phaeopigments extracted in 90% acetone was launched in the early nineteen-sixties (Yentsch AND Menzel 1963), but the method itself and the calibration-factors have later been changes several times (e.g. Holm-Hansen et al. 1965, Jeffrey AND Humphrey 1975, Welschmeyer 1994, Humphrey AND Jeffrey 1997, Jeffrey AND Welshmeyer 1997). The measurement of chlorophyll *a* and phaeopigments by the fluorometer was performed per the guidelines of the producer (Turner Designs 1992), and the present version of the method was first described by Holm-Hansen AND Riemann (1978). As part of the post-analysis quality control, the within-station depth profiles for chlorophyll as well as the chlorophyll/phaeopigment ratios were evaluated. This revealed a few values that were believed to be incorrect, and for that reason were excluded from the dataset here presented.

Nutrient samples

Seawater samples (20ml) for nutrient analyses (nitrate, nitrite, silicate and phosphate) were taken from the Niskin water-bottles. Samples were collected from the standard depths of 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 stored in 20 ml polyethylene vials, conserved with 0.2 ml chloroform, and kept cool and dark in a refrigerator (Hagebø and Rey, 1984). The analyses were made on shore by Institute of Marine Research (Bergen, Norway), using a modified Alpkem AutoAnalyzer C (O I Analytical, USA) and following standard procedures (Strickland and Parsons, 1972). Extra standards were added during the analysis to cover the whole measurement range. During the laboratory's quality control of the data, some outlying values that were obviously wrong were excluded. The quality control included evaluation of the ratios between the different nutrients.

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). 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.

Once the Multinet was back on board after a haul, the sample was 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 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 belonging to *Sardinella* spp. 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. In most cases the identified eggs were photographed for documentation purposes.

Microscopic observations of fish egg and larvae were made using a Leica M80 stereo microscope with 10x ocular and 1x objective (microscope 1 and 2). The Nikon D610 dslr camera was mounted on an original Leica beam splitter photo tube. The M80 was equipped with Leica TL5000 Ergo - Flat LED Transmitted Light Base, a Leica LED5000 SLI LED Spotlight Illuminator with Gooseneck and a Leica LED 3000 RL, ring light. The camera exposure and settings was controlled using the Digicam Control version 2.0.0.0 and post processed using Adobe Photoshop CS6. For more details on the Imaging equipment and software see Annex VI.

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 meso-zooplankton. Two hauls were made with the WP2 net at each station. The first from 25 m to the surface, and the second from 200 m (or near the bottom in shallower areas) 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 ~65 °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.

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 last calibrated 21/02/15 in Baia Dos Elefantes, Angola.

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 1.9.0. 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 based on 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:

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

or in the form

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

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

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

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:

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

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

External forcing

The main factors determining the functioning of the Congo-Gabon ecosystem are; i) the freshwater discharge by the Congo River, ii) the large-scale ocean circulation, and iii) the regional wind field.

The Congo River discharge is estimated to about 40.000 m^3/s including a prominent seasonal cycle with maximum during the rainy season in Nov-Jan period, a relative minimum in March, and absolute minimum about July-August (Dai and Trenberth, 2002). The main transport off fresh water the river mouth is westward, and with increasing turbulence, mixing and fan shaping as the water is transported offshore. This light water provides large concentrations of nutrients to the ocean. As the water becomes gradually less turbid downstream from the river mouth, favourable conditions for primary production occur.

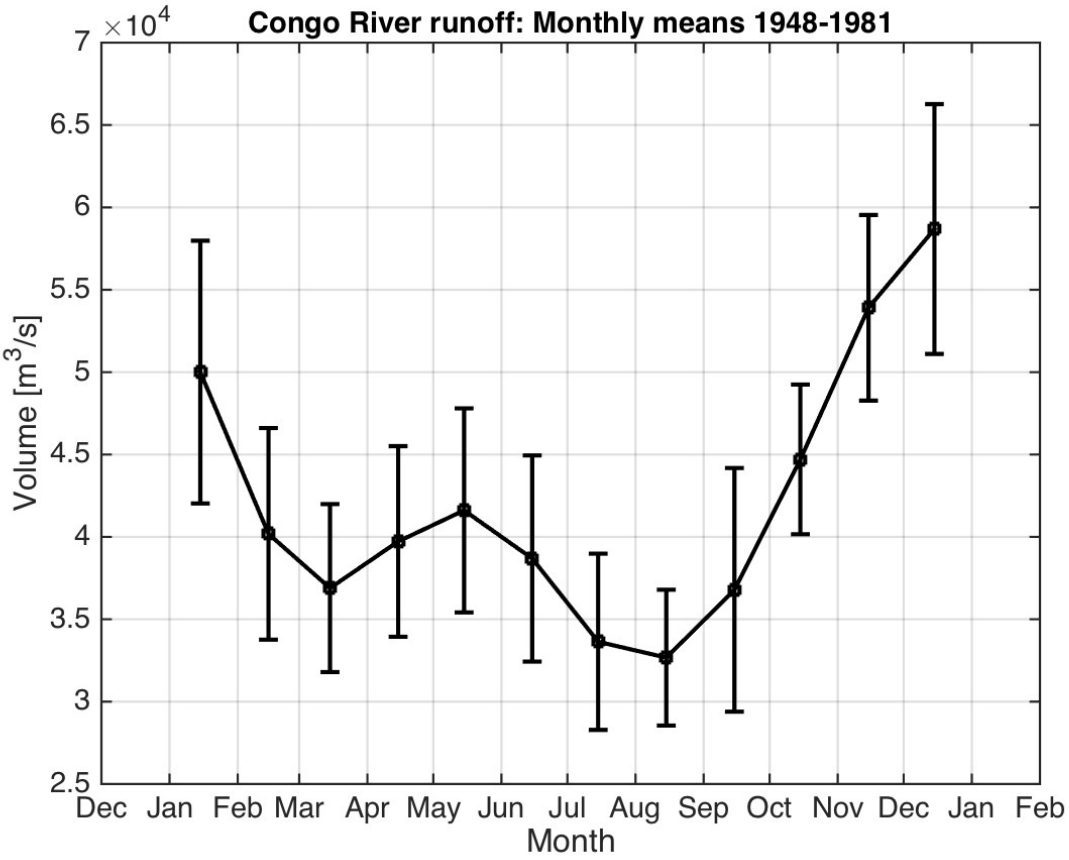


Figure 3.1 The Congo River freshwater discharge showing the mean seasonal cycle over the period 1948-1982. The solid line represents the monthly means and the bars indicate the +/- one standard deviation for a given month. The data are taken from Dai and Trenberth (2002) and downloaded from the http://www.cgd.ucar.edu/cas/catalog/surface/dai-runoff/

To represent the wind forcing we used the Ncep Ncar reanalysis data at a 2.5 by 2.5 degree resolution on a 6 hour time interval to provide near real time data.

(http://www.esrl.noaa.gov/psd/data/gridded/data.ncep.reanalysis.pressure.html). The along-coast component of the wind field is at maximum at 10°S, then decreasing northwards but with a relative maximum at about 4°S (Figure 3.2). Note that this maximum is stronger during May-June compared to the Nov-Jan period. During the cruise 27th April - 7th May 2016 the mean winds were from the south that decrease in magnitude northwards (Figure 3.3)

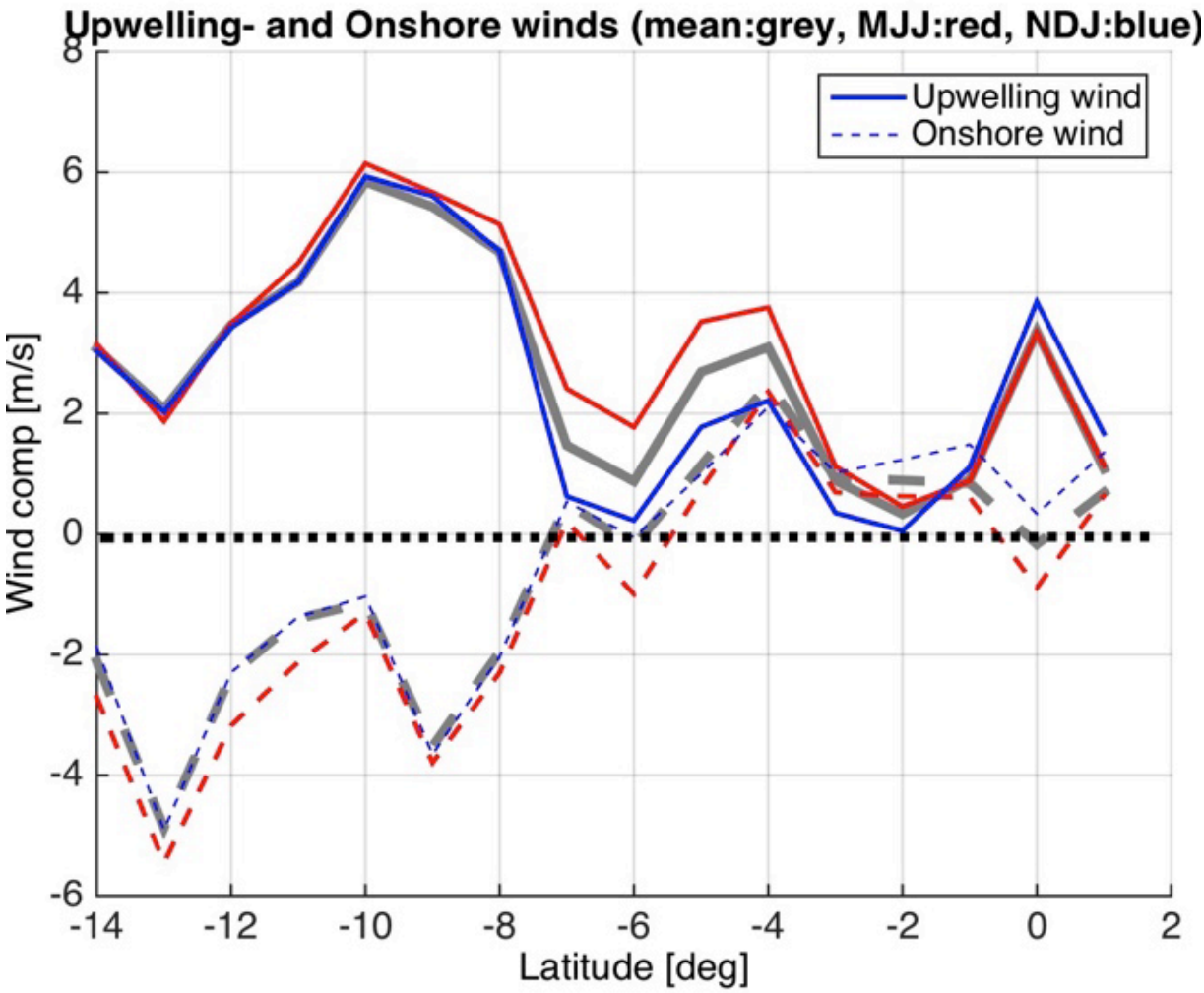


Figure 3.2 The along- and on-shore component of the wind. The convention is such that the along-shore component is defined positive with the coast on the right. Grey colour represent the mean while red is the May-June and blue is the Nov-Jan periods.

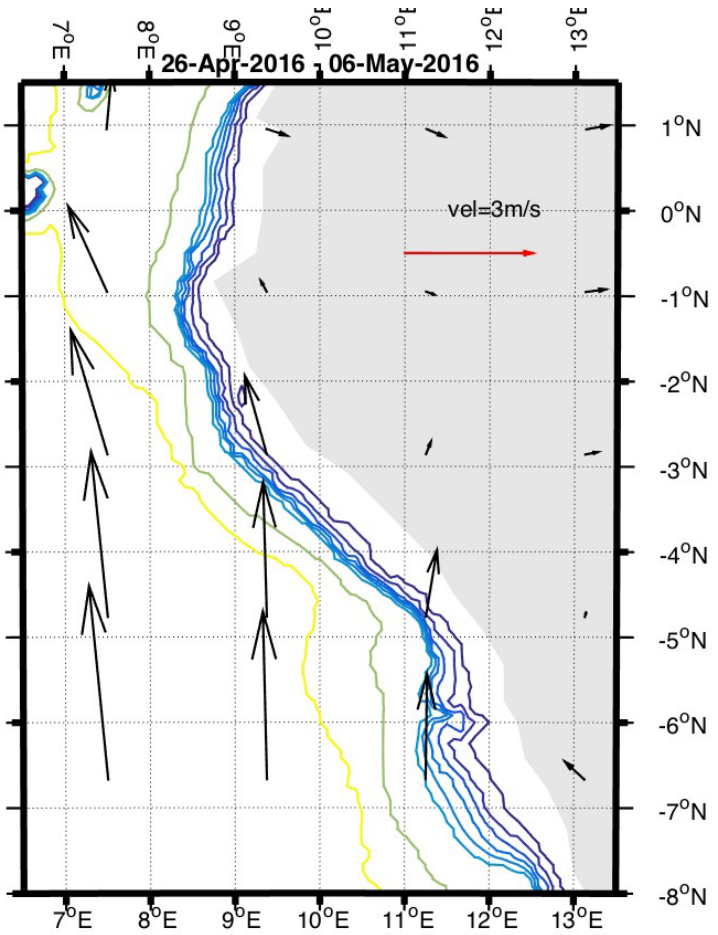


Figure 3.3 The mean wind field during the cruise period from 26 April to 6 May 2016.

The regional scale ocean circulation is illustrated using the Mercator 1/12-degree resolution ocean model (Figure 3.4). Near the surface (5m depth) the light and fresh Congo River water is deflected offshore across the isobaths. Below the subsurface the Gabon-Congo Undercurrent is expected to flow in the opposite direction, i.e. toward southeast, this can be observed in Figure 3.8, however this current is also highly variable (Wancoigne and Piton, 1992; Stramma and Schott, 1999).

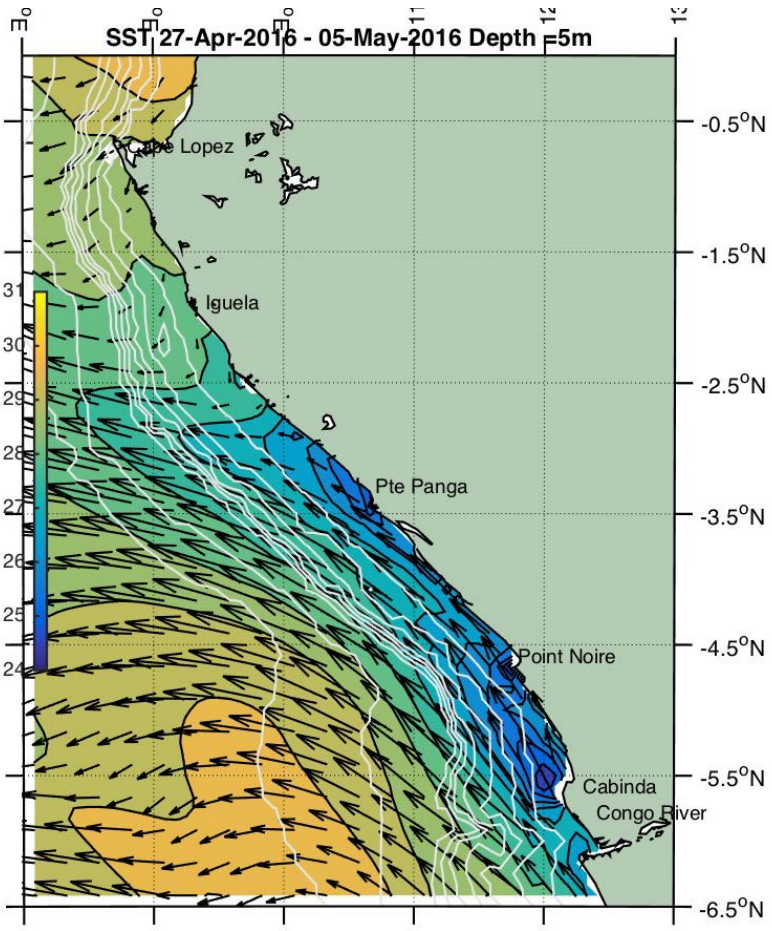


Figure 3.4 Temperature (in colour) and ocean currents (arrows) at 5 m (left) during the cruise period form 27 April to 5 may 2016. The data are from the operational Mercator ocean analysis at 1/12° resolution. The plot is calculated based on daily averaged fields. Data are downloaded from http://marine.copernicus.eu.

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 temperature data may be slightly affected by the vessel pipes systems, but this effect is assumed to be small in this region, due to small temperature difference between the surface water and the ship. The continuous sampling (10 s sampling interval) from this instrument (compared with CTD data) makes it interesting since it captures smaller scale dynamics.

The most prominent feature affecting surface distribution of water masses in the Gabon-Congo region is the Congo River. This water spreads offshore in a fan that transport the water offshore but is deflected mainly to the north due to the current direction under the fresh water plume from the river. In the thermosalinograph data (Figure 3.5). This effect is most visible in the maxima in chlorophyll and turbidity in the southernmost section off Point Noire. For reference the same cruise during 2014 extending further south confirmed this view. Inshore, the effect of the Congo River causes a different situation where colder and more saline water masses are

prominent in the surface layers. This layer is advected from oceanic water masses below the river influenced water. Further north the surface (5 m) temperature increase and salinity decrease. The chlorophyll and turbidity levels show consistent low values except for the southernmost sections where the Congo River surface water is still prominent. Off Gabon, Iguèla, relative high concentrations were found in a narrow band near the coast.

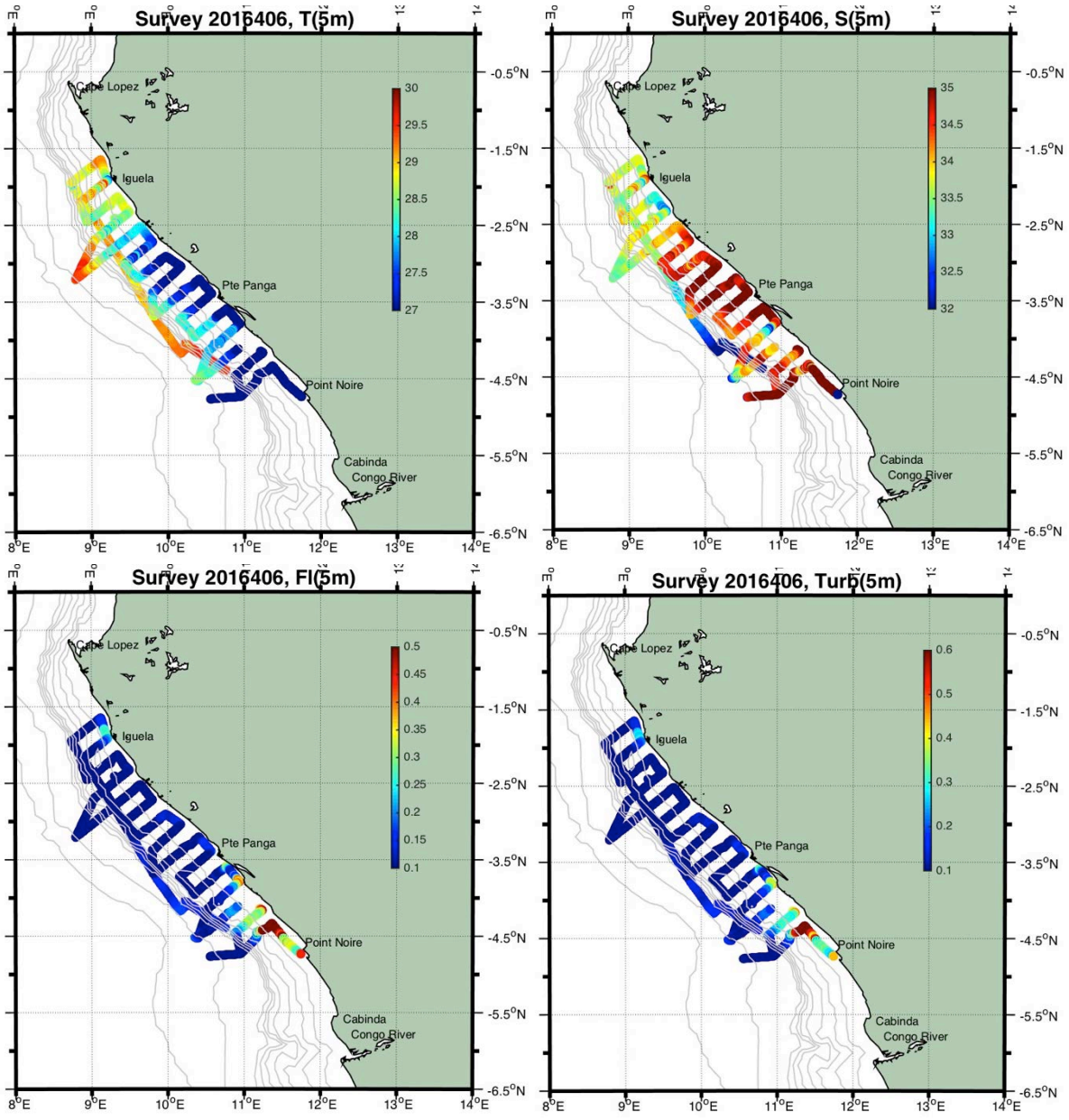


Figure 3.5 Sea surface distributions of temperature, salinity, chlorophyll and turbidity recorded by the thermosalinograph in Gabon–Republic of the Congo in the period 27 April – 6 May 2016.

Based on the CTD data at 50 m (Figure 3.6) the temperature is relatively homogeneous about (about 21^{o}C) but with some higher values near the coast and increasing from Pte. Panga toward Iguèla. For salinity, the minimum is found in the south and near the coast, and increasing northwards.

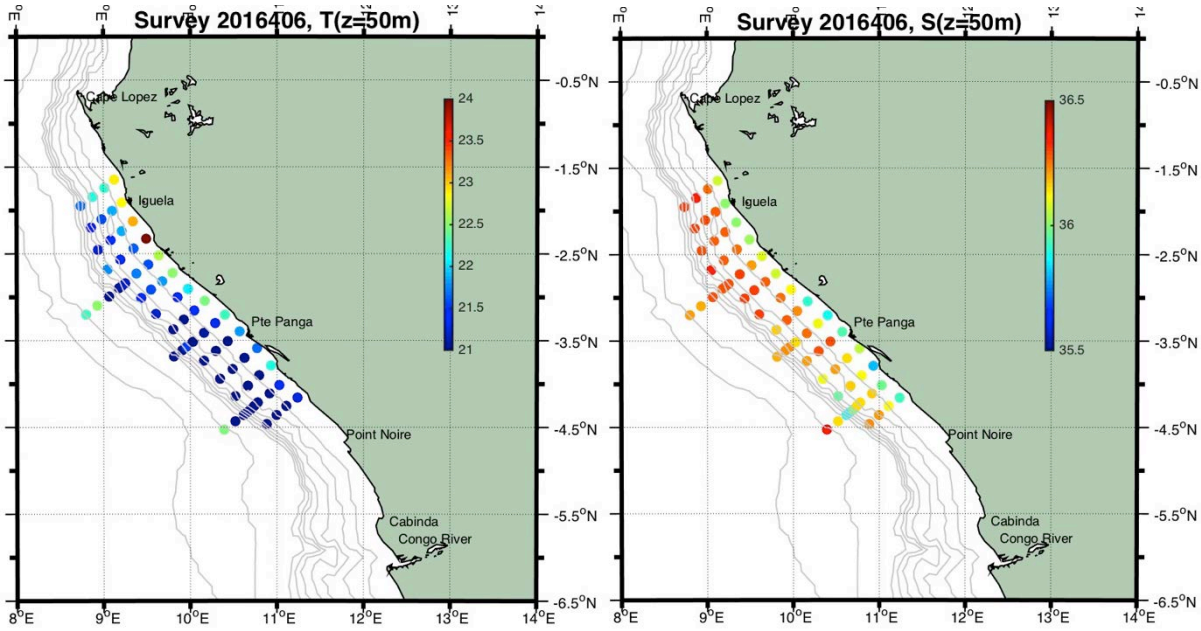


Figure 3.6 Temperature °C (left) and salinity (right) at 50 m depth from the CTD stations.

The depth of maximum in chlorophyll (from the CTD) is shallow (in the upper 10 m) in the south, and northwards on the central shelf this depth increase typically to depths of 30 to 40 m. In the north along the coast these depths are also shallow (range 10 to 20 m).

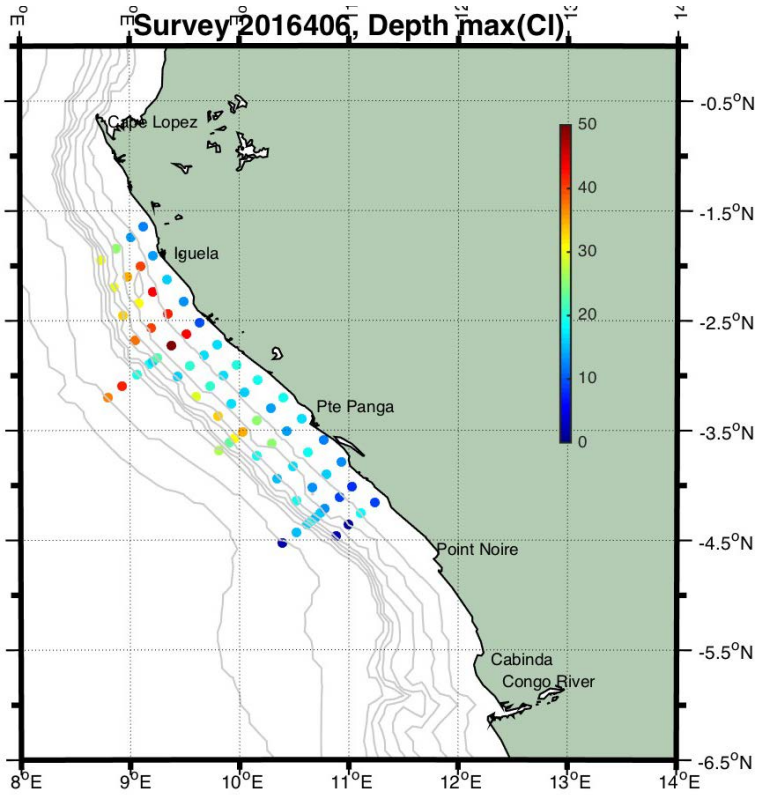


Figure 3.7 Depth of maximum on fluorescence (µg/l) based on the CTD profiles

During the cruise the Vessel Mounted Acoustic Doppler Current Profiler (VM-ADCP) was continuously running providing vertical profiles of the horizontal currents at from the

shallowest depth 24 m and downward at 8 m depth intervals. Maximum depth range is about 400 m. On the shelf the currents consistently flow toward southeast with a tendency for the strongest currents at about 48 m (Figure 3.8). This result confirm the GCUC discussed by Wancogne and Piton, 1992. On the slope, there is indication of a relatively weaker return current (toward northwest) at the 128 m depth. In terms of variability of the GCUC the VM-ADCP currents during the cruise in May-June 2014 showed no indication of the GCUC. In fact, the current was in the opposite direction, toward northwest, at a depth of 25m. This points to the important fact that the Gabon- Congo system is very much coupled to the highly variable and seasonally changing equatorial current system. Stramma and Schott (1999) noted the seasonal change in the position where the Equatorial Under Current turns south in the north-eastern corner of the south Atlantic hence affecting the Angola Dome and the GCUC.

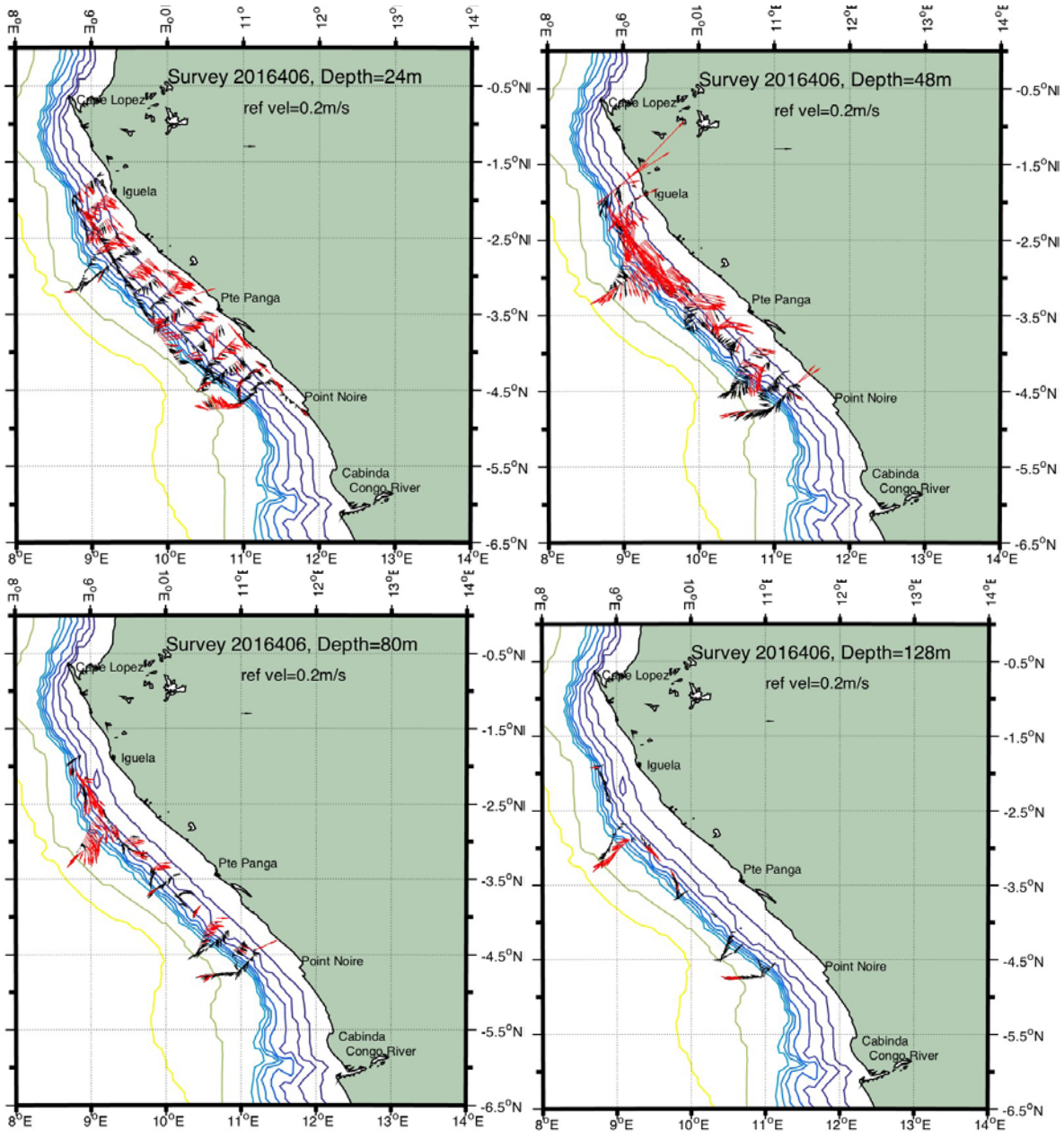


Figure 3.8 Horizontal velocity based on the ship VM ADCP at 24 m (upper left), 48 m (upper right), 80 m (lower left), and 128 m (lower right). Reference velocity at 0.2 m/s are included, and velocities > 0.20 m/s are shown as red.

To resolve the spatio-temporal variability in the upper ocean currents six SVP (Surface Velocity Program) drifters were deployed 6 May 2016 at about 4º31' S 11º09' E. Only one of these have produced reliable data in is still transmitting data (Figure 3.9). The drifter was initially captured in some eddies, and then drifting rather steadily northwest-ward along the slope, before it got a mainly westward direction for a period before continuing northwest-ward. The vector mean velocity over the period with good data from 17 May to 30 June 2016 is about 9 cm/s toward northwest. Note that these drifters have a drogue at 15-20 m.

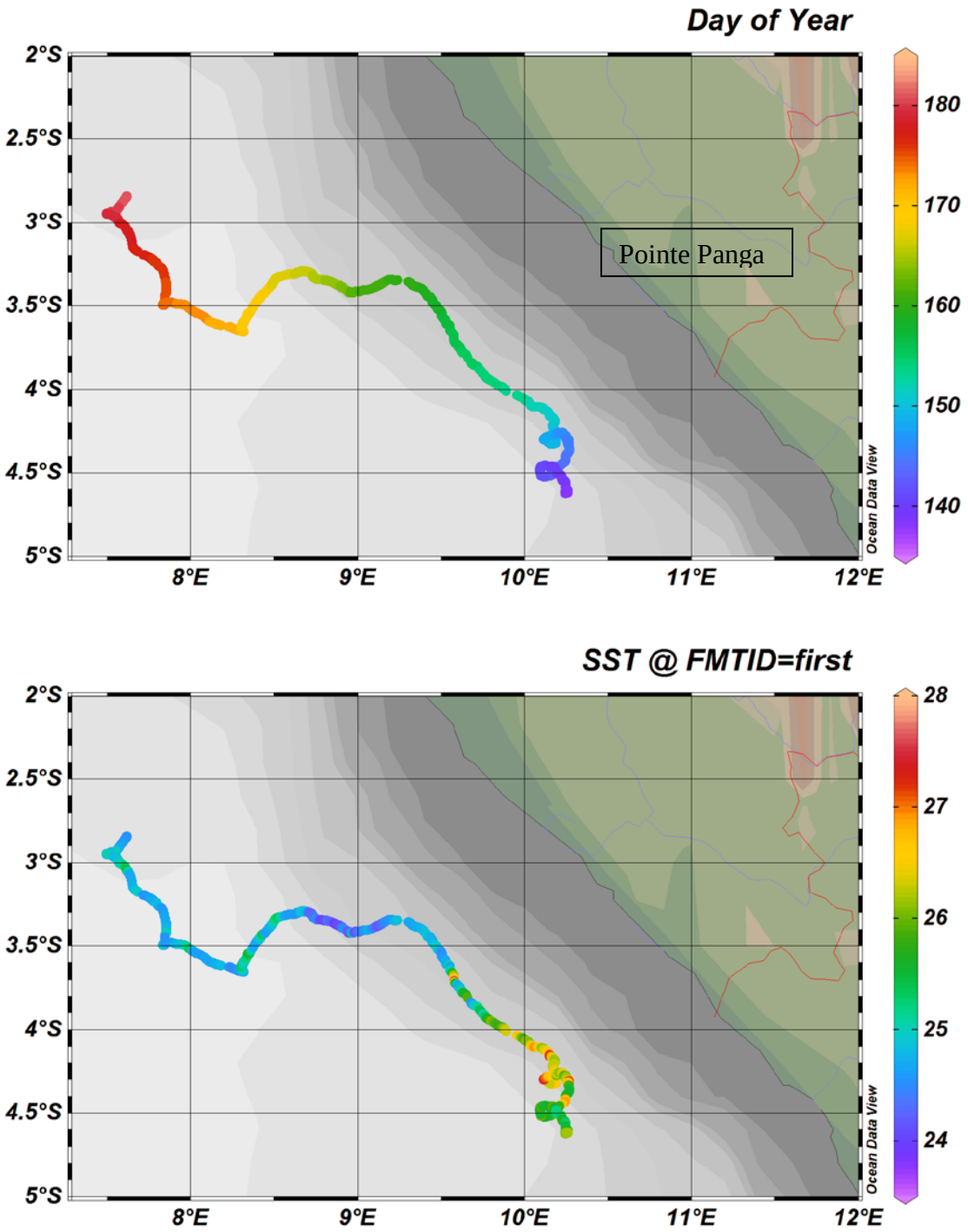


Figure 3.9 Trajectory of SVP drifter ID 1606 from 17 May – 30 June 2016. The colour indicates days since 16 May (upper canvas) and temperature at drifter depth (15 m) (lower canvas). grey lines indicate bottom contours.

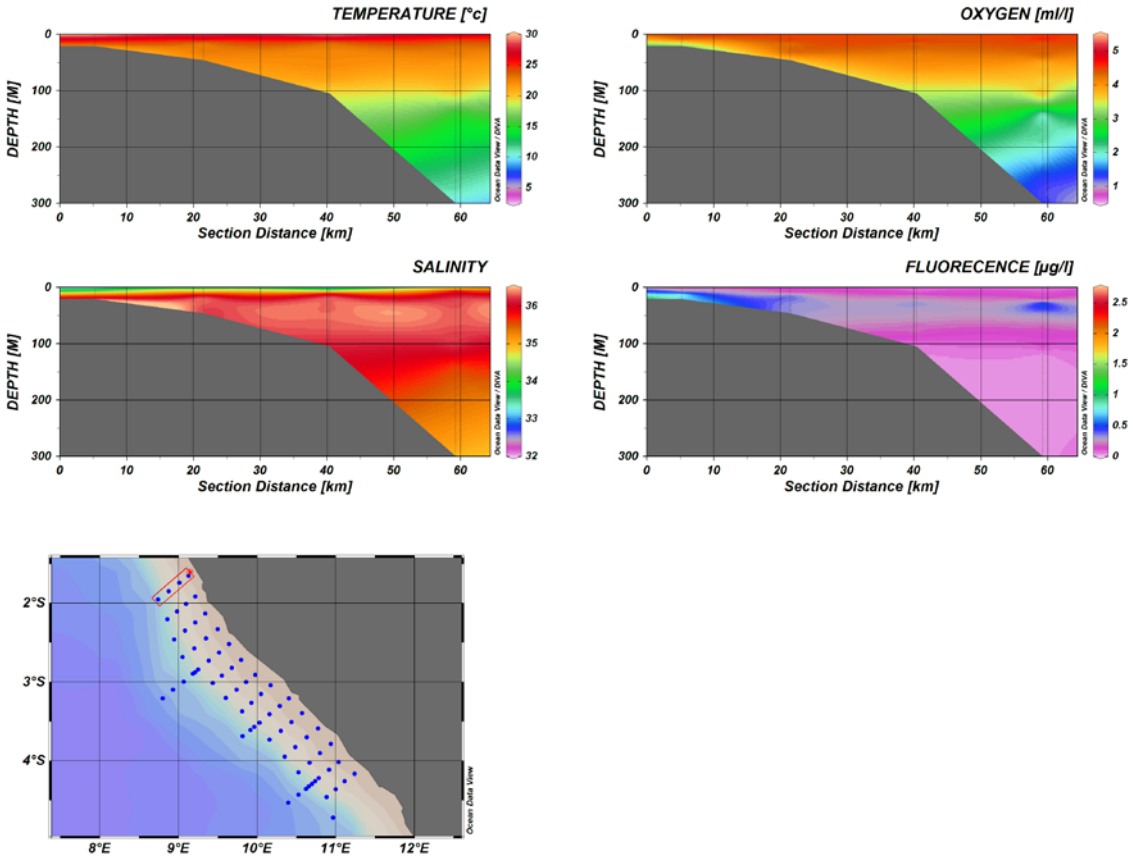
Vertical distribution

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 3.10). CTD casts were made from the surface to approximately 5 m from the bottom. The plots depict the distribution of the environmental

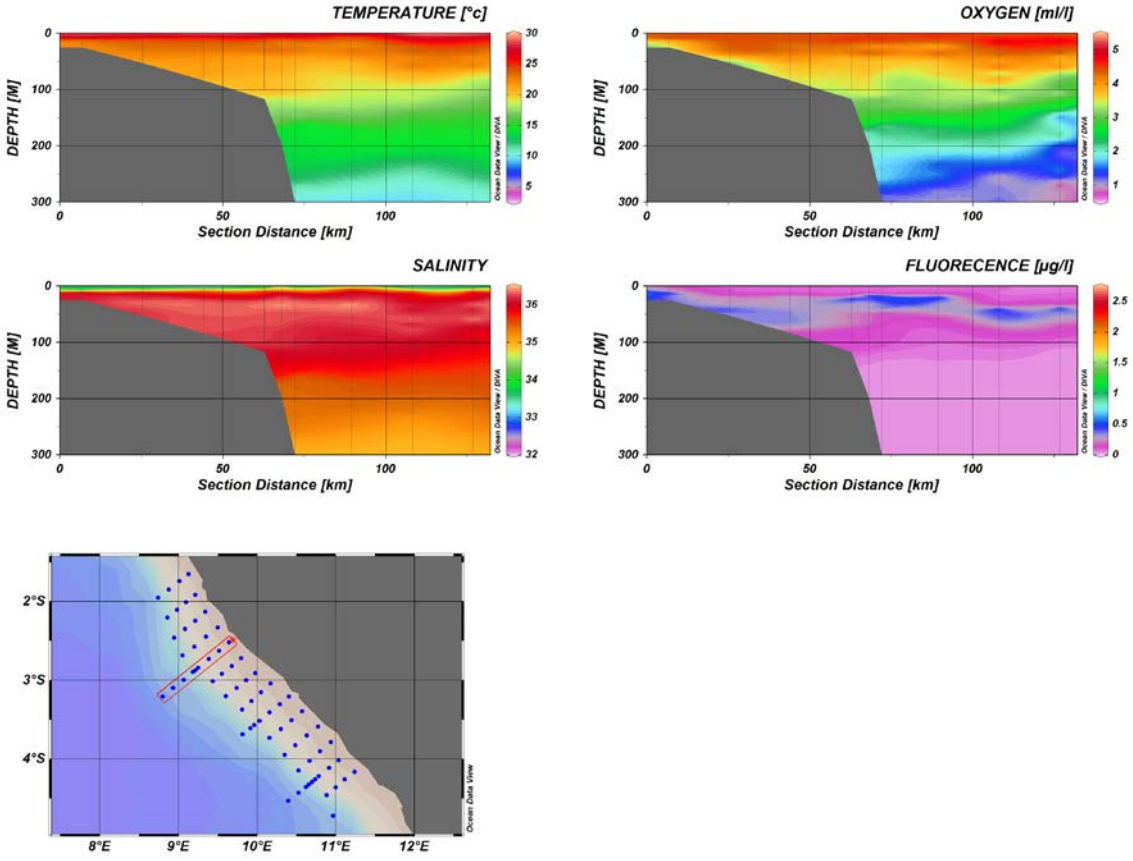
parameters in the upper 300 m as since the focus of this study is mainly on the pelagic system. Note, that chlorophyll samples for laboratory analysis were collected from the CTD water-bottles during the entire cruise (presented in a separate chapter below).

In the northernmost section (off Iguèla) temperature in the surface layers were > 26°C and relatively stable across shelf with well mixed conditions in the upper 15 m. The salinity shows a thin layer of lower salinity water at the surface (<34.0), slightly deeper in the coastal zone and overlaying relatively high salinity waters of 36.5. 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 a sub-surface layer below the layer of minimum in salinity. Further offshore the depth of maximum in fluorescence increased to about 50 m depth. At the next environmental transect off Sette Cama, the observations are similar 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. 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 Pointe 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.

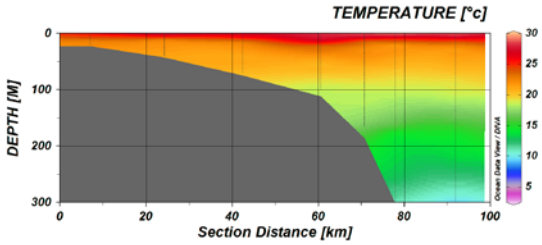
a) South of Olinde

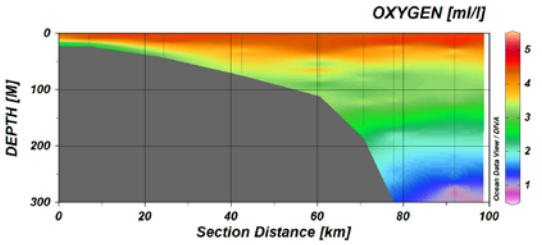


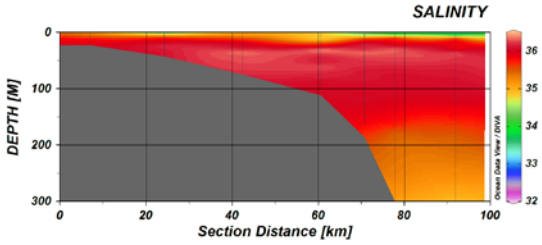
b) Sette Cama

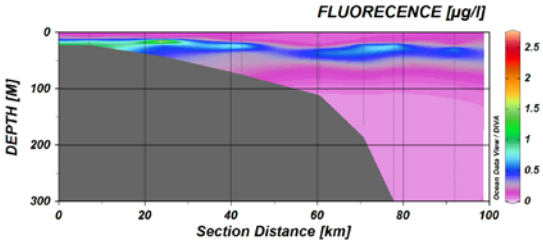


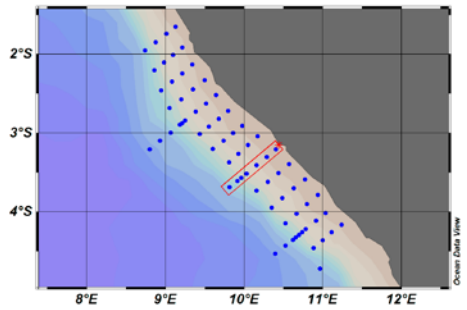
c) Pte. Panga



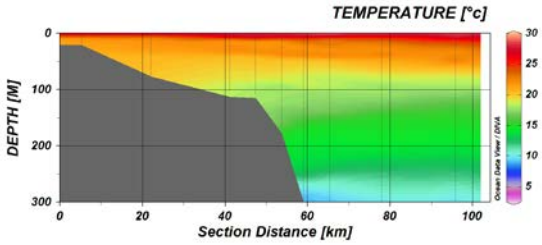


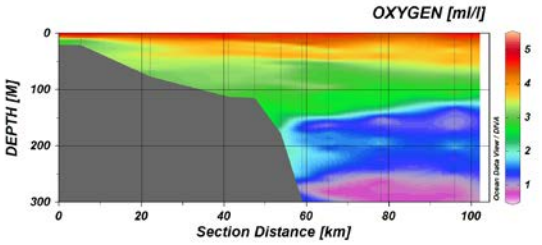


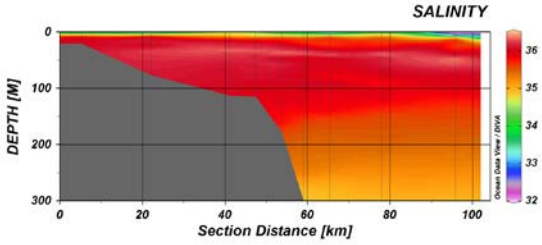


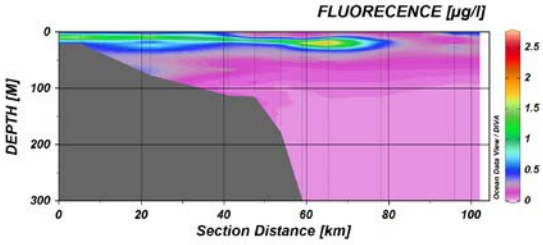


d) North of Pointe Noire









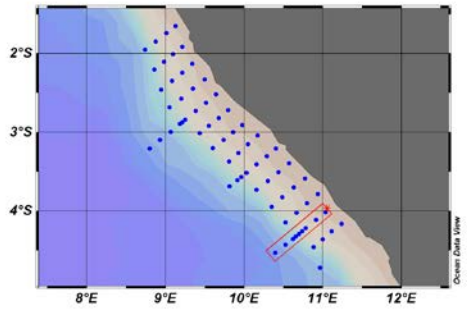


Figure 3.10 Vertical distributions of temperature, salinity, oxygen and relative fluorescence across the shelf at: South of Olinde a), Sette Cama b) Pte. Panga c) and North of Point Noir d)

The along-shelf changes in the hydrographic properties are summarized in Figure 3.11. In the southernmost profile the maximum fluorescence is found near the surface. As going northwards this maximum increase (> 1.6 mg/l) and is shifted downwards to about 15 m, coincident with a decrease on oxygen. This depth is just below the fresh surface layer. Further northwards the maximum on fluorescence is further shifted downwards to about 30 m at 3.4^{o}S, and at the northernmost station at 1.84^{o}S there is little fluorescence, values are consistently low.

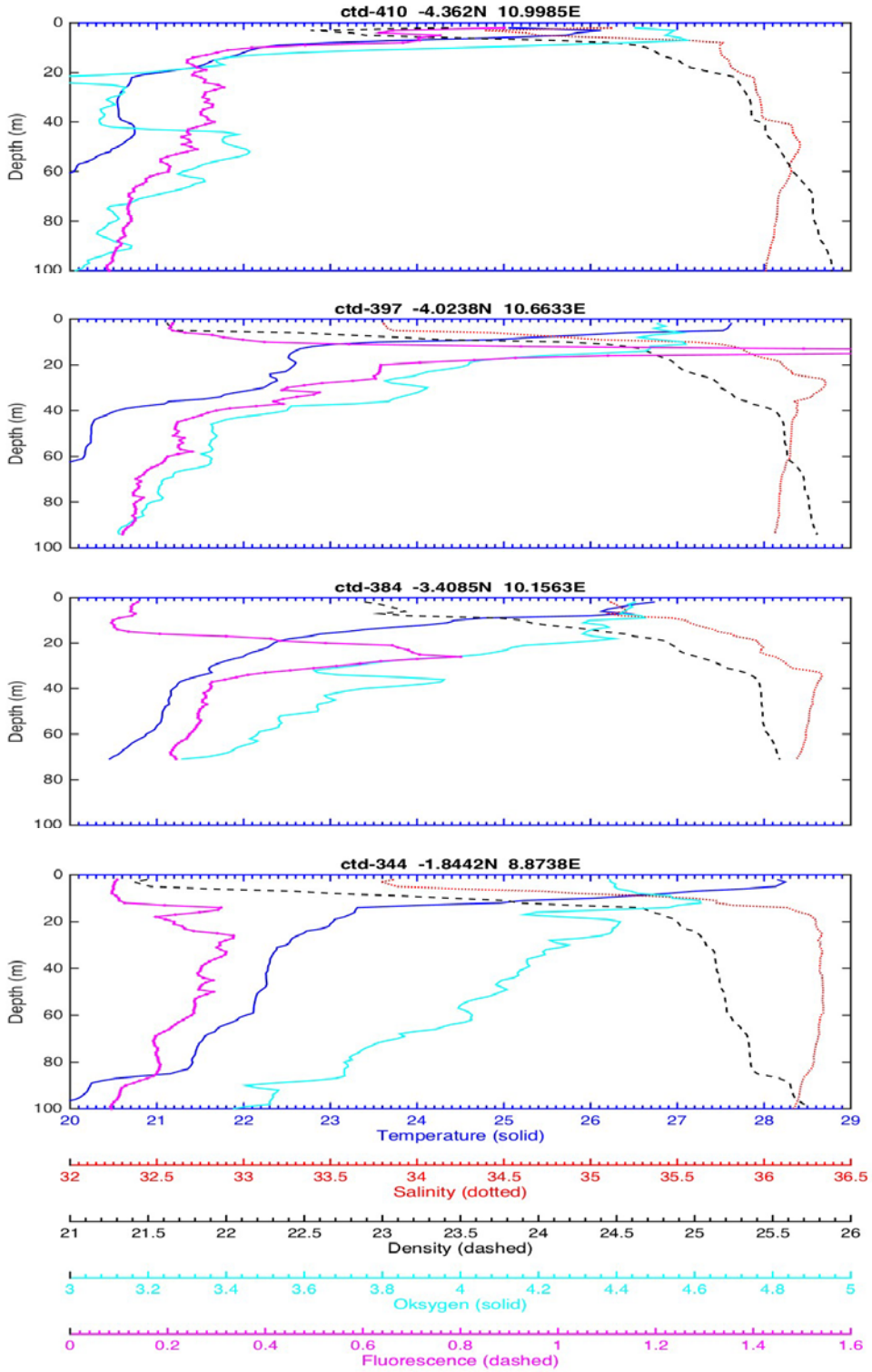


Figure 3.11 CTD profiles from the south closest to the Congo River (uppermost: station: 410) and along-stream northeast ward along the shelf (lowermost: station 344).

CHAPTER 4 NUTRIENTS AND PLANKTON

Nutrients

In upper waters, inorganic nutrients tended to occur in higher concentrations in the southern part of the study area (i.e. off southern Gabon - northern R. of the Congo) than further north. This was most evident for nitrate and phosphate, while the pattern was less clear for silicate (Figures. 4.1 and 4.2). At depth of 10 m, when considering the whole study-area, concentrations of silicate ranged between 1.2-6.3 μg/L, nitrate between 0-8.6 μg/L, and phosphate between 0-0.8 μg/L (Figure 4.1). At depth of 50 m, the concentrations of silicate ranged between 2.0-5.9 μg/L, nitrate between 2.0-11.5 μg/L, and phosphate between 0.4-0.9 μg/L (Figure 4.2)
The vertical profiles for silicate, nitrate and phosphate at the deeper stations revealed increasing concentrations with increasing depth, and regardless of latitude, their concentrations were very high in the deeper waters (e.g. at 500 m), and showing very similar values across latitude for a given nutrient (Figure 4.3). For instance, at depth of 500 m, silicate would typically reach concentrations of ca. 20 μg/L, nitrate about 35 μg/L (slightly lower in the north), and phosphate about 2.5 μg/L ((slightly lower in the north) (Figure 4.3). The shapes of the vertical profiles also indicate some differences regarding the changes in concentrations of silicate, nitrate and phosphate with depth in the uppermost 100m between station located at different latitudes. From the 3 profiles presented in Figure 4.3, an elevated level and larger increase per unit of increased depth of these nutrients at the station furthest to the south is indicated in the uppermost part of the water-column. However, this needs to be analysed in more detail for more stations before any solid conclusions can be made.

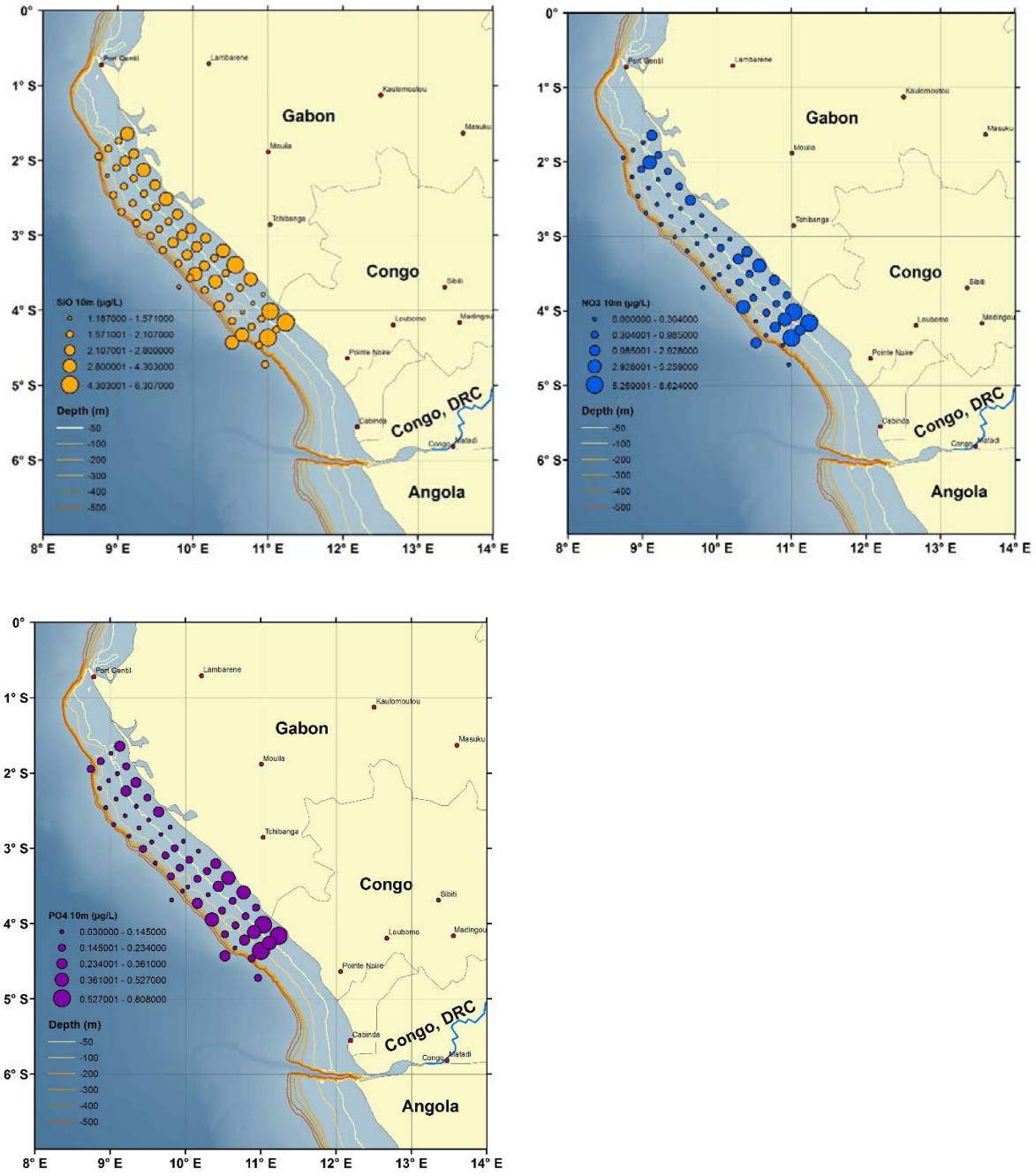


Figure 4.1. Nutrient concentrations (µg/L) at depths of 10 m. Silicate (upper left), nitrate (upper right), and phosphate (lower left). Figure legends show concentrations as bubble-size, while bottom-depths are indicated by coloured lines. NB! Note different classification for bubble-size among the subfigures. Classification in each figure based on "Natural Breaks (Jenks)" and 5 size-classes.

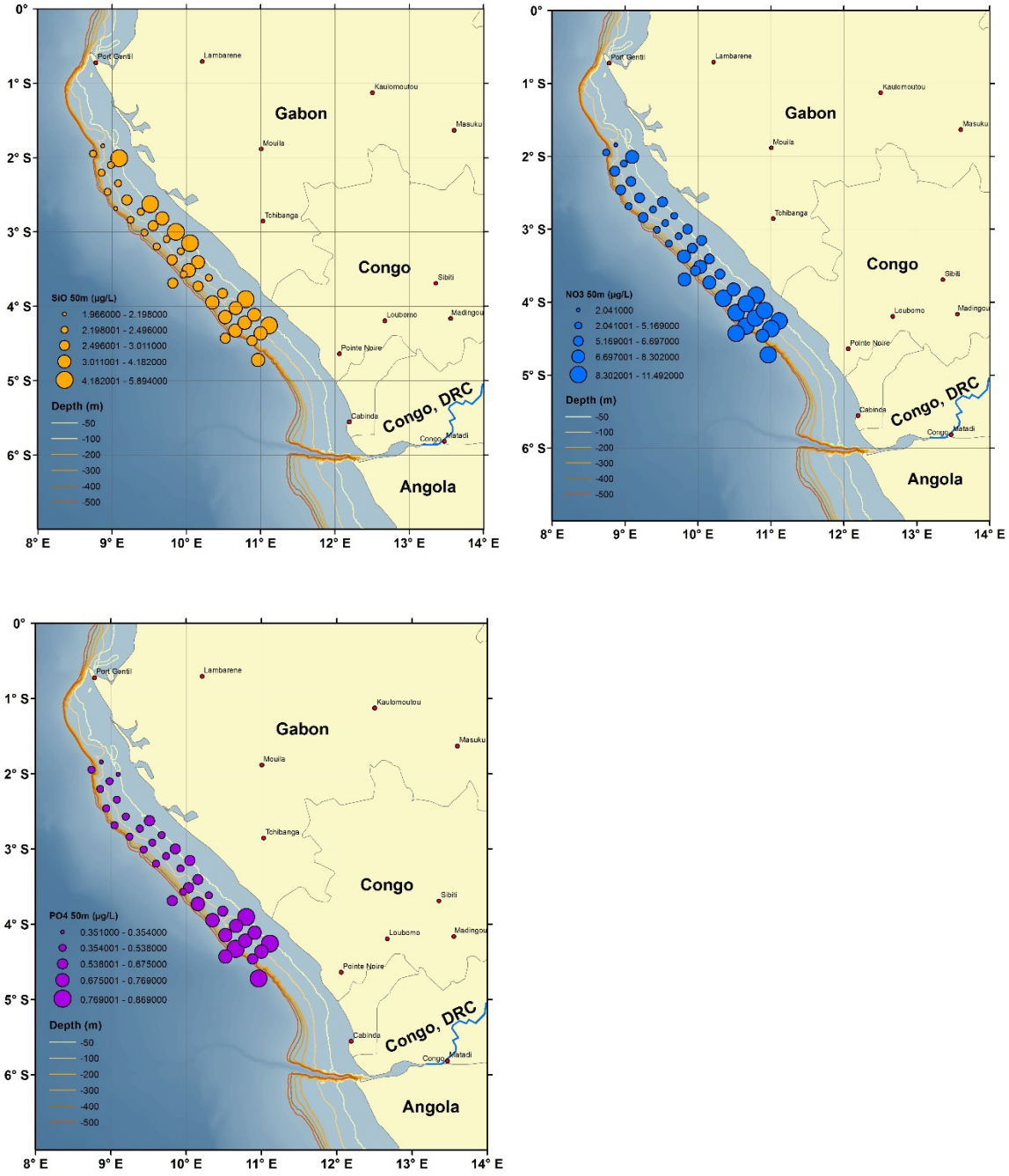


Figure 4.2. Nutrient concentrations (µg/L) at depths of 50 m. Silicate (upper left), nitrate (upper right), and phosphate (lower left). Figure legends show concentrations as bubble-size, while bottom-depths are indicated by coloured lines. NB! Note different classification for bubble-size among the subfigures. Classification in each figure based on "Natural Breaks (Jenks)" and 5 size-classes.

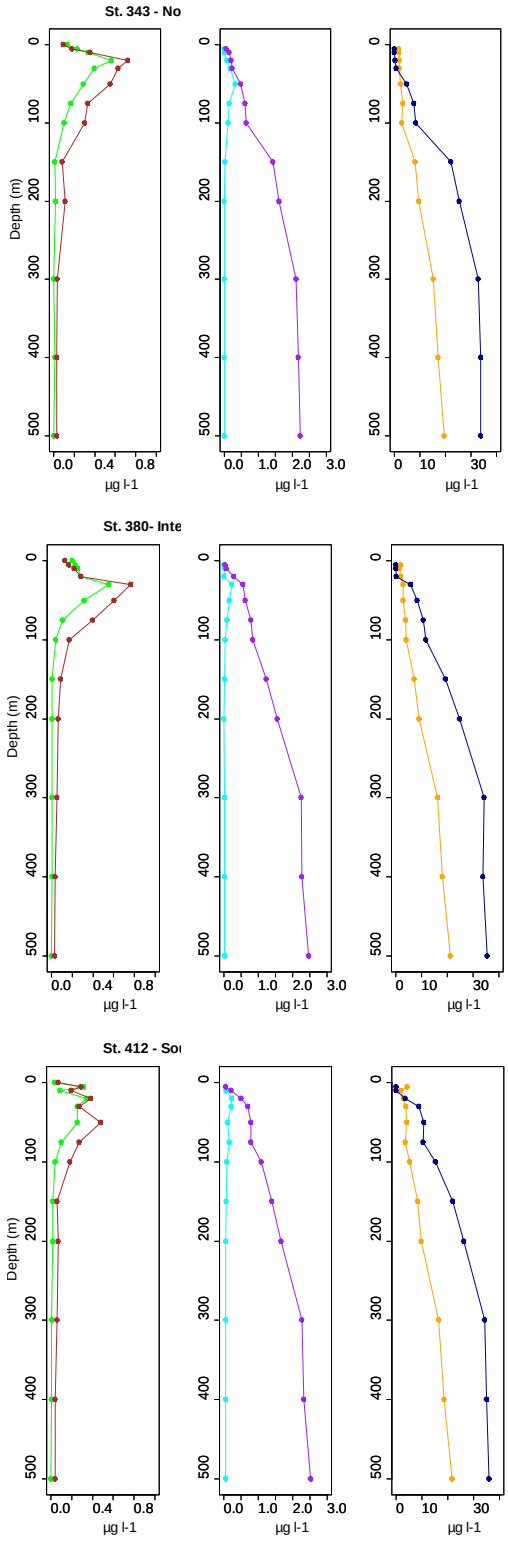


Figure 4.3. Vertical profiles for chlorophyll (green), phaeopigment (brown), nitrite (turquoise), phosphate (purple), silicate (orange) and nitrate (dark blue). The profiles represent 3 semi-randomly selected deep stations, with station 343 representing the northern part of the study area (upper panel), station 380 representing the mid-part of the sampling region, and station 412 representing the southern part of the region. Please note that there is some variability in the profiles even between nearby stations. Hence, the profiles above are just intended to serve as illustrative examples for the areas they were located in.

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 southern part of the study area, i.e. off southern Gabon - northern Republic of the Congo (Figure 4.4). At depth of 10 m, the latitudinal trend was much the same, but a generally stronger pattern of decreasing concentrations with increasing cross-shelf distance from land can be observed for the whole study region (Figure 4.4). For sampling-depth of 20 m, the concentrations were still enhanced in the southern part of the study area but perhaps more homogeneous with respect to distance from shore, at least in the southern part of the area. However, when considering sampling depth of 50 m, the geographic pattern changed, now showing a tendency of higher chlorophyll levels in the mid-region. When considering all stations, and including all depths, the levels ranged between 0 and 9.5 $\mu g\ L^{-1}$.

Vertical distributions of chlorophyll revealed some interesting patterns when considering the deeper stations (Figure 4.5). In the northern part of the study area (south of Port Gentil, Gabon), a subsurface maximum at roughly 20-30 m was typical (Figures. 4.4 and 4.5). The peak concentrations were typically below 0.5 $\mu g\ L^{-1}$. In contrast, further south off Gabon, the peaks seem to occur at similar or slightly greater depths, ca. 20-50m, but with a fair amount of variation among the stations. Here the peak-concentrations were slightly higher than further north, generally below 1.0 $\mu g\ L^{-1}$. In the southern part of the study area, off southern Gabon – northern Republic of the Congo, the peaks typically occurred shallower (often ca. 10 – 20 m) than elsewhere, and the peak-concentrations also tended to be higher (typically ca. 1.5 $\mu g\ L^{-1}$) . In all three sub-areas, the concentrations became low when approaching a depth of 100 m, and were near zero at greater depths. There were, however, exceptions within the different regions to the somewhat subjective descriptions of the patterns given above. Moreover, it should be expected that stations located at different distances from the coast and hence with different bottom-depths will vary regarding vertical profiles – although we have not taken this into consideration in the present report.

We do not discard the possibility of some of the chlorophyll measured in samples from certain areas representing not only marine phytoplankton, but perhaps residue from other plant sources as well. Several 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 (described below).

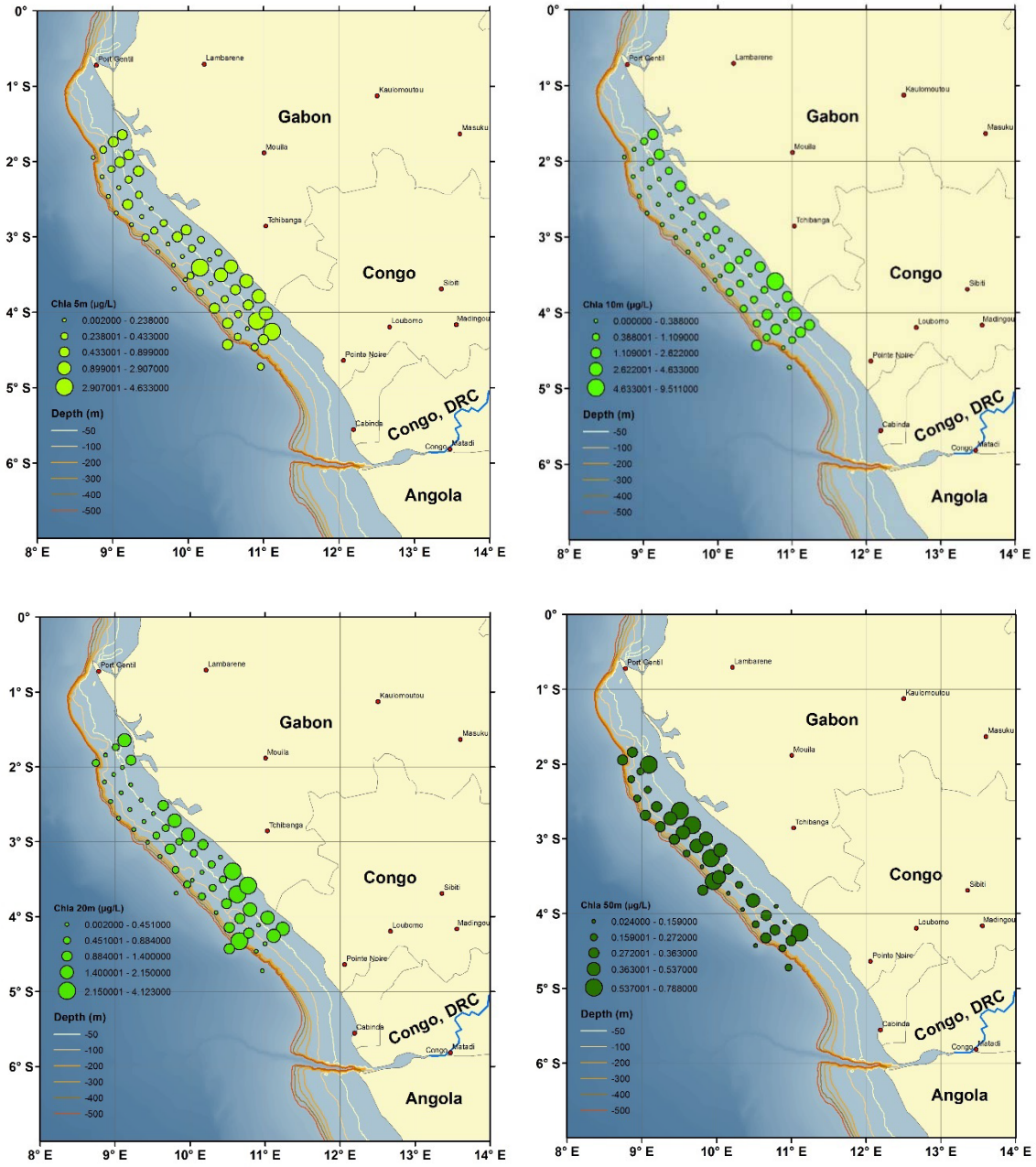


Figure 4.4. Chlorophyll *a* concentration (µg/L) at standard sampling-depths of 5 m (upper left), 10 m (upper right), 20 m (lower left) and 50m (lower right). Figure legends show concentrations as bubble-size, while bottom-depths are indicated by coloured lines. NB! Note different classification for bubble-size among the subfigures. Classification in each figure based on "Natural Breaks (Jenks)" and 5 size-classes.

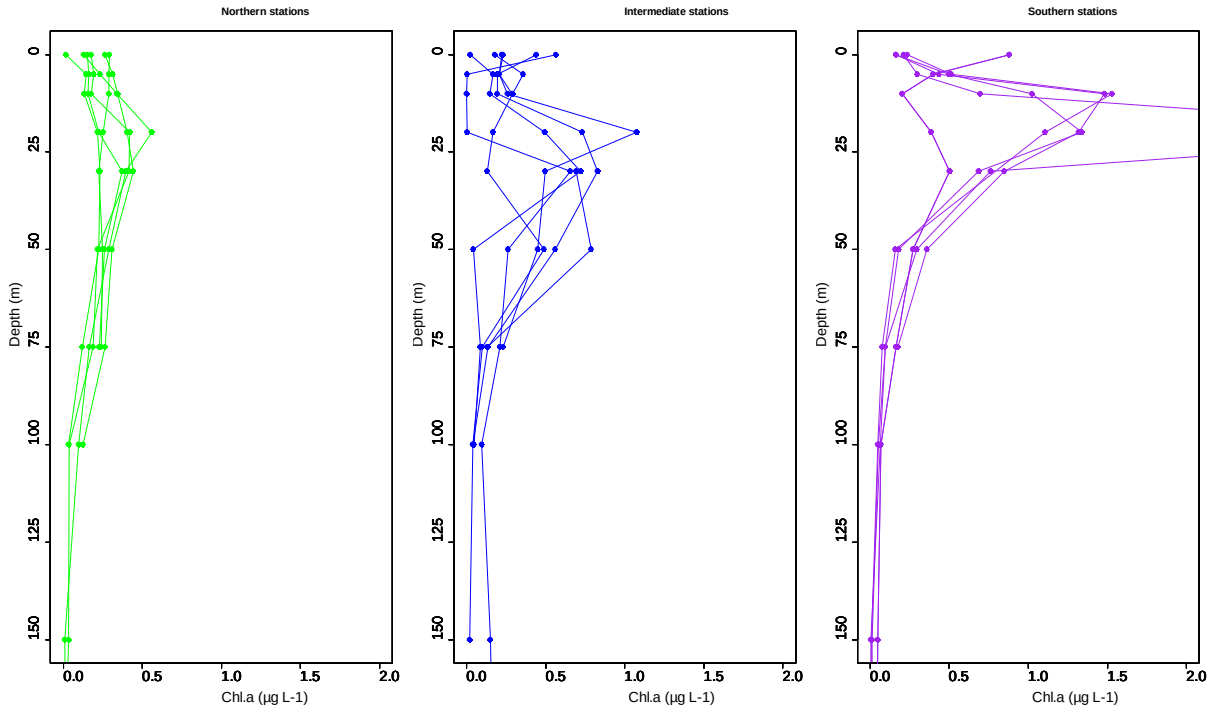


Figure 4.5. Vertical profiles of chlorophyll *a* concentration (µg/L) for 6 "deep" stations in the northern part of the study region (left panel), for 6 "deep" stations around the mid-region (mid-panel), and for 6 "deep" stations in the southern part of the region (right panel). The stations were selected *a priori* from the station map with the criterions for selection being that they represented the deeper parts of the study area as well as belonging to the northern, intermediate or southern parts of the region, respectively.

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 differed somewhat regarding the horizontal patterns. When considering the whole water-column (or from the bottom to the surface in areas shallower than 200m) (not shown), there was a tendency for total zooplankton biomass increasing towards the south, though less pronounced than when considering only the uppermost 25m (see below). Moreover, the biomasses for the deeper WP2s were as a rule somewhat higher than for the samples representing only the 25-0 m stratum, as they should be. We present only the biomasses for the upper 25 m in this report (Figure 4.6). For the uppermost 0-25 m depth-stratum, the total biomass (sum of all three size-fractions) ranged between 0.75 and 7.2 g dry-weight per square meter surface, with an average of 2.6 g DW m^{-2} for the whole study area.

The most notable pattern for the uppermost 25 m was that total zooplankton biomass at the stations in the southernmost half the study area – off southern Gabon and northern Republic of the Congo –were higher than further north (Figure 4.6– upper left panel). Further, in the very south-most part of the study- area, just off the border between Gabon and Republic of the Congo, 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 typical elsewhere (Figure 4.6– upper right panel). 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 yellow in Figure 4.6 (lower panel). These stations were located off southern Gabon and northern Republic of the Congo. 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 samples will not only represent zooplankton but also some plant material. To what extent this material contributed to the total biomass for the affected samples is not clear, but at least for some stations it obviously dominated the weight for the smallest size-fraction. Considering the sampling location of many of the samples with registered green-brownish colour along with the comparatively high proportions of the smallest size-fraction (see Figure 4.6), it seems reasonable to believe that the higher "zooplankton" biomasses outside of southern Gabon and northern Republic of the Congo – at least to some degree may be a result of this artefact. 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 the reasons given above, we cannot conclude that there was more zooplankton in the upper waters outside northern Republic of the Congo – southern Gabon than elsewhere. Separate studies would be needed to elucidate this issue.

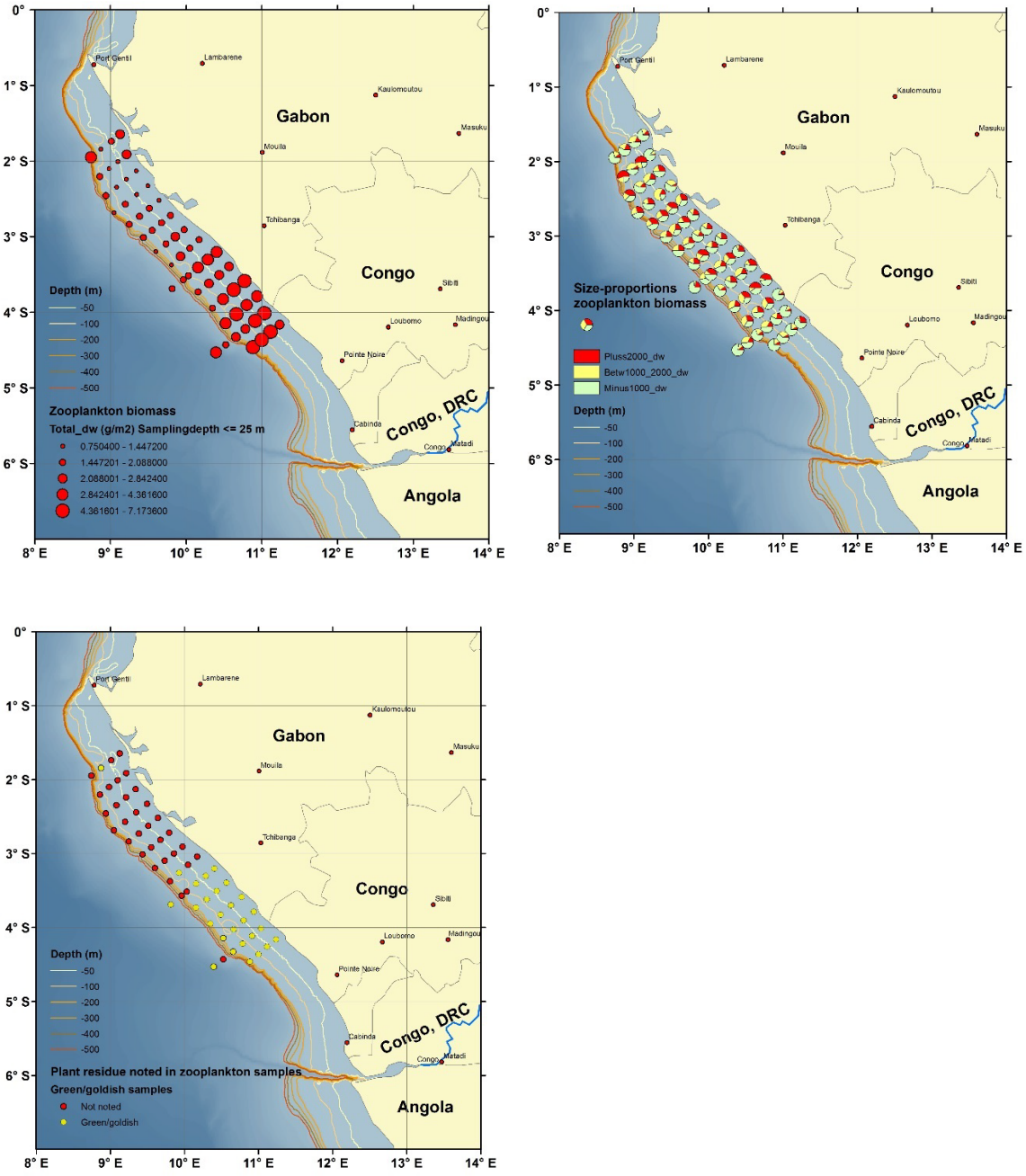


Figure 4.6. Zooplankton biomasses in uppermost 25 m of water-column. Total biomass is shown in upper left panel (but see comments in the text above regarding a possible bias), weight-proportions of different size-classes corresponding to size-fractioning sieves (0.18-1 mm in green, 1-2 mm in yellow, and > 2mm in red) are shown in upper right panel, whereas stations with notable contents of green-goldish residue assumed to represent phytoplankton or other plant material are indicated with yellow in lower left figure. Classification in figure to the upper left based on "Natural Breaks (Jenks)" and 5 size-classes.

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

Figure 5.1 illustrates the distribution within the region surveyed. One low density distribution of sardinella was found inshore mainly inside of 50 m depth between Iguèla and Sette Cama in Gabon, south of this a few sardinellas were found in a small concentration, while the largest densities were found in the border areas extending from Pte. Panga (Mayomba) and southward. The fish here was also mainly of low density but with an area of slightly higher density at 20 m depth and close to the coast north of the Republic of the Congo – Gabon border, and a larger and high density area further from the coast between 50-100 m depth.

The *S. aurita* in the region consisted only of one cohort with large individuals, the length distribution showed a modal peak around 25 cm (Figure 5.2), while the *S. maderensis* was smaller and had a wider size-distribution, with modal peaks at 7, 16 and 23 cm (Figure 5.2).

Summarised information of sex, maturity stage and average length for fish caught in Gabon and Republic of the 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". *S. maderensis* found in the region generally showed a dominance of smaller immature fish and mature fish in maturity stage 2. The main concentration of these was found in the medium density area just north of the border between Republic of the Congo and Gabon. No fish were found in stage 4 and 5. One station was different from this general pattern, on station 1 both sardinella species were found, and both species were either "ripe-4" or "running-5". On this station, most fish were also of similar size.

A biomass estimate has been calculated from the survey but due to the vessel break down and the fact that the survey ended in the main abundance area of the sardinella this estimate is difficult to compare with any previous estimate. It is therefore not shown here. However, densities of fish in the region is similar to what was observed in the same time period in 2014, while fish size is slightly smaller.

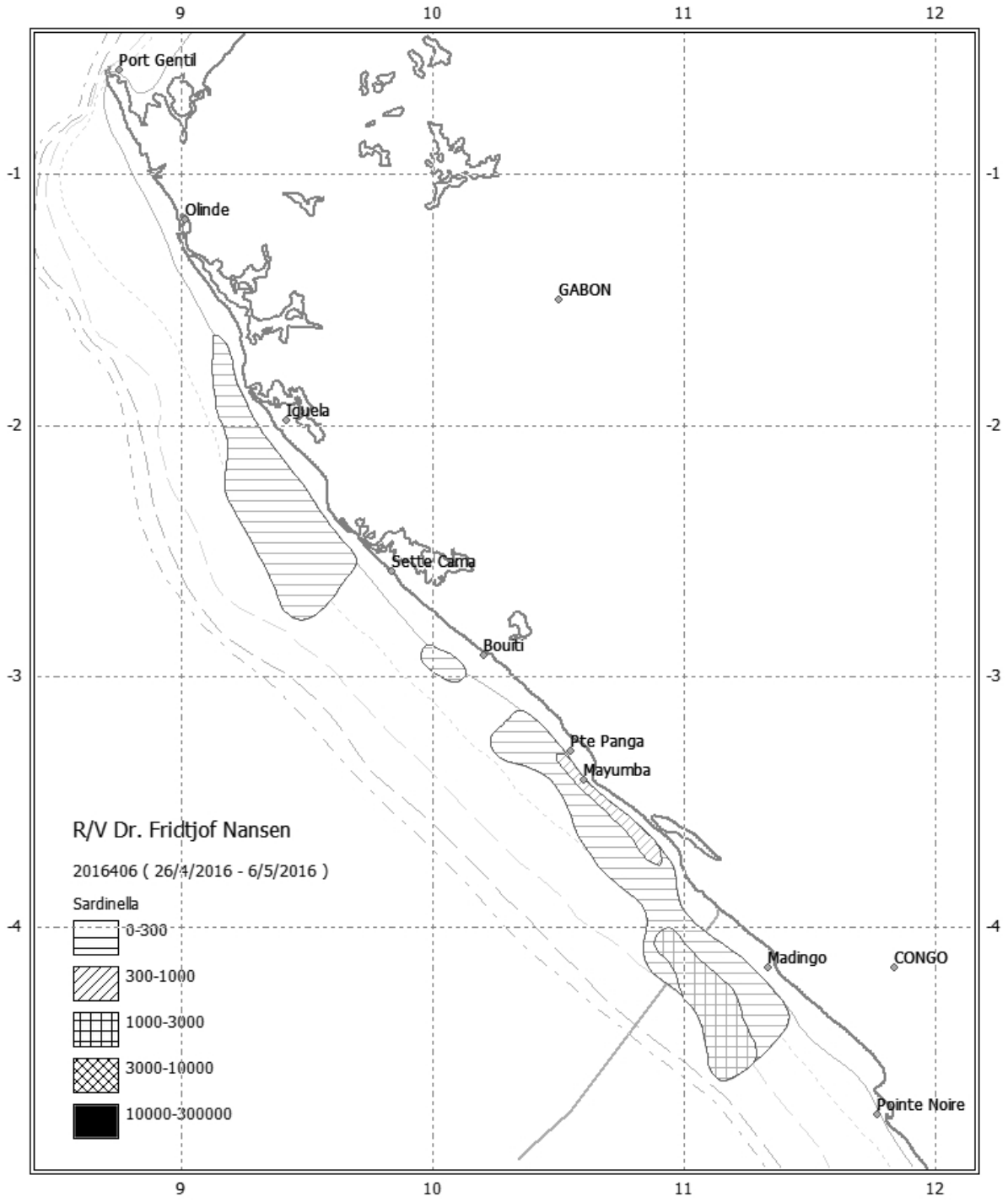


Figure 5.1. Distribution of acoustic recordings of sardinella (s_A) in a) Gabon and Republic of the Congo. The south-west directed line in the lower part of the map illustrate the border between the countries.

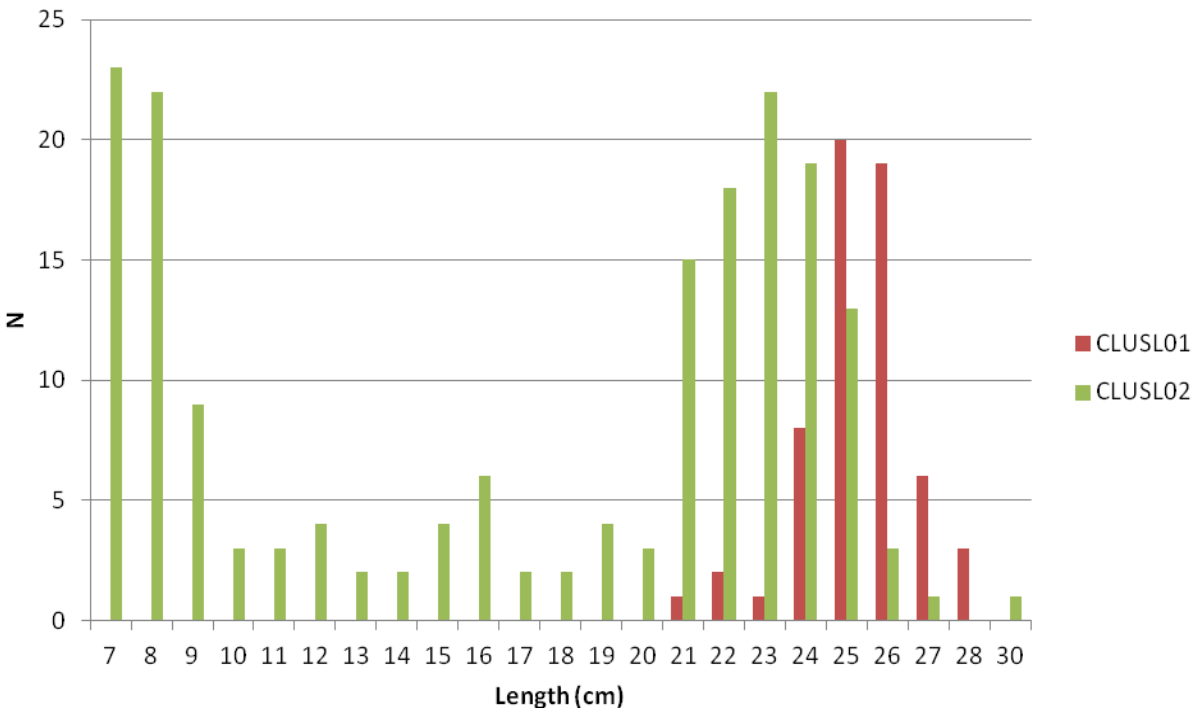


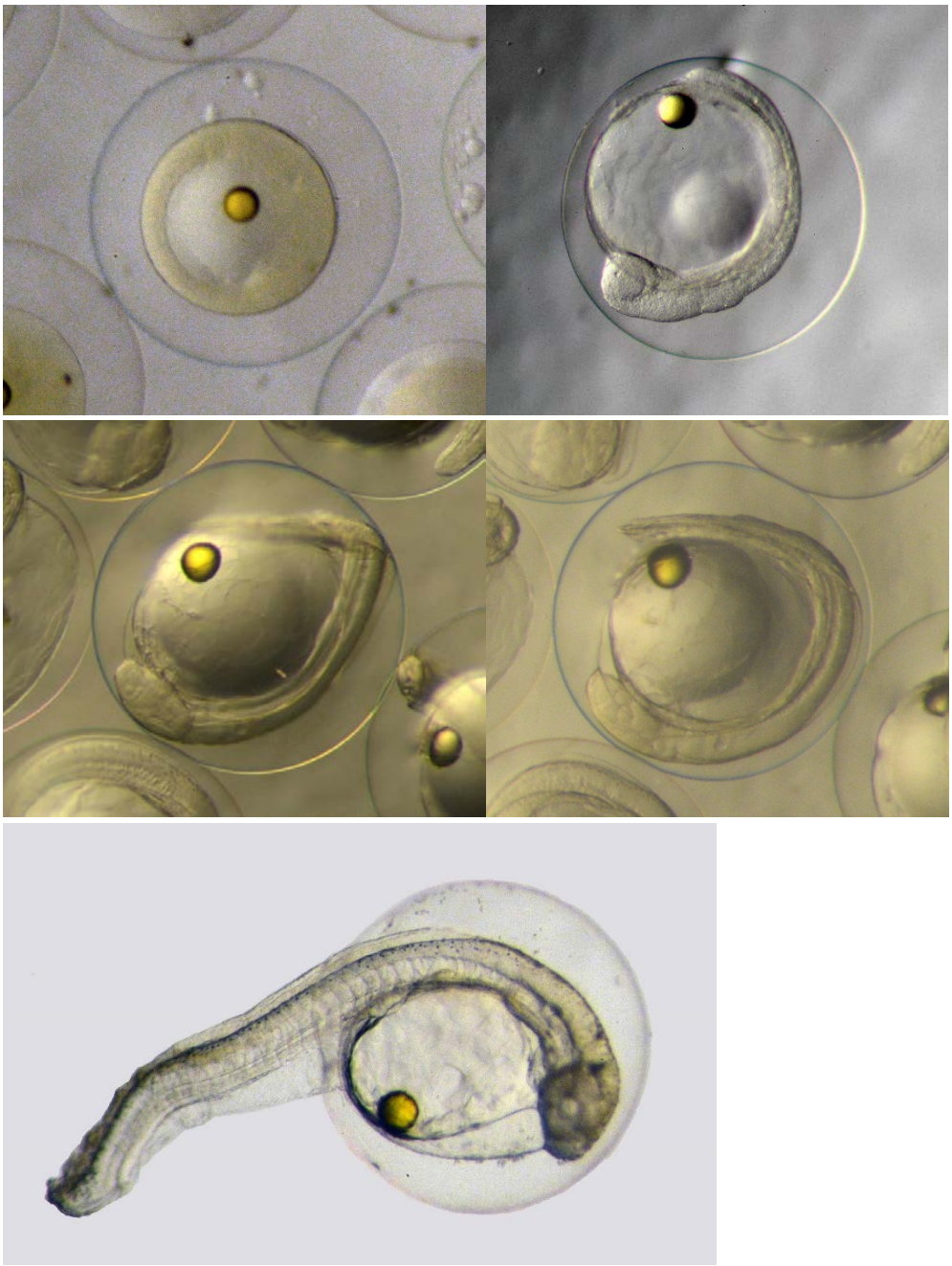
Figure 5.2 Size distribution of *S. aurita* (CLUSL01) and *S. maderensis* (CLUSL02) caught in Republic of the Congo-Gabon

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

Station	Bottom depth	Species	Maturity Stage						Average Length (cm)	Sex		
			0	1	2	3	4	5		Juvenile	Male	Female
1	*45*	*S. aurita*					1	2	22.8		2	1
1		*S. maderensis*				5	8	2	20.2		9	6
4	*47*	*S. maderensis*	13		3	2			15.8	13	2	3
6	*24*	*S. maderensis*	64	1	2	8			10.3	64	3	8
7		*S. maderensis*		2	10	23	16		23.6		25	26
9	*32.5*	*S. aurita*	7	9	6	9	14	8	25.2		29	17
9		*S. maderensis*	1	8	13				21.6		18	4

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 sardinella eggs were identified according to Olivar and Fortuno (1991), Matsuura (1971), and supplemented with of our own experience previously acquired from western Africa. Pictures verifying the sardinella eggs and development stage was taken routinely and corresponds well with the drawings by Olivar, and Fortuno (1991).



Picture 5.1. Sardinella eggs in different stages, from upper left; fertilized egg Aa, embryo before eye is developed Ba, matured embryos, Cb and a hatching egg.

The eggs found off Congo River were 1,2 mm in diameter with an oil globule of 0,12 mm which is consistent with the measurements from the reviewed literature. The photos of eggs taken under the binocular confirm that the description in literature is applicable also for the sardinella in the region of the survey.

Our observations and identification of larvae of *Sardinella aurita* were consistent with the available descriptions in the existing literature. During the two surveys in the region (survey 2014404 and 2016406) we observe that the size at hatching is slightly smaller than reported in literature, 2,6 mm compared with 3.5 mm (Olivar and Fortuño 1991). The oil globule is situated

medially on the ventral portion of the yolk. see Picture 5.2a. The larvae were identified based on the guides by Conand, F. and Fagetti, E. (1971) and Olivar, M-P. and Fortuño. J-M. (1991).

Picture 5.2. From upper left; Yolk sack larvae 2,6 mm at hatching, 2 larvae 10 and 13 mm, and two 12 mm larvae.

Horizontal distributions

The horizontal distributions of sardinella eggs and larvae are described in Figure 5.3, which shows that the main concentrations off eggs were found off Republic of the Congo. The station with the highest egg concentration (PL164) was situated off the shelf break at a bottom depth of 111 m. This area was also characterised by a thin layer (8 m) of high temperature and low

salinity surface water originating from the Congo River overlaying high salinity waters, and with strong fluorescence. The egg concentration measured at the station was 100 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 very wide area but with large changes in density. The highest distributions were found immediately west of the highest egg concentrations extending north-east towards Mayomba at the border between Gabon and Republic of the Congo. From there on the concentration was reduced somewhat on a few transects before increasing again off Bouiti. North of this there was a gradual decrease in larvae. The main sub-surface current direction in the region was northwards, and the highest larvae concentration gives the impression of following directly northward toward the coast with declining densities on each side of the maximum (Figure 5.4).

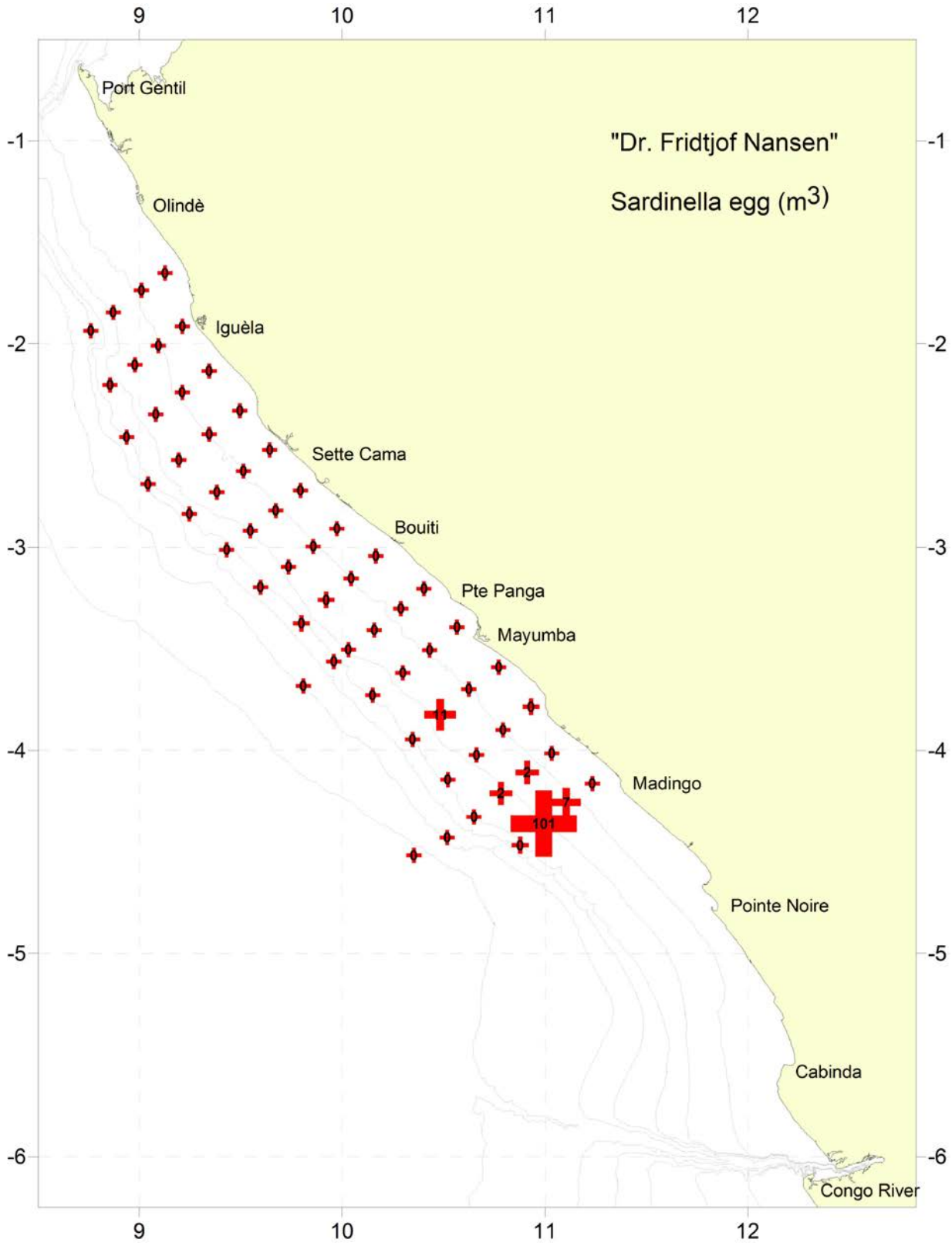


Figure 5.3. Horizontal distribution of number of sardinella eggs/m^3 calculated for the upper 25 m (red cross with black number) per station in Republic of the Congo and Gabon.

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

microscope during counting and identification and the larvae found were mainly yolk-sac larvae. The observations of larval size coming from this year's survey was less consistent that what was observed in 2014, giving the impression that the larva had been produced from several batches of spawning. The largest larva was found inshore and towards the north especially in the area off Point Panga. 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 be transported / actively move towards this region.

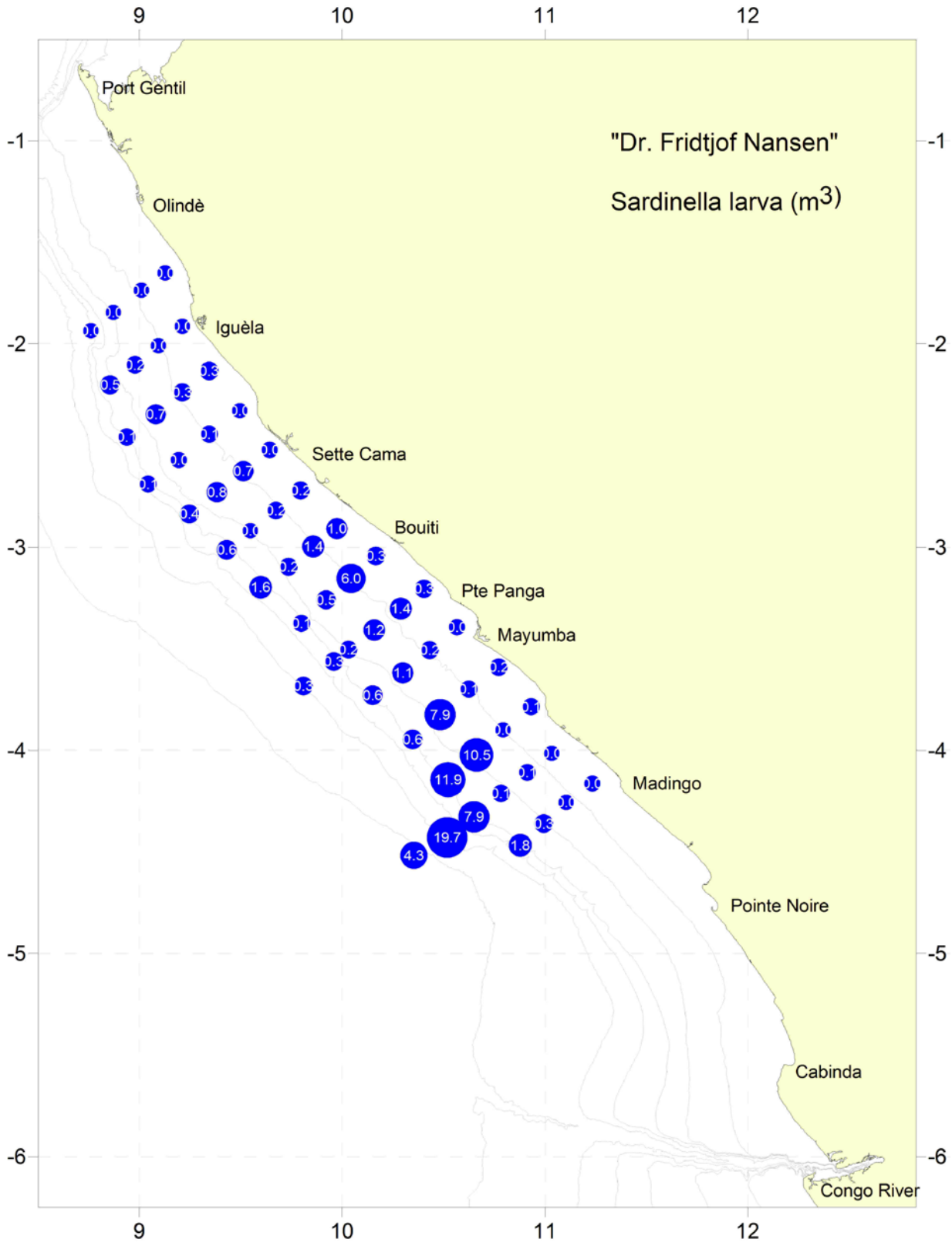


Figure 5.4. **Horizontal distribution of number of sardinella larvae/m³ (blue circle with white number) calculated for the upper 25 m per station in Republic of the Congo and Gabon.**

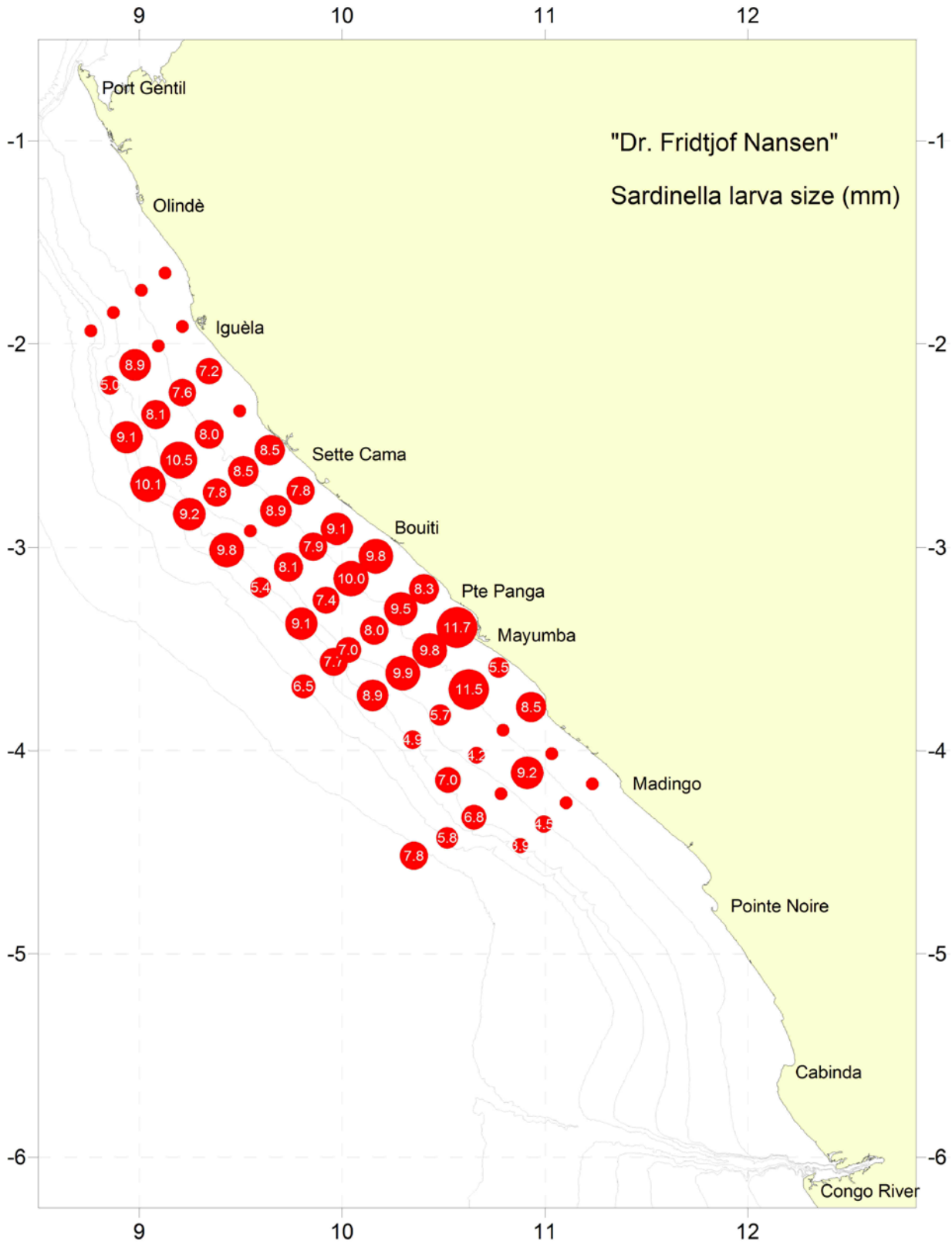


Figure 5.5. Horizontal distribution of average larvae size per station where sardinella was found.

It is not possible to distinguish between the larval stages of *S. aurita* and *S. maderensis* visually. It is assumed that the larvae encountered in the high density area in the north of Republic of the Congo belong to *S. aurita* 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*.

CONCLUSIONS

Sardinella aurita and *S. maderensis* are important pelagic fish stocks in West Africa. This study focus on recruitment of Sardinella in a coastal ecosystem influenced by fresh water from Congo River who forms a massive northwest directed plume. Two surveys were made with R/V Dr. Fridtjof Nansen around May 2014 (Gabon - Northern Angola), and 2016 (Gabon - northern Republic of the Congo). Despite a highly variable oceanographic environment, seasonally and spatially, the main distributional patterns for nutrients, plankton, and sardinella eggs and larvae were surprisingly similar the two years. Nitrate, phosphate and chlorophyll concentrations in upper waters were enhanced in the border area off Gabon-Republic of the Congo downstream of the Congo River outlet, decreasing northwards (nutrient data only for 2016). Sardinella spawned in the outskirt of the river plume and *Sardinella* eggs and larvae were mainly encountered in the same area with increasing larval size north of the highest egg concentrations, ca. 4-5°S. In 2016, sardinella larvae were also observed further north.

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ANNEX I Fishing Stations

R/V Dr. Fridtjof Nansen SURVEY:2016406 STATION: 1
DATE :29/04/16 GEAR TYPE: PT NO: 4 POSITION:Lat S 2°14.50
start stop duration Lon E 9°14.20
TIME :02:58:30 03:29:05 30.6 (min) Purpose : 1
LOG : 365.45 367.06 1.6 Region : 3300
FDEPTH: 0 0 Gear cond.: 0
BDEPTH: 46 44 Validity : 3
Towing dir: 0° Wire out : 0 m Speed : 3.1 kn
Sorted : 0 Total catch: 4.48 Catch/hour: 8.79

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Sardinella maderensis	3.34	29	37.95	2
Euthynnus alletteratus	1.77	2	20.09	
Sphyraena guachancho	1.57	4	17.86	
Sardinella aurita	0.98	6	11.16	1
Brachydeuterus auritus	0.59	10	6.70	
Selene dorsalis	0.55	4	6.25	
Total	8.79		100.00	

R/V Dr. Fridtjof Nansen SURVEY:2016406 STATION: 2
DATE :29/04/16 GEAR TYPE: PT NO: 4 POSITION:Lat S 2°26.20
start stop duration Lon E 9°19.30
TIME :09:57:19 10:36:47 39.5 (min) Purpose : 1
LOG : 404.35 406.36 2.0 Region : 3300
FDEPTH: 35 40 Gear cond.: 0
BDEPTH: Validity : 3
Towing dir: 0° Wire out : 120 m Speed : 3.1 kn
Sorted : 0 Total catch: 18.16 Catch/hour: 27.61

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Sphyraena guachancho	13.07	44	47.36	
Chloroscombrus chrysurus	4.45	46	16.11	
Scomberomorus tritor	4.35	3	15.75	
Selene dorsalis	2.46	15	8.89	
Pagellus bellottii	1.17	5	4.24	
Caranx crysos	1.12	2	4.07	
Trichiurus lepturus	0.40	2	1.46	
Sardinella maderensis	0.30	2	1.07	
Chelidonichthys capensis	0.17	2	0.61	
Brachydeuterus auritus	0.12	2	0.44	
Total	27.61		100.00	

R/V Dr. Fridtjof Nansen SURVEY:2016406 STATION: 3
DATE :30/04/16 GEAR TYPE: PT NO: 1 POSITION:Lat S 3°8.00
start stop duration Lon E 9°41.30
TIME :20:11:07 20:39:57 28.8 (min) Purpose : 1
LOG : 603.70 605.35 1.6 Region : 3300
FDEPTH: 0 20 Gear cond.: 0
BDEPTH: 109 109 Validity : 3
Towing dir: 0° Wire out : 120 m Speed : 3.4 kn
Sorted : 0 Total catch: 18.66 Catch/hour: 38.83

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Ariomma bondi	22.10	587	56.91	
Trachurus trecae	7.19	341	18.53	
Scomber japonicus	4.20	35	10.83	
Selene dorsalis	2.64	10	6.81	
Sphyraena guachancho	1.10	4	2.84	
Echeneis naucrates	1.08	2	2.79	
Saurida brasiliensis	0.48	154	1.23	
Total	38.81		99.93	

R/V Dr. Fridtjof Nansen SURVEY:2016406 STATION: 4
DATE :01/05/16 GEAR TYPE: PT NO: 4 POSITION:Lat S 2°59.00
start stop duration Lon E 9°52.80
TIME :00:07:01 01:08:40 61.6 (min) Purpose : 1
LOG : 620.60 623.88 3.3 Region : 3300
FDEPTH: 0 0 Gear cond.: 0
BDEPTH: 50 44 Validity : 3
Towing dir: 0° Wire out : 130 m Speed : 3.2 kn
Sorted : 0 Total catch: 18.96 Catch/hour: 18.45

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Scomberomorus tritor	5.53	8	29.96	
Trachinotus ovatus	3.99	10	21.62	
Brachydeuterus auritus	1.83	32	9.92	
Sphyraena guachancho	1.75	23	9.49	
Selene dorsalis	1.73	21	9.39	
Ilisha africana	1.27	40	6.86	
Trichiurus lepturus	0.68	1	3.69	
Sardinella maderensis	0.56	17	3.06	
Trachurus trecae	0.45	22	2.43	
Ariomma bondi	0.31	10	1.69	
Sardinella aurita	0.14	1	0.74	
Cypselurus sp.	0.12	1	0.63	
Echeneis naucrates	0.04	1	0.21	
Caranx rhonchus	0.04	9	0.21	
Boops boops	0.02	2	0.11	
Total	18.45		100.00	

R/V Dr. Fridtjof Nansen SURVEY:2016406 STATION: 5
DATE :01/05/16 GEAR TYPE: PT NO: 4 POSITION:Lat S 3°22.26
start stop duration Lon E 10°12.24
TIME :19:33:49 20:05:16 31.5 (min) Purpose : 1
LOG : 725.36 726.96 1.6 Region : 3300
FDEPTH: 0 15 Gear cond.: 0
BDEPTH: 59 60 Validity : 3
Towing dir: 0° Wire out : 120 m Speed : 3.0 kn
Sorted : 0 Total catch: 6.54 Catch/hour: 12.47

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Sphyraena sphyraena	4.97	34	39.83	
Trichiurus lepturus	2.35	13	18.88	
Selene dorsalis	1.53	21	12.23	
Brachydeuterus auritus	1.49	797	11.93	
Sphyraena guachancho	1.02	2	8.18	
Scomber japonicus	0.45	2	3.59	
Lagocephalus laevigatus	0.44	2	3.52	
Alloteuthis africana	0.13	65	1.07	
Caranx rhonchus	0.08	10	0.61	
Saurida brasiliensis	0.02	11	0.15	
Total	12.47		100.00	

R/V Dr. Fridtjof Nansen SURVEY:2016406 STATION: 6
DATE :02/05/16 GEAR TYPE: PT NO: 7 POSITION:Lat S 3°22.80
start stop duration Lon E 10°33.40
TIME :02:24:08 02:54:11 30.1 (min) Purpose : 1
LOG : 760.95 762.47 1.5 Region : 3300
FDEPTH: 0 0 Gear cond.: 0
BDEPTH: 23 25 Validity : 0
Towing dir: 0° Wire out : 90 m Speed : 3.0 kn
Sorted : 17 Total catch: 17.16 Catch/hour: 34.26

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Sphyraena guachancho	13.02	58	38.00	
Sardinella maderensis	8.47	0	24.71	
Ilisha africana	4.59	371	13.40	
Brachydeuterus auritus	3.47	94	10.14	
Chloroscombrus chrysurus	3.39	44	9.91	
Selene dorsalis	1.36	24	3.96	
Trichiurus lepturus	0.08	2	0.23	
Total	34.38		100.35	

R/V Dr. Fridtjof Nansen SURVEY:2016406 STATION: 7
DATE :02/05/16 GEAR TYPE: PT NO: 7 POSITION:Lat S 3°38.15
start stop duration Lon E 10°48.49
TIME :18:25:32 19:04:37 39.1 (min) Purpose : 1
LOG : 855.99 858.01 2.0 Region : 3300
FDEPTH: 10 10 Gear cond.: 0
BDEPTH: 28 28 Validity : 0
Towing dir: 0° Wire out : 120 m Speed : 3.1 kn
Sorted : 0 Total catch: 30.37 Catch/hour: 46.63

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Sardinella maderensis	25.98	236	55.71	
Stromateus fiatola	6.47	11	13.88	
Sphyraena guachancho	3.64	12	7.80	
Brachydeuterus auritus	3.24	124	6.95	
Galeoides decadactylus	2.18	15	4.68	
Ilisha africana	1.08	49	2.32	
Sardinella aurita	1.02	6	2.19	
Arius parkii	0.94	2	2.03	
Sepia officinalis	0.74	2	1.60	
Trichiurus lepturus	0.45	3	0.97	
Selene dorsalis	0.45	9	0.95	
Chloroscombrus chrysurus	0.43	6	0.92	
Total	46.63		100.00	

R/V Dr. Fridtjof Nansen SURVEY:2016406 STATION: 8
DATE :03/05/16 GEAR TYPE: PT NO: 4 POSITION:Lat S 4°2.57
start stop duration Lon E 10°40.26
TIME :01:26:17 02:26:55 60.6 (min) Purpose : 1
LOG : 897.42 900.76 3.3 Region : 3300
FDEPTH: 0 0 Gear cond.: 0
BDEPTH: 105 111 Validity : 0
Towing dir: 0° Wire out : 125 m Speed : 3.3 kn
Sorted : 21 Total catch: 140.32 Catch/hour: 138.84

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Trichiurus lepturus	56.75	317	40.88	
Selene dorsalis	37.60	8	27.08	
Auxis thazard thazard	19.63	49	14.14	
Trachurus trecae	16.98	307	12.23	
Trachinotus ovatus	3.28	8	2.37	
Ariomma bondi	1.98	10	1.43	
Echeneis naucrates	1.74	2	1.25	
Scomber japonicus	0.87	4	0.63	
Total	138.84		100.00	

R/V Dr. Fridtjof Nansen SURVEY:2016406 STATION: 9
DATE :03/05/16 GEAR TYPE: PT NO: 7 POSITION:Lat S 4°10.86
start stop duration Lon E 11°12.89
TIME :23:53:38 00:24:23 30.8 (min) Purpose : 1
LOG : 1008.58 1010.32 1.7 Region : 3400
FDEPTH: 0 0 Gear cond.: 0
BDEPTH: 30 35 Validity : 0
Towing dir: 0° Wire out : 100 m Speed : 3.4 kn
Sorted : 7 Total catch: 409.00 Catch/hour: 798.05

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Sardinella aurita	745.64	5889	93.43	
Chloroscombrus chrysurus	12.68	224	1.59	
Selene dorsalis	10.05	176	1.26	
Sardinella maderensis	9.83	121	1.23	
Ilisha africana	9.39	367	1.18	
Sphyraena guachancho	4.15	21	0.52	
Stromateus fiatola	3.17	6	0.40	
Brachydeuterus auritus	2.50	103	0.31	
Trachinotus ovatus	0.65	6	0.08	
Total	798.06		100.00	

ANNEX II Maturity 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 III 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 IV 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 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.

ANNEX V Imaging equipment and software.

This annex gives a description of the stereo bioncular configuration and photo equipment used onboard Dr. Fritjof Nansen used for plankton identification and documentation.

Stereo microscope configuration:

- Microscope 1; Leica M80, 7,5 – 60 times magnification, 10x ocular and 1x objective equipped with a manual fine focus drive and a beam splitter phototube.
  Light sources: Leica TL5000 Ergo - Flat LED Transmitted Light Base, a Leica LED5000 SLI LED Spotlight Illuminator with Gooseneck and a Leica LED 3000 RL, ring light.
- Microscope 2; Leica M80, 7,5 – 60 times magnification, 10x ocular and 1x objective equipped with a manual fine focus drive and a beam splitter phototube.
  Light sources: Leica TL4000 BFDF - Transmitted Light Base and a Leica LED5000 SLI LED Spotlight Illuminator with Gooseneck.

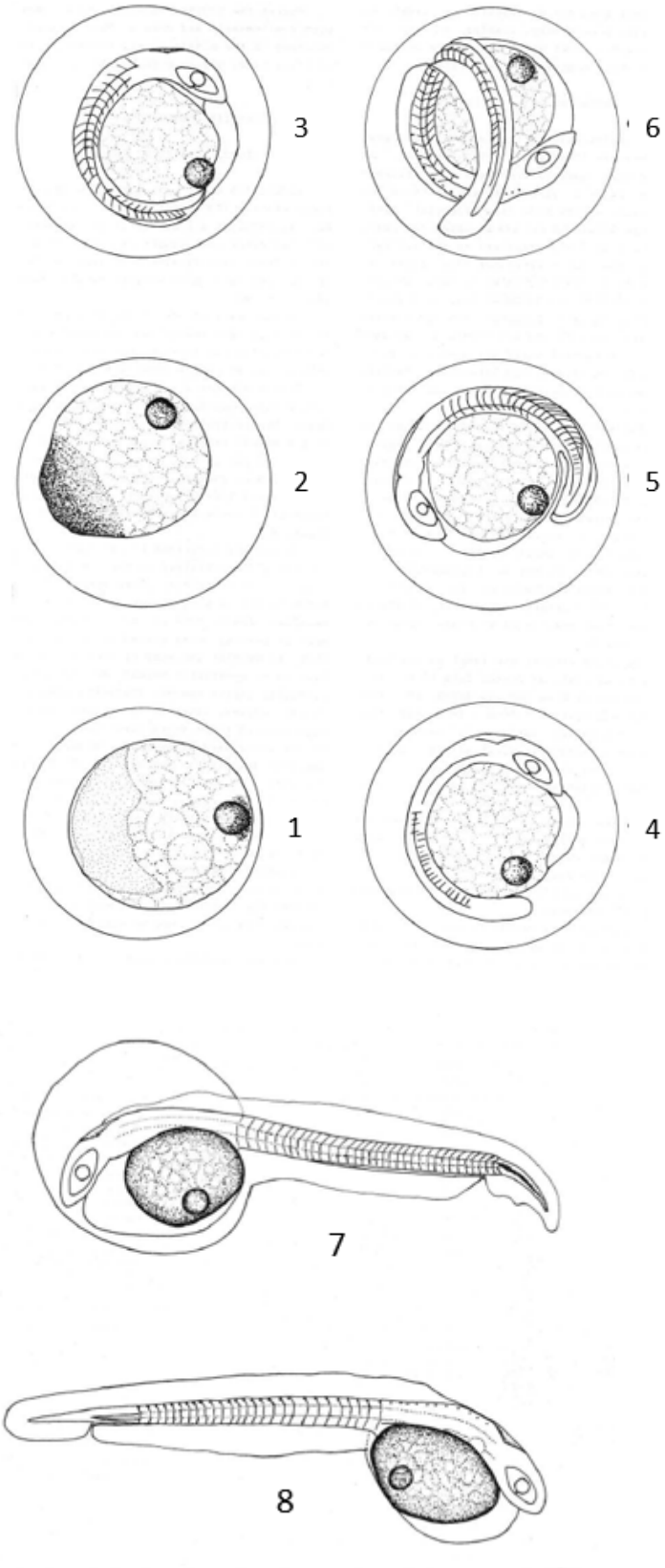
Camera: Nikon D610 mounted on a Leica beam splitter with phototube.

Capture software: Digicam control, version 2.0.0.0

Photo editing program: Photoshop CS6.

ANNEX IV. Identification guide to egg and larvae of *Sardinella aurita*.

Sardinella aurita egg



Aa, Ab and Ac from the earliest stage of development up to closure of the blastopore. Stage B includes stages from the end of A up to the beginning of the separation of the tail bud from the yolk.
B may be substituted for the subdivisions Ba, Bb and Bc. Stage C extends the end of B to hatching and is divided into Ca and Cb.

Figure 1 Sardinella eggs and larvae of different developmental stages. (Matsuura, Y. 1971). 1. Stage Aa, 2. Stage Aa, 3. Stage Bb, 4. Stage Bc, 5. Stage Bc, 6. Stage Ca, 7. Stage Cb hatching egg and 8. Yolk sack larvae.

Sardinella aurita larvae

1. Distinctive characters in early larval stages up to 6 mm.
   A) Size of larvae on hatching 3.5 mm (Olivar AND Fortuño 1991) 2,6 mm (survey 2014404 and 2016406) The oil globule is situated medially on the ventral portion of the yolk. see picture 5.2 (p42 upper left).
   B) Size of larvae when eyes become pigmented is around 5 mm for S. aurita (Conand and Fagetti 1971).
   C) Pigmentation on head is absent up to about 8 mm head pigmentation visible after that (Ditty et al. 1994) (Gulf of Mexico).
   D) Pigmentation on body: No melanophores visible on the body of yolk sack larvae, two melanophores around the anal, no pigmentation posterior to the anal.

2. Distinctive characters from 6 mm.
   A) Shape of gut and swim bladder: The foregut is strait and narrower than posterior to the swim bladder; the hindgut is also striated in appearance.
   B) Length of gut (key distinctive feature): End of gut is situated 8-9 myomeres behind the end of the dorsal fin. The length of the foregut is smaller than in Pilchard larvae.
   C) Shape of head: similar to Pilchard and Anchovy.
   D) Distinguishing pigmentation. 7-10 mm relatively sparse postanal pigmentation. After 10 mm stronger pigmentation as in pilchard.
   E) Number of myomers 41+ 7 (pre and post anal) (conand and Fagetti 1971)

From; Guide to ichthyoplankton of the Southeast Atlantic
(Benguela Current Region) Olivar, M-P. and Fortuño. J-M. 1991

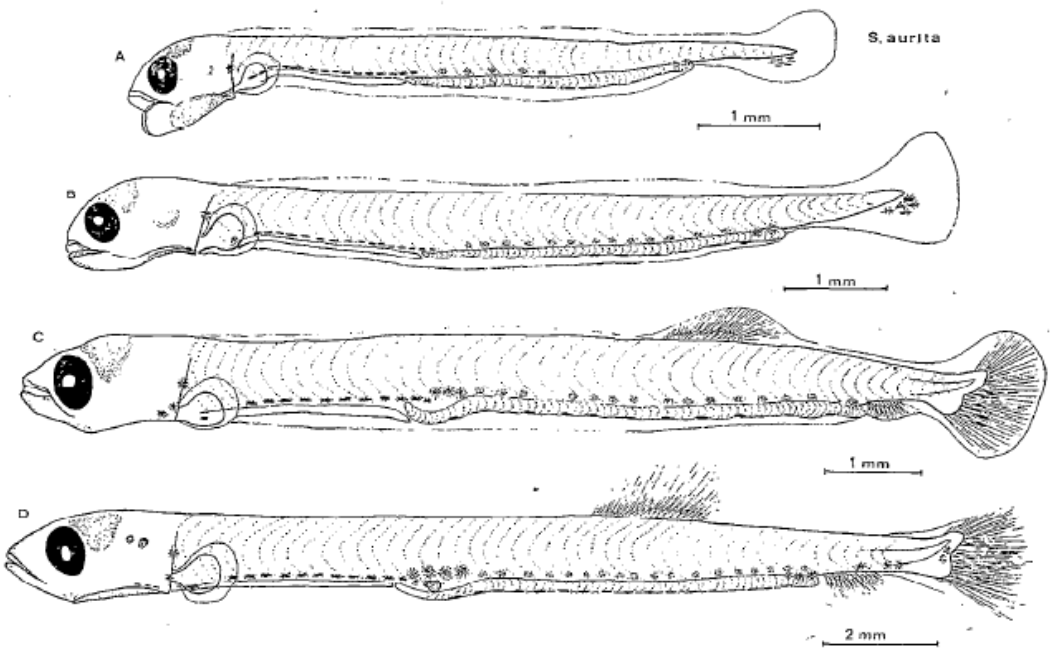
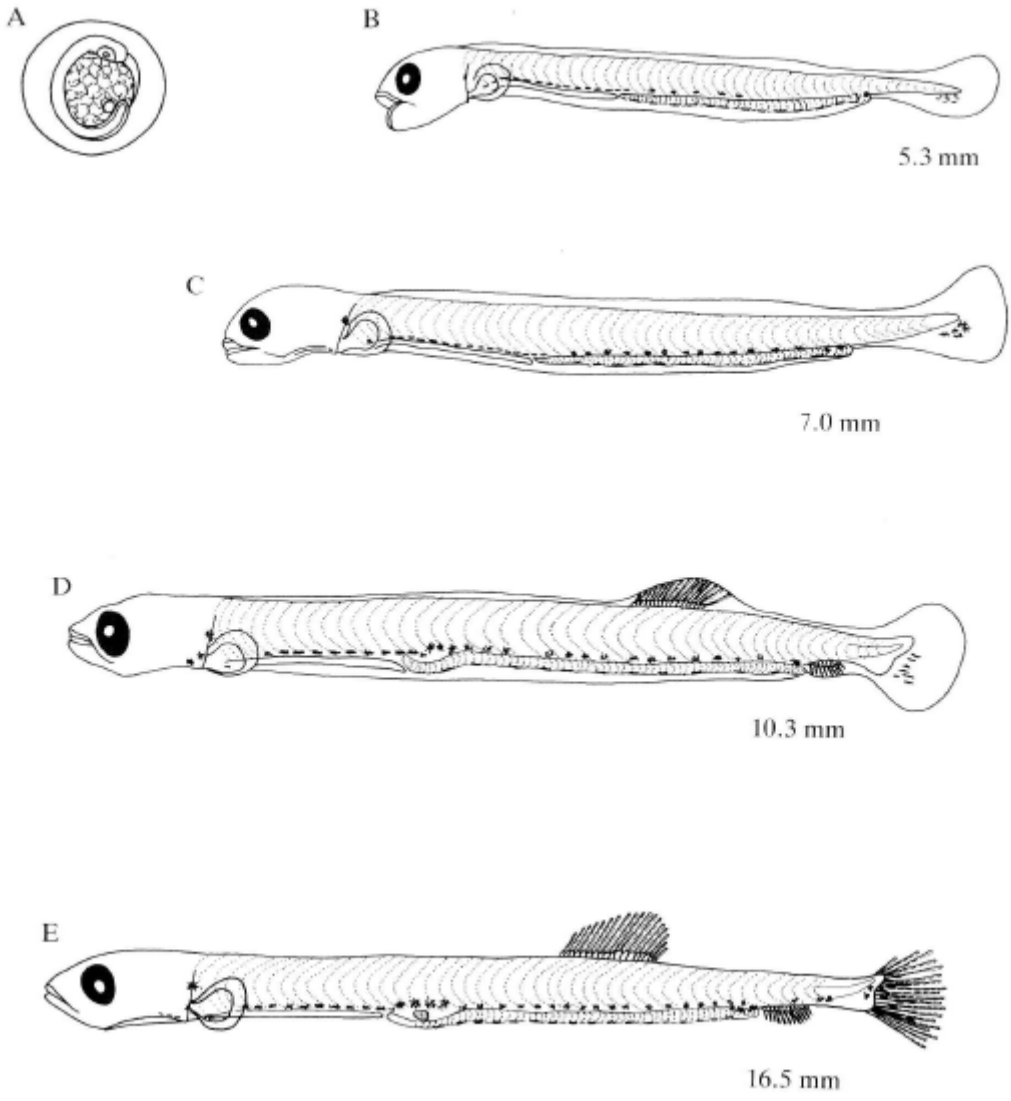


Figure. Different development stages of S. aurita larvae. A) 5.3 mm, B) 7.0mm, C) 10.0 mm, D) 16.5 mm (Conand, F. and Fagetti, E. 1971)



Figure; Guide to ichthyoplankton of the Southeast Atlantic (Benguela Current Region) Olivar, M-P. and Fortuño. J-M. 1991