Diversity and distribution of algal settlement in Mangrove of Londji, Kribi-Southern-Cameroon

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Original submitted in on 9th March 2020. Published online at www.m.elewa.org/journals/ on 31st May 2020

https://doi.org/10.35759/JABs.149.9

ABSTRACT

Objective: Phytosociological characterization of microalgae in the mangrove area of Londji in Kribi, South Region of Cameroon while analysing the physicochemical parameters related to it.

Methodology and results: Geo-textiles were laid in the river and water samples taken. One hundred and eight (108) samples were collected in 6 different areas. One hundred and twenty-four (124) species of microalgae were inventoried in this ecosystem, divided into 87 genera, 50 families, 26 orders, 11 classes and 5 groups (phyla). The Bacillariophyceae class was the highest with 59.68%, followed by Xyngophyceae 3.23% and Haptophyceae 2.42%. Euglenophyceae and Xanthophyceae both had 1.61% while Chrysophyceae, Rhodophyceae and Cryptophyceae all had 0.81%. Finally, Cyanophyceae represented 5.65% of total number of species. The analyses of the physicochemical parameters did not show major organic pollution however little metallic pollution was observed.

Conclusion and application: This work made it possible to set up three aspects of biodiversity: to know the algal diversity of the environment, to inventory different species, and to know the state of the ecological environment of this ecosystem. Thus, to know the state of the environment for the development of this ecosystem, within the framework of the emerging shrimp farming in Cameroon.

Keys words: Cameroon, Kribi, mangrove, microalgae, plant sociology.
INTRODUCTION

Algae are poorly known and inventoried in Cameroon with the exception of a few reports and authors who worked in river and lakes (Kengne et al., 2005; Njine et al., 2007; Ngquetsop et al., 2009; Mama et al., 2016) but none in mangroves. The mangrove is a major contributor to nutrient trapping, the transformation of organic matter and suspended solids from estuarine and coastal waters. A complex ecosystem characterized by high dynamics and high primary productivity, the mangrove is able to accept such excess intake, without causing biological imbalance or functional disruption (Tomlinson, 1986; Herteman, 2010). In fact, microalgae ensure the production of renewable resources up to about 100 million tons per year through fishing (Muller-Feuga, 1997). They are considered as the first link in the food chain (phytoplankton) for secondary producers (fish, crustaceans), they are a source of animal and human food, hydrocarbon production, pharmaceuticals, soil fertilization, natural pigment production and they are used in aquaculture. At a time when there is increasing growth in marine pollution and poor management of the marine and coastal environment, there is a compelling need to know about biodiversity and to understand the functioning of mangrove ecosystems for their wise exploitation and the conservation of their resources. The development and management of ecosystems is a major environmental issue in the process of development and sustainable management of natural resources in Cameroon (Envirep, 2014). Mangroves are multi-purpose ecosystems that hold a key function for the processes involved in marine production, quality or biodiversity of coastal resources. They play the role of spawning grounds for many species of fish and shrimp. It is in this ecosystem in southern Cameroon at Londji-Kribi that microalgae have been inventoried and identified. Folack (1989) distinguished four phytoplankton groups in this ecosystem. To better understand algal diversity, a study was conducted in six zones of the river at the same time as physicochemical parameters of the environment were studied. The main objective of this study is to phytosociologically characterize the mangrove microalgae of Londji-Kribi in southern Cameroon while analysing the related physicochemical parameters. This study aims specifically to:

- identify microalgae in the mangrove area;
- locate areas that abound with more microalgae;
- study the physicochemical parameters of the ecosystem.

MATERIAL AND METHOD

Study area: The city of Kribi is located in the department of the Ocean, Southern Region having geographical coordinates 2° 56′14 N of latitude and 9° 54′27 E of longitude. The Mangrove of Londji-Kribi, in area 4 (Kribi-Campo), is in the Republic of Cameroon, Southern Region, Department of the Ocean and Kribi District 2, bathing in the coasts of the Atlantic Ocean. It is also bounded: in the north by the village Bebambwe; in the south by the village Mpalla; in the East by the Londji River and in the West by the Atlantic Ocean. The sampling distance is 900 m in length and 15 m (approximately) wide, or 13,500 m² of surface area evenly distributed at 2,250 m² each. The maximum depth is 2.84 m and the minimum 0.50 m (Fig. 1).
Fig.1. Study area and sampling site

Sampling and measurement of physico-chemical parameters in situ: Sampling was performed on October and November 2013 between 8 am and 6 pm. These samples were packaged in 125 ml glass bottles and 1.5-liter polyethylene bottles. Samples of microalgae samples were done following the phytoplankton standardization protocol method (Laguerre, 2008); water samples were collected in 108 vials in the field, and were transported to the laboratory for analysis. In the field, parameters such as: temperature, pH, electrical conductivity and total dissolved solids were measured using a HANNA model HI 98130 pH/EC/TDS after plunging the electrode in glass in the river. The salinity was obtained using a refractometer after soaking the glass plate in the water. The dissolved oxygen was measured by an EXTECH Model Exstik II DO 600 brand oximeter after the glass electrode had been immersed in a vessel containing river water drawn in situ. In the laboratory, the different physicochemical parameters such as nitrite (NO₂),...
phosphorus (P), ammonium (NH₄), cadmium (Cd), lead (Pb), iron (Fe) and biological oxygen demand (BOD₅) were measured (Rodier; 1996). The samples were taken between 8 and 9 am, placed in 1.5-liter polyethylene bottles, and stored in the cooler. These bottles of water were transported to the IRAD laboratory in Nkolbisson-Yaoundé for the analysis of nitrite, phosphorus, ammonium, cadmium, iron, lead and the Department of chemistry of the University of Yaoundé I. The determination of the Biochemical oxygen demand was made by the so-called 'manometric' method using a Hach brand BOD₅ apparatus (model 2173B).

**Identification and counting of microalgae:** The identification was made by using catalogs, after microscopic observation from the description. The drawings, dimensions and identification of the species was made possible by comparison of the data with the works of some authors (Heurck, 1899; Itlis, 1980; Carmelo, 1997; Botes, 2001; Verlenkar, 2004; Ba, 2006; Gopinathan et al., 2007; Blais, 2008; Karlson, 2010).

**Quantitative analysis**

**Abundance:** Taking into account the phytoplankton was done using the Malassez Cell method (Guiraud, 1998; Gueret, 2002; Ba, 2006; Laguerre, 2009). The technique relies on the sedimentation of organisms in a counting cell of a known volume sample. After fixing the lugol water samples, 0.1 ml was placed in 50 ml of the sample. 1 ml of the sample was taken after homogenization. Subsequently, moisten the outer parts of the coverslip and place the coverslip on the Malassez Cell, for the sample on the edge of the blade with an eye dropper. Then put the slide under the microscope and count the number of cells for three square and average (at least three counts are made) then calculate the cell concentration in cells per ml according to the formula: $C = n \times 100 \times 1000$ (Ba, 2006).

**Specific dominance:** The dominance index "d" of Berger and Parker which has the formula $N_{\text{max}}/N$; $N_{\text{max}}$ is the maximum abundance or number of the most common individuals in the environment and N is the total abundance or total number of individuals. It establishes the dominance of the species and shows that, if d is weak, that is to say that it tends to 0, the diversity is great and the dominance is zero. When "d" tends to 1, we have dominant species and low diversity.

Simpson's $D$ index is $D = \sum \left( \frac{N_{i} (N_{i} - 1)}{N (N - 1)} \right)$ or $D = \sum P_{i}^{2}$. This index represents the probability that two individuals selected at random from a sample belong to the same species.

**Diversity of Shannon-Weaver and the regularity of Pielou:** The Shannon-Weaver index ($H'$) indicates the diversity or specific richness of the environment,

$$H' = -\sum P_{i} \log_{2} P_{i}$$

The regularity or "evenness index" or equitability of Pielou is: $R = \frac{H'}{H'_{\text{max}}}$, with $H'_{\text{max}}$ maximum diversity $H'_{\text{max}} = \log_{2}S$, (where $S$ is the number of species) (Priso et al., 2012).

**Sørensen similarity index:** The Sørensen similitude index $S$ measures the similitude of species between two habitats.

$$S = \frac{2ab}{2a+b+c} \times 100.$$ It is used for comparing different areas (with $a=\text{number of species present on the surface or area}$, $b=\text{the number of species present in depth}$, and $c=\text{number of common species in the two zones}$).

**Statistical analyses:** For statistical analysis, Microsoft Excel 2010 was used for the descriptive statistics as well as the calculation of means and variances. The Student's test was carried out in R3.0.1, and allowed to compare the numbers of species present on the surface in depth with a significance level of 5% ($P$ value 0.018).

**RESULTS**

**Taxonomic composition of phytoplankton:** The results show a great diversity of environments. One hundred and twenty-four (124) species have been recorded throughout the study area. They include 87 genera, 50 families, 26 orders and 11 classes. The largest number of species are found in the Bacillariophyceae group (Fig. 2). This group represents the most important class (59.68%), followed by Chlorophyceae (12.90%), then Dinophyceae (10.48%), Xyophyceae (3.23%) and Haptophyceae (2.42%). Euglenophyceae and Xanthophyceae each represented 1.61% while Chrysophyceae, Rhodophyceae and Cryptophyceae each represented 0.81%. In addition, Cyanophyceae showed 5.65% of the total number of species.
Inventory and specific richness of the microflora:
The identification has allowed to classify the different species and to establish the specific richness of the microflora of the area. There were 124 species recorded in the Londji mangrove at Kribi, including 32 other species that could not be fully identified. In the six areas, 45, 28, 34, 64, 26 and 23 species were inventoried respectively. In the first and fourth zones, the diversity is high downstream (respectively $H'_1s = 3.97$, $H'_4s = 4.22$ and $H'_1p = 4.43$, $H'_4p = 4.34$), but downtrends ($H'_5s = 3.27$, $H'_6s = 2.94$ and $H'_5p = 3.38$, $H'_6p = 3.49$). The Student's test showed that there are more species at the bottom than at the surface (P-value = 0.018, $\alpha = 0.05$). The phytoplankton biomass in bacillariophyceae is higher compared to the rest of the classes, which are Chlorophyceae, Chrysophyceae, Cryptophyceae, Dinophyceae, Rhodophyceae, Zygophyceae, Haptophyceae, Euglenophyceae and Cyanophyceae (Table 1).

Table 1: Numbers of the 11 classes inventoried in the six zones at different levels

| Classes         | Frequencies |
|-----------------|-------------|
| Bacillariophyceae | 74          |
| Chlorophyceae   | 15          |
| Chrysophyceae   | 1           |
| Cryptophyceae   | 1           |
| Cyanophyceae    | 7           |
| Dinophyceae     | 13          |
| Euglenophyceae  | 2           |
| Haptophyceae    | 4           |
| Rhodophyceae    | 1           |
| Xanthophyceae   | 2           |
| Zygophyceae     | 4           |

Contribution of species
Abundance of majority species: The different species of phytoplankton inventoried are composed of 124 species, of which 25 species have a population greater than or equal to $5 \times 10^6$. All of these 25 species represent 68.09% of the total population. Among these dominant species, 9 constitute 44.41% of the assemblage of the species Navicula pigmeeae, Pleurosigma sp., Closterium sp., Navicula cuspidata, Navicula cryptocephalia, Navicula sp., Nitzschia sigma, Nitzschia longissima and Coccolithus sp. divided in 4 genera Navicula, Pleurosigma, Nitzschia and Coccolithus, three genera Bacillariophyceae and one Chlorophyceae (Fig. 3a).

Abundance of minority species: Another 14 species also have populations of between $1.66 \times 10^6$ and $5 \times 10^6$ cells/ml in various samples. These are Ethmodicus sp., Asterionellopsis sp., Azpeita africana, Biddulphia...
sp., *Chlorella* sp., *Diploneis weissflogii*, *Fragilloria* sp., *Oscillatoria quadripunctata*, *Coscinodiscus* sp., *Isthmia enervis*, *Thalassiosira* sp., *Microcystis*, *Nitzschia closterium*, *Nitzschia* sp. (Fig. 3a).

**Abundance of dominant species classes:** In the samples, the amount of phytoplankton is very high in *Bacillariophyceae* with 72% in the volumes of water sampled (Fig. 3b).

**Fig. 3a.** Microalgae species as a function of phytoplankton quantities

**Fig. 3b.** Classes of inventoried species based on the amount of cells in the sample

**Abundance of dominant species by area:** In different areas, depending on the living level of the harvested species, more species are found at depth than on the surface and a small category of species is found between the two levels. (Fig. 4). Five groups emerge from this dendrogram, distributed in three levels, species represented only in depth, species present only at the surface, species that are found in both environments.
Fig. 4. Grouping species according to levels
Diversity of the site and survey of the different zones: The different areas sampled between the sampled levels are shown in the figures below. According to abundance, several species dominate this space *Ethmodicus* sp., *Navicula* sp., *Nitzchia* sp., *Pleurosigma* sp., *Prorocentrum* sp. and *Thalassiosira* sp. on the surface and *Ethmodicus* sp., *Navicula* sp., *Nitzchia* sp., *Pleurosigma* sp. and *Thalassiosira* sp. at the bottom (Fig. 5a, 5b).

**Fig.5a.** Number of abundant species in area 1 at the surface

| Species | Frequencies |
|---------|-------------|
| Ale     |              |
| Bid     |              |
| Eth     |              |
| Ist     |              |
| Lic     |              |
| Noc     |              |
| Nav     |              |
| Nitz    |              |
| Nav     |              |
| Ple     |              |
| Pro     |              |
| Rhi     |              |
| Tha     |              |
| Tha1    |              |
| Tri     |              |
| Tri1    |              |

**Fig.5b.** Number of abundant species in zone 1 at depth

| Species | Frequencies |
|---------|-------------|
| Azp     |              |
| Bid     |              |
| Clo     |              |
| Coc     |              |
| Cos     |              |
| Dic     |              |
| Eth     |              |
| Ism     |              |
| Lic     |              |
| Nav     |              |
| Nit     |              |
| Nitz    |              |
| Nav     |              |
| Ple     |              |
| Pro     |              |
| Rhi     |              |
| Tha     |              |
| Tha1    |              |
| Tri     |              |
| Tri1    |              |

After sampling in zone 2, at the surface, the predominant species are *Navicula* sp., *Nitzchia* sp., *Pleurosigma* sp., *Prorocentrum* sp. and *Thalassiosira* sp., at the bottom we find *Ethmodicus* sp., *Navicula* sp., *Nitzchia* sp., *Pleurosigma* sp. and *Thalassiosira* sp. (Fig. 6a, 6b).
Fig. 6a. Number of abundant species in Area 2 at the surface
Cal. *Calyprolithophora* sp. (papillifera), Chl. *Chlorella* sp, Eth. *Ethmodiscus* sp, Fra. *Fragilloria* sp, Has. *Haslea wawrika*, Mic. *Microcystis* sp., Nav. *Navicula* sp., Nit. *Nitzschia* sp., Noc. *Nocticuca* sp, Pin. *Pinnularia* sp, Ple. *Pleurosigma* sp, Pro. *Prorocentrum* sp, Prot. *Protoperidium* sp, Rhi. *Rhizosolenia* sp, Tha. *Thalassiosira* sp.

Fig. 6b. Number of abundant species in zone 2 at depth
Cos. *Coscinodiscus* sp., Eth. *Ethnodicus* sp., Hem. *Hemselmis* sp., Nav. *Navicula* sp., Nit. *Nitzschia* sp., Noc. *Noctiluca* sp., Pin. *Pinnularia* sp, Ple. *Pleurosigma* sp, Pro. *Protoperidium* sp, Rhi. *Rhizosolenia* sp., Syn. *Synechocystis* sp, Tha. *Thalassiosira pseuodonana*. Tha1. *Thalassiosira* sp.

Species abundance surveys reveal the abundant surface species *Ethnodicus* sp., *Navicula* sp., *Nitzschia* sp. and *Pleurosigma* sp.; in depth *Navicula* sp., *Nitzschia* sp., *Pleurosigma* sp. and *Thalassiosira* sp. (Fig. 7a, 7b).

Fig. 7a. Number of abundant species in Area 3 at the surface
Eth. *Ethnodicus* sp., Nav. *Navicula* sp., Nit. *Nitzschia* sp., Ple. *Pleurosigma* sp, Pro. *Prorocentrum* sp, Rhi. *Rhizosolenia* sp., Str. *Striatella* sp, Syn. *Synechocystis* sp, Tha. *Thalassiosira eccentric*, Tha1. *Thalassiosira* sp., Tri. *Triceratium* sp, Tri1. *Trichodesmium* sp.
In zone 4 (Fig. 8a, 8b), a high number of species are observed compared to other areas, the abundant species at the surface Ethnodicus sp., Navicula sp., Nitzchia sp., Pleurosigma sp. and Thalassiosira sp.; in depth Closterium sp., Navicula sp., Pleurosigma sp. and Thalassiosira sp. In zone 5, the number of species decreases. The most abundant species at the surface are Navicula sp., Nitzchia sp., and Pleurosigma sp. and in depth, Navicula sp., Nitzchia sp., Rhizosolenia sp. and Synechocystis sp. (Fig. 9a, 9b). In zone 6, the dominant surface species are Navicula sp., Nitzchia sp., Thalassiosira sp. and Pleurosigma sp. Those found at the bottom are Ethnodicus sp., Navicula sp. Nitzchia sp. and Pleurosigma sp. (Fig. 10a; 10b).
Motto et al., J. Appl. Biosci. 2020 Diversity and distribution of algal settlement in Mangrove of Londji, Kribi-Southern-Cameroon

Fig. 8b. Number of abundant species in zone 4 at depth Ach. Achnauthes exignoides, Amp. Amphora ovalis, Azp. Azpeita sp., Clo. Closterium sp., Coe. Coelastrum sp., Col. Colacium cyclopicola, Cos. Coscinodiscus rudolfii, Cos. cosmarium caudianum, Cos. Cosmarium ociculaire, Cym. Cymatopleura solea, Cymb Cymbella turgid, Den. Denticula thermalis, Din. Dinploneis sp (weissflogii), Gom. gomphonema olivaceum, Gon. Goniochloris gigas, Hya. Hyalotheca mucosa, Ist. Isthmia sp., Lic. Licmophora sp., Myc. Mycocystis sp., Nav. Navicula cuspidate, Nav1. Navicula sp., Nit. Nitzschia sigma, Osc. Oscillatoria sp., Pin. Pinnularia cardinalis, Ple. Pleurosigma sp., Pro. Prorocentrum sp., Pro. Protoperidinium sp., Rhi. Rhizosolenia sp., Ste. Stephanodiscus astraea, Sur. Surirella linearis, Tet. Tetraedron sp. (muticum), Thal. Thalassiosira pseudonana, Thal1. Thalassiosira sp.

Fig. 9a. Number of abundant species in Area 5 at the surface Clo. Closterium sp., Nav. Navicula sp., Nit. Nitzschia sp., Osc. Oscillatoria sp., Oxy. Oxytoxum sp., Ple. Pleurosigma sp., Pro. Protoperidinium sp., Rhi. Rhizosolenia sp., Tha. Thalassiosira pseudonana, Thal1. Thalassiosira sp., Thal. Thalassiothrix sp. (longissima), Tri. Trichodesmum sp.
Fig. 9b. Number of abundant species in zone 5 at depth

Cer. Ceratium sp., Eth. Ethmodiscus sp., Fra. Fragilariaopsis sp. (pseudonana), Gos. Gossleria sp., Mic. Microctinum sp. (pusillum), Nav. Navicula sp. bort arrondi, Nit. Nitzschia sp., Par. Paralia sp., Pla. Planktoniella sp., Pse. Pseudo-Nitzschia sp., Rhi. Rhizosolenia sp., Syn. Synechocystis sp., Tha. Thalassiothrix sp. (longissima), Tri. Trichodesmium sp.

Fig. 10a. Number of abundant species in Area 6 at the surface

Eth. Ethmodiscus sp., Cer. Ceratium sp., Hel. Helicotheca sp., Nav. Navicula sp., Nit. Nitzschia sp., Osc. Oscillatoria sp., Pla. Planktoniella sp., Ple. Pleurosigma sp., Tha. Thalassiosira sp.

Fig. 10b. Number of abundant species in zone 6 at depth

Cer. Ceratium sp., Clo. Closterium sp., Cru. Crucigenia sp., Eth. Ethnodicus sp., Gom. Gomphonema sp., Lic. Licmophora sp., Nav. Navicula sp., Neo. Neotreptotheca subindica, Nit. Nitzschia sp., Ple. Pleurosigma sp., Pse. Pseudo-Nitzschia sp., Rhi. Rhicoseolema sp., Tha. Thalassiosira sp., Tri. Triceratium sp.
Surveys of the different inventoried areas show that zones 1 and 4 have more species than the other zones. **Diversity index and evaluation of site specific diversity:** The three most representative species (*Navicula* sp., *Nitzschia* sp. and *Pleurosigma* sp.) are found in all areas. *Ethmodiscus* sp. is in almost all areas except Area 4 as well as *Thalassiosira* sp. that we also find everywhere in average number. Areas 1 and 4 have the highest diversity index while zones 5 and 6 have the lowest diversity index. The regularity index is close to 1 (Table 2).

**Table 2. Analysis of diversity indices**

| Areas | Abundance (individuals/ml) | Number of species | Index | Regularity |
|-------|---------------------------|-------------------|-------|------------|
|       | Mean | Maximum |                   | Diversity (H’) | Maximum Diversity |        |
|       | S    | B      | S      | B      | S    | B      | S    | B      | S  |
| 1     | 2442667 | 3102667 | 330000 | 360000 | 18  | 27    | 3,96776 | 6 | 4,434289 | 4,169925 | 4,754888 | 0,95152 | 0,93 2196 |
| 2     | 1626667 | 2143000 | 360000 | 360000 | 15  | 13    | 3,49332 | 1 | 3,573636 | 3,584693 | 4,59432 | 0,89414 | 0,96 5733 |
| 3     | 1782667 | 2528333 | 330000 | 360000 | 12  | 22    | 3,39508 | 3 | 4,157148 | 4,58963 | 4,59432 | 0,97030 | 0,93 2215 |
| 4     | 2816667 | 3092667 | 460000 | 360000 | 30  | 34    | 4,22425 | 1 | 4,344344 | 4,90691 | 5,08746 | 0,86088 | 0,85 3949 |
| 5     | 1531667 | 1157000 | 360000 | 230000 | 12  | 14    | 3,26971 | 3 | 3,78867 | 3,58463 | 3,80735 | 0,91206 | 0,88 7459 |
| 6     | 1165000 | 1320333 | 300000 | 260000 | 9   | 14    | 2,94455 | 3 | 3,486606 | 3,169925 | 3,80735 | 0,92890 | 0,91 5755 |

S = surface; B = Bottom

**Similarity index of Sørensen:** In zones 1, 2 and 6, respectively corresponding to the mouth, to the photic zone, and downstream, the similarity coefficient is greater than 50%. Zones 3 to 5, which each have a photic zone, and another aphotic zone have a similarity coefficient less than 50% (Table 3).

**Table 3. Sørensen similarity index**

| Areas (S+B) | Number of common species at surface and bottom | Sørensen index |
|-------------|-----------------------------------------------|----------------|
|             | 13 9 8 15 4 6                                | 57.77% 64.28% | 47.77% 46.87% | 30.76% 52.17% |

S+b= Surface + Bottom

**Analyses of physicochemical parameters in the Londji mangrove:** Samples showed decreasing temperatures in all areas, as well as pH and dissolved oxygen. In addition, the conductivity, salinity and total dissolved solids have very high fluctuations with considerable differences between areas 1 and 2 on the one hand, and areas 3, 4, 5 and 6 on the other hand (Fig. 11). The pH varies from neutral to acid between downstream and upstream. The mean pH value is 7.1 ± 0.3 downstream in zones 1 and 2, and 6.72 ± 0.17 in the middle part (zones 3 and 4). The temperature decreases progressively from downstream to upstream with 28.63 ± 0.32 °C downstream in zone 1 and 2, and 28.15 ± 0.14 °C in the middle part of zones 3, 4 and 27.47 ± 0.11 °C downstream in zones 5, 6. The conductivity, very high upstream, drops downstream. 9.28 ± 3.92 mS/cm upstream (zone 1 and 2); 0.82 ± 0.69 mS/cm in the middle part (3 and 4) and 0.41 ± 0.27 mS/cm in zones 5 and 6. Salinity and total dissolved solids decrease from downstream to upstream, respectively 8.9 ± 1.20; 4.73 ± 2.11 % downstream then 1.57 ± 0.74; 0.39 ± 0.33 % in the middle part then 0.23 ± 0.17; 0.21 ± 0.13 %. For heavy metals, cadmium, iron and lead, the values are decreasing from upstream to downstream respectively 0.152; 1.359; 0.448 mg/L downstream. They decrease in median area 0.055; 0.672; 0.041 mg/L and rise upstream 0.148; 0.469; 0.183 mg/L (Fig. 12). Nitrite concentrations are very low in zones 1 and 2, slightly increasing in area 3 and area 4 almost non-existent in areas 5 and 6 (Fig. 12). The biological oxygen demand (BOD5) is 18 mg/L in the four areas and decreases slightly in the last two 14 mg/L and 14 mg/L (Fig. 13).
Fig. 11. Variation of the physical parameters in the Londji-Kribi River according to the areas.
DISCUSSION

Taxonomic composition of microalgae and physicochemical parameters: Knowledge of the taxonomic composition of settlement is a necessary source of information. In the case of algal microflora, it provides a list of species used in aquaculture and assesses pollution (Ba, 2006). In the Londji mangrove, more Bacillariophyceae (59.68%), followed by Chlorophyceae (12.10%) are encountered. The high number of Bacillariophyceae shows that the environment has not yet experienced major pollution because these microscopic algae are particularly sensitive and responsive to changes in nutrient concentration in water, organic and mineral loads from fertilizers that run along farmland. Diatoms are used by a growing number of countries to monitor the quality of river or sea water because they are a reliable indicator of aquatic pollution (Mollo and Noury, 2013; Benoit-Chabot, 2014). Phytoplankton can react directly to pollutants, their high sensitivity to environmental factors and the high specificity of certain species in their ecological preferences and tolerances provides information on a large number of physicochemical parameters of water (temperature, pH, salinity, eutrophication) (Table 4).
Table 4. Comparison of the physicochemical parameters of the study

| Parameters          | This study                  | Other studies                      |
|---------------------|-----------------------------|------------------------------------|
| Temperature         | 27.40 – 28.85 °C            | 16 – 27 (FAO, 1996)                |
| Salinity            | 0.1 – 9.75 %                | 12 – 40 (FAO, 1996)                |
| pH                  | 6.69 – 7.18                 | 7 – 9 (FAO, 1996)                  |
| Dissolved oxygen    | 2.4 – 3.3 mg/L              | > 4.0 mg/l (Lazur, 2007)           |
| Nitrite             | 0 – 0.007 mg/L              | < 4.5 mg/l (Lazur, 2007)           |
|                     |                             | 0,01 mg/L (Siaebvelg, 2004)        |
| Ammonium            | 0.63 – 0.45 mg/L            | <1 mg/L (De Villier, 2005)         |
| Phosphore           | 0.014 – 0,084 mg/L          | 0 – 0.23 mg/l (Moreau, 2006)       |
| BOD5                | 14 – 18 mg/L                | 2-20 mg/L (MDDEFP, 2003)           |
| Conductivity        | (0.2 – 12.05) mS/cm         | 50 et 1500 μS/cm (De Villier, 2005) |
| Cadmium             | 0.055 – 0.148 mg/L          | 0.001 mg/L (De Villier, 2005)      |
|                     |                             | 2 mg/kg (Talbot, 1985)             |
| Lead                | 0.448 – 0.041 mg/L          | 0.05 mg/L (De Villier, 2005).      |

However, in the Londji River there has been an onset of metallic pollution, inherent in the installation of offshores in the sea and the construction of the deepwater port, which requires the use of metallic materials and discharges of hydrocarbons.

Richness and specific diversity of phytoplankton:
The richness and species-specific diversity of phytoplankton in this study are inferior to those obtained by Lung’Ayia et al. (2000), Ba (2006) in the lakes of the tropical zone (170 species); Huszar et al. (2000), Ba (2006) in Baleta Lake in Brazil (174 species), Niamien-Ebritte et al. (2013) in rivers in southeastern Côte d’Ivoire (192 species) and Radji et al. (2013) in aquatic ecosystems in southern Togo (203 species). On the other hand, they are close to those obtained by Ba (2006) in Lake Guiers in Senegal (111 species). This high species diversity would allow greater stability in the functioning of the ecosystem in the face of environmental disturbances (Ba, 2006). Phytoplankton biomass is higher in the Bacillariophyceae class and lower in the other classes (Fig. 14).

Diversity index and Sørensen index: The study reveals a Shannon-Weaver index value between 2.94 and 4.43. Generally, and regardless of the taxonomic group, the Shannon-Weaver index is between 1 and 4.5 rarely more (Bouzille, 2007). The study reveals a regularity close to 1, thus suggesting a stable community. In addition, the Sørensen index reveals that...
surface and depth microalgae in areas 1 (57%), 2 (64%) and 6 (52%) belong respectively to the same community. On the other hand, those in areas 3 to 5 (47%, 46%, 30%) do not belong to the same community. In addition, the Sorensen index reveals that surface and depth microalgae in areas 1 (57%), 2 (64%) and 6 (52%) belong respectively to the same community. On the other hand, those in areas 3 to 5 (47%, 46%, 30%) do not belong to the same community.

CONCLUSION
This work made it possible to set up three aspects of biodiversity: to know the algal diversity of the environment, to inventory different species, and to know the state of the ecological environment of this ecosystem. Thus, to know the state of the environment for the development of this ecosystem, within the framework of the emerging shrimp farming in Cameroon.

ACKNOWLEDGMENTS
Authors heartily thanks Dr Noé Woin, Director General of IRAD; Mrs. Ebelle Etame Rebecca, Secretary General of MINRESI; Senator Her Majesty Salomon Madiba Songuè, President of NGO AQUASOL and Mrs. Annie Trochery, President of the association Bleu Cameroun, for their advice and financial support.

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