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

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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 *Xygophyceae* 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; Nguetsop *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 m^2 of surface area evenly distributed at 2,250 m^2 each. The maximum depth is 2.84 m and the minimum 0.50 m (Fig. 1).

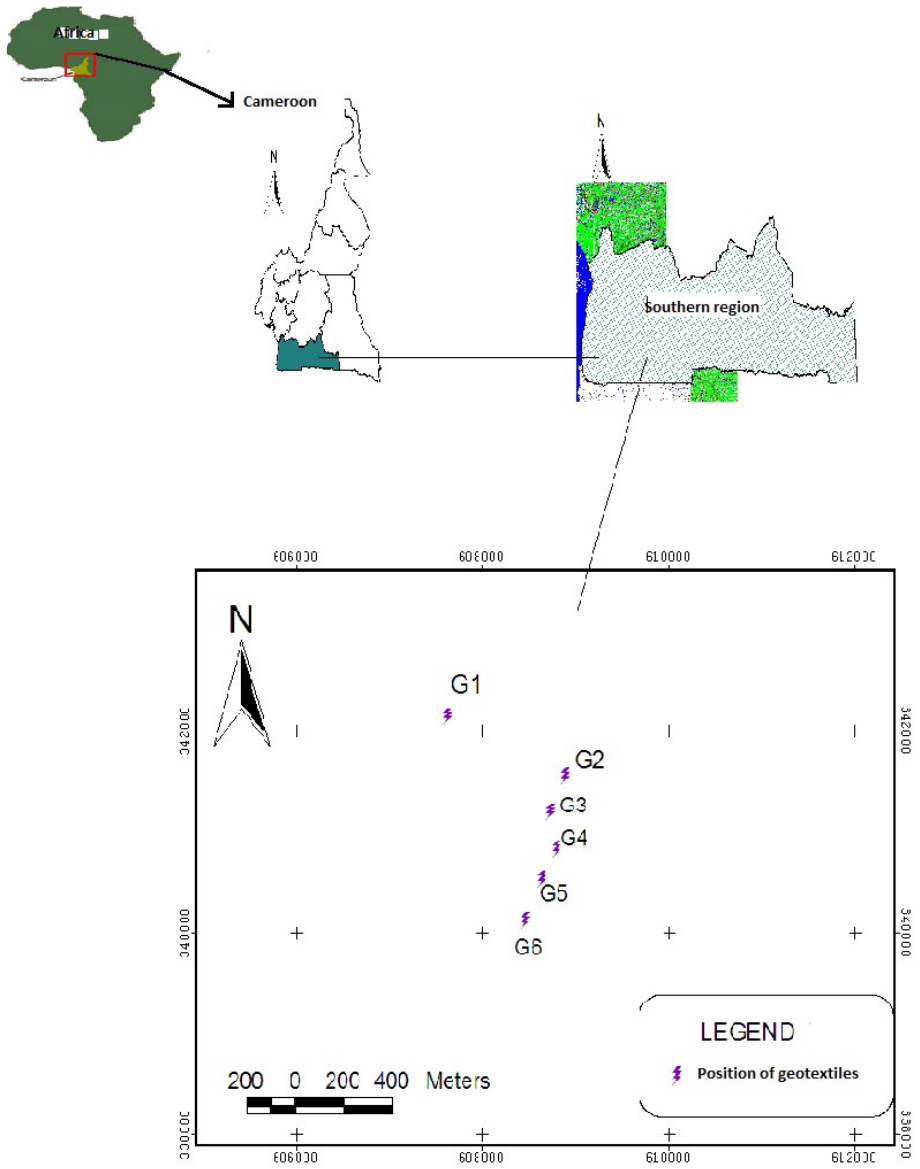

Fig.1. Study area and sampling site

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 (NO_2),

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; Iltis, 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 $= Nmax/N$; *Nmax* 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 $D = \sum \left(\frac{Ni\,(Ni-1)}{N\,(N-1)} \right)$ or $D = \sum Pi^2$. 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,

: $H' = -\sum Pi\, log_2\, Pi$

The regularity or "evenness index" or equitability of Pielou is: $R = \frac{H'}{H'_{max}}$ with H'_{max} maximum diversity $H'_{max} = Log_2 S$, (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.

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

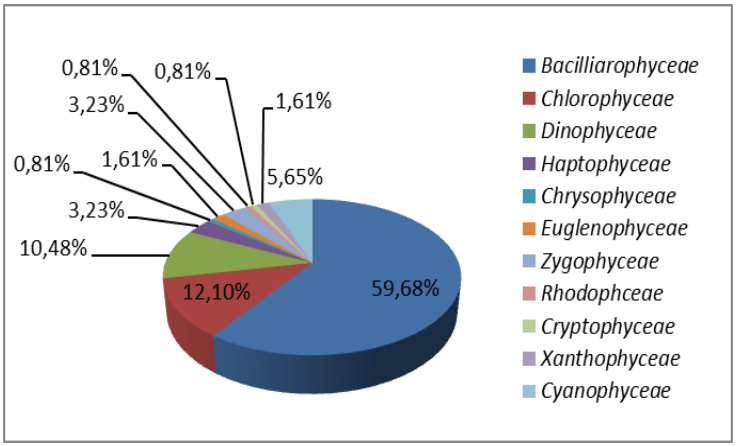

Fig.2. Percentage of the number of species by class

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, α = 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
Bacilliarophyceae	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 x 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 pigmaea*, *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 x 10^6 and 5 x 10^6 cells /ml in various samples. These are *Ethmodicus* sp., *Asterionellopsi* 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 *Bacillariophycea* with 72% in the volumes of water sampled (Fig. 3b).

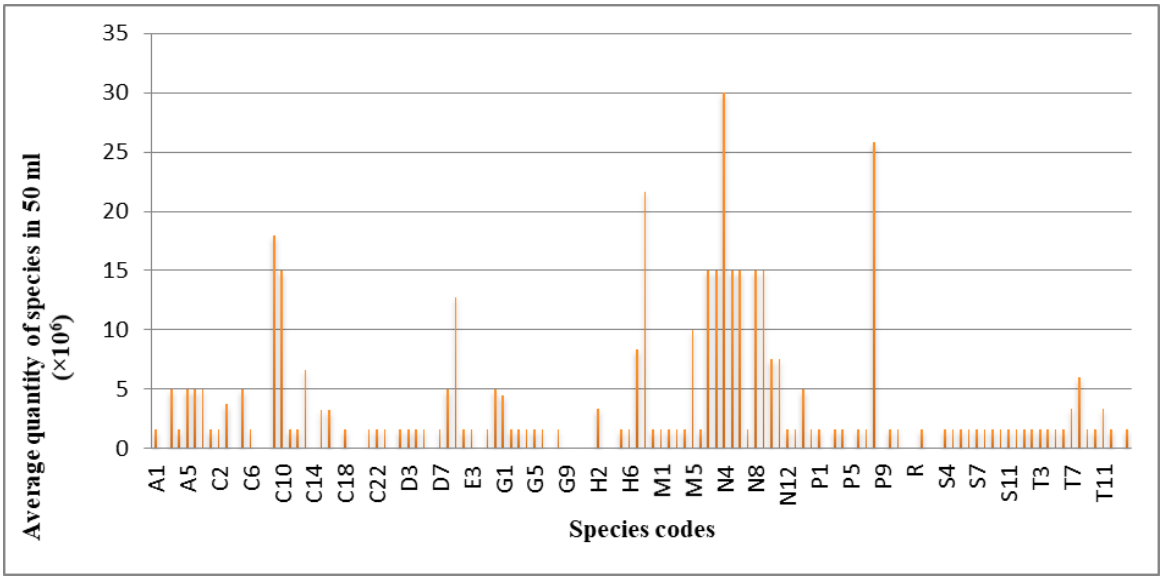

Fig.3a. Microalgae species as a function of phytoplankton quantities

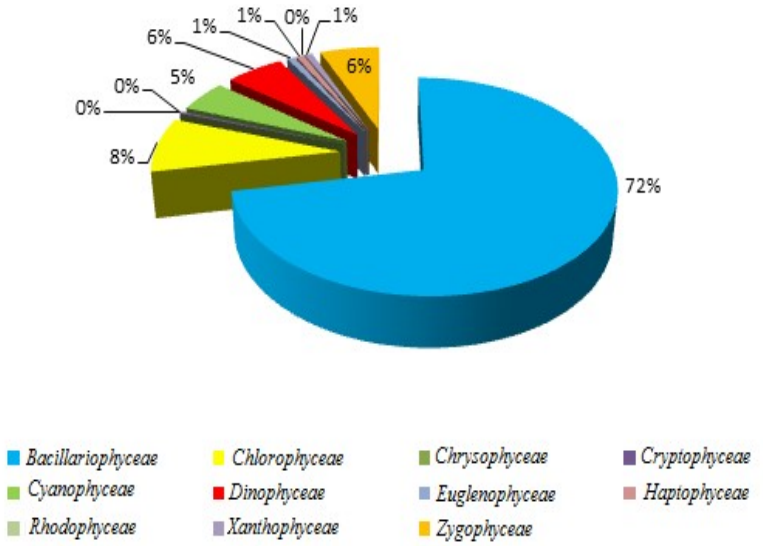

Fig.3b. Classes of inventoried species based on the amount of cells in the sample

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.

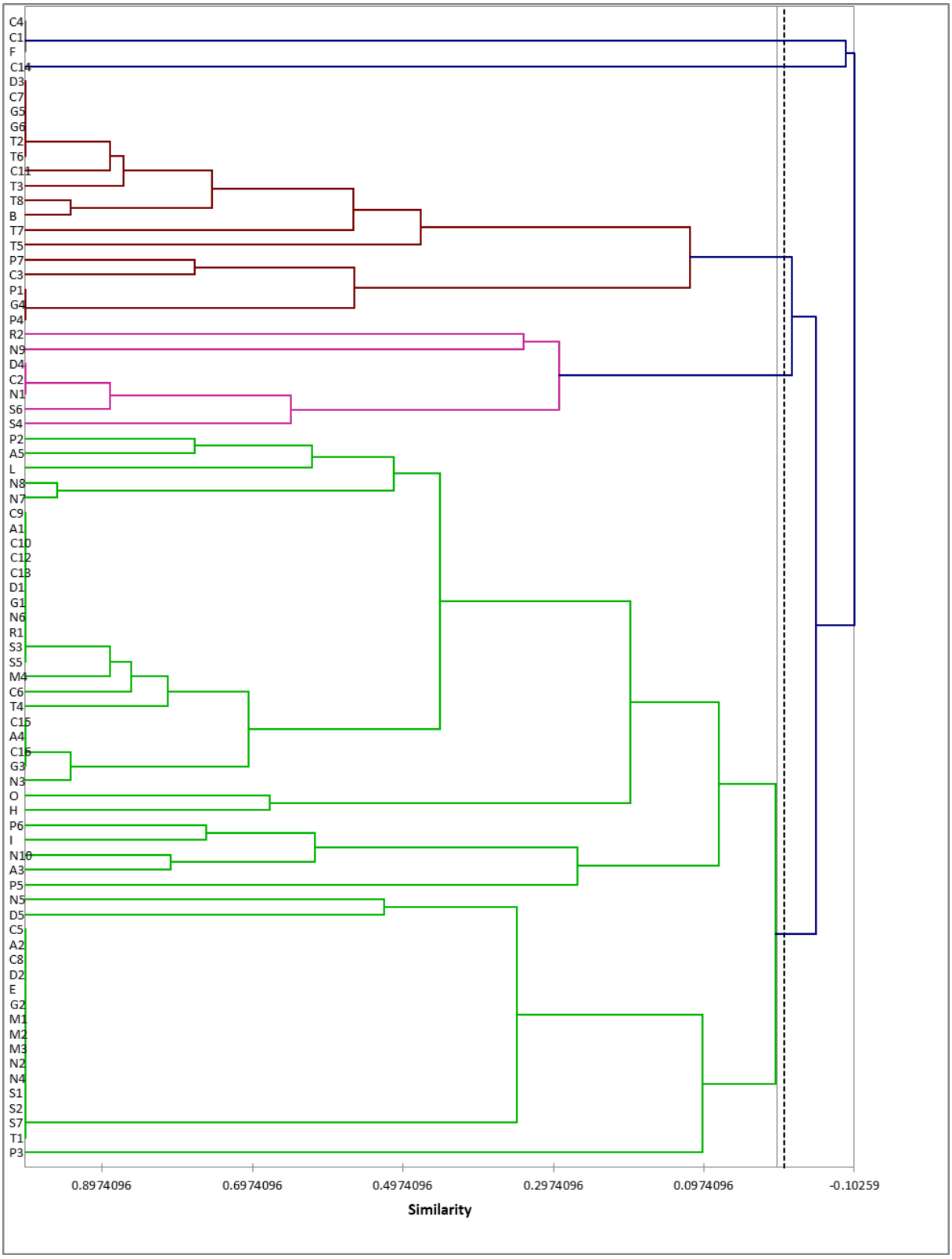

Fig.4. Grouping species according to levels

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., *Nitzschia* sp., *Pleurosigma* sp. and *Thalassiosira* sp. at the bottom (Fig. 5a, 5b).

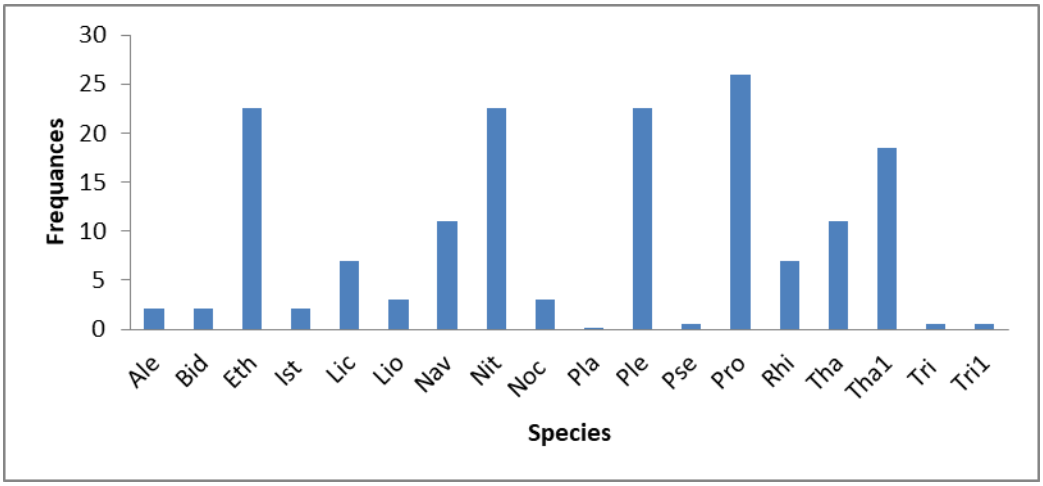

Fig.5a. Number of abundant species in area 1 at the surface
Ale *Alexandrium* sp., **Bid** *Biddulphia* sp., **Eth** *Ethnodicus* sp., **Ist** *Isthmia* sp., **Lic** *Licrmophora* sp., **Lio** *Lioloma* sp., **Nav** *Navicula* sp., **Nit** *Nitzschia* sp., **Noc** *Noctiluca* sp., **Pla** *Planktoniella* sp (muriformis), **Ple** *Pleurosigma* sp., **Pse** *Pseudo-nitzschia* sp., **Pro** *Prorocentrum* sp., **Rhi** *Rhizosolenia* sp., **Tha** *Thalassiossira pseudonana*, **Tha1** *Thalassiosira* sp., **Tri** *Trichodesmium theibaulii*, **Tri1** *Trichodesmium crypthreaum*.

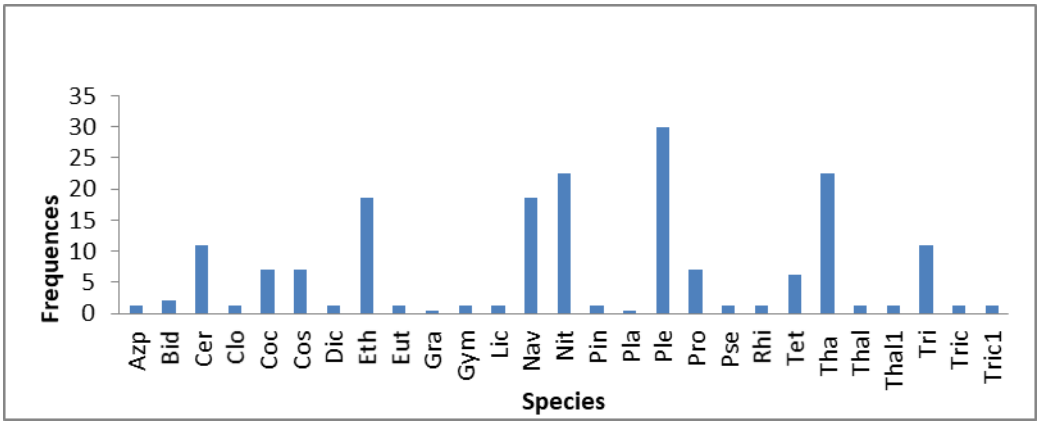

Fig.5b. Number of abundant species in zone 1 at depth **Azp**. *Azpeita* sp., **Bid**. *Biddulphia* sp., **Cer**. *Ceratium* sp., **Clo**. *Closterium* sp., **Coc**. *Coccolithus* sp., **Cos**. *Coscinodiscus* sp., **Dic**. *Dictyocha* sp., **Eth**. *Ethnodicus* sp., **Eut**. *Eutreptia* sp., **Gra**. *Grammatophora* sp., **Gym**. *Gymnodinium* sp., **Lic**. *Licmophora* sp., **Nav**. *Navicula* sp., **Nit**. *Nitzschia* sp., **Pin**. *Pinnularia* sp., **Pla**. *Planktoniella* sp. (*muriformis*), **Ple**. *Pleurosigma* sp., **Pro**. *Prorocentrum* sp., **Pse**. *Pseudo-Nitzschia* sp., **Rhi**. *Rhizosolenia* sp., **Tet**. *Tetraselmis* sp., **Tha**. *Thalassiossira* sp., **Thal**. *Thallasiothrix* sp., **Thal1**. *Thallassionema* sp., **Tri**. *Triceratium* sp., **Tric**. *Trichodesmium* sp., (*theibaulii*) **Tric1**. *Trichodesmium* sp., (*crypthreaum*).

After sampling in zone 2, at the surface, the predominant species are *Navicula* sp., *Nitzschia* sp., *Pleurosigma* sp., *Prorocentrum* sp. and *Thalassiosira* sp., at the bottom we find *Ethmodicus* sp., *Navicula* sp., *Nitzschia* sp., *Pleurosigma* sp. and *Thalassiosira* sp. (Fig. 6a, 6b).

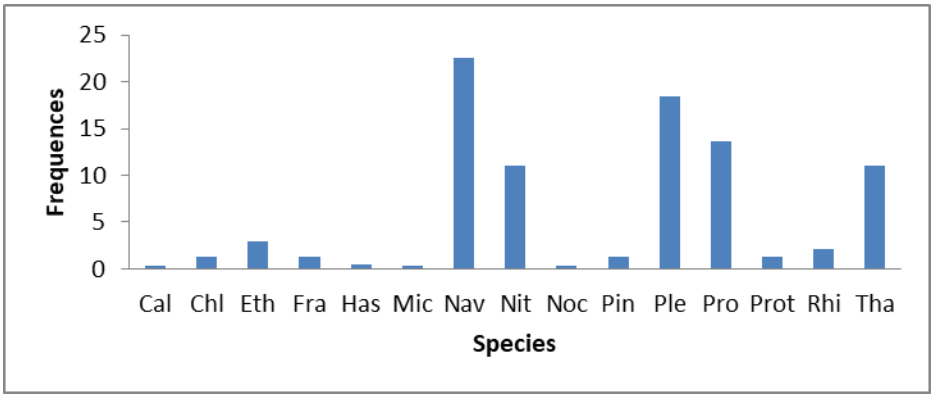

Fig.6a. Number of abundant species in Area 2 at the surface

Cal. *Calyptrolithophora* 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.

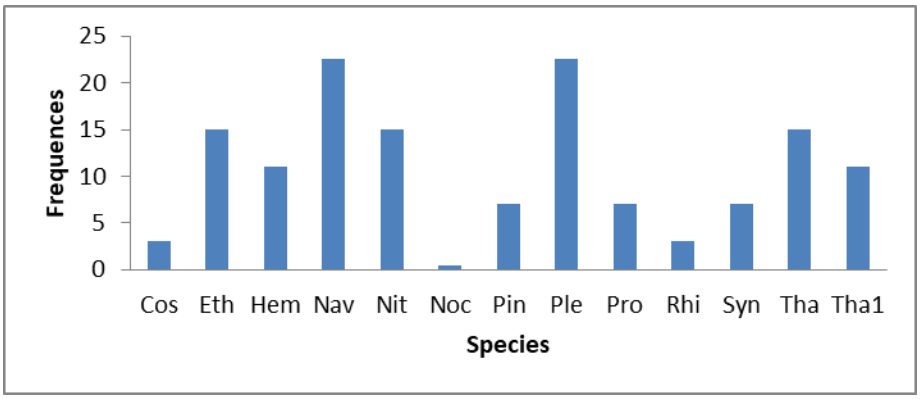

Fig.6b. Number of abundant species in zone 2 at depth

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 pseudonana.* **Tha1**. *Thalassiosira* sp.

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

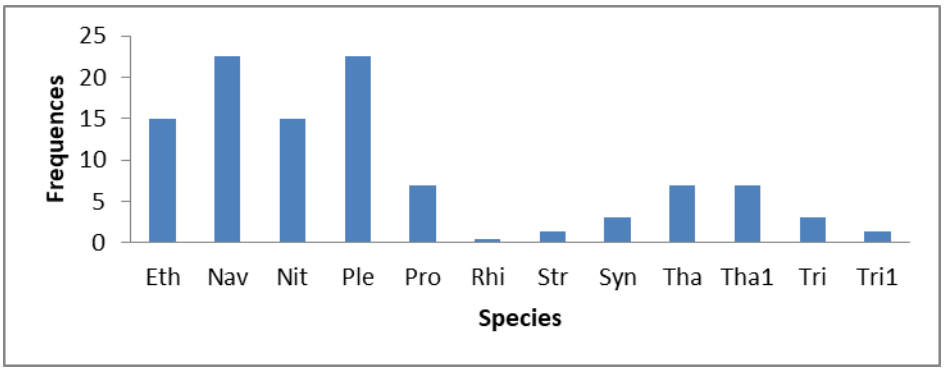

Fig.7a. Number of abundant species in Area 3 at the surface

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*, **Tha.** *Thalassiossira* sp., **Tri**. *Triceratium* sp., **Tri1.** *Trichodesmium* sp.

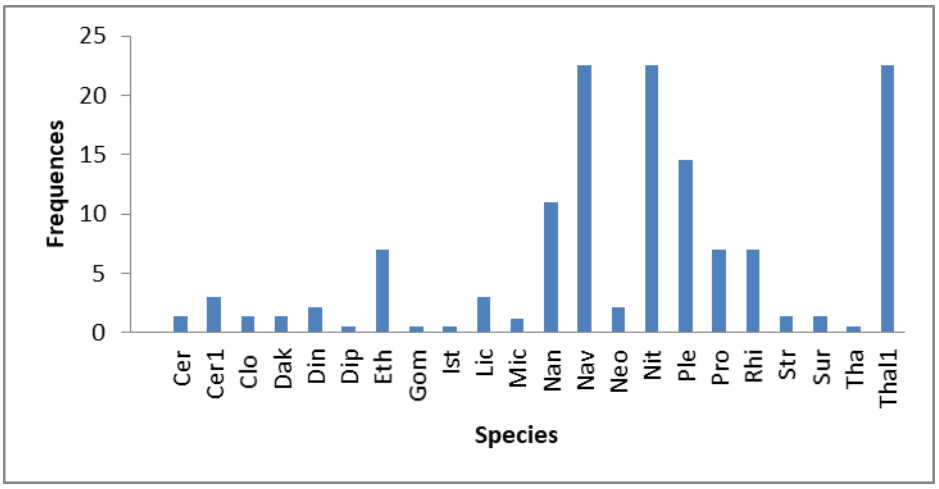

Fig.7b. Number of abundant species in zone 3 at depth
Cer. *Cerataulina* sp., **Cer1**. *Ceratium* sp., **Clo**. Closterium sp**., Dak**. *Daktyletra* sp.(*pirus*), **Din.** *Dinophysis* sp., **Dip.** *Diploneis* sp.(*weissflogii*)., **Eth.** *Ethnodiscus* sp., **Gom**. *Gomphonema* sp., **Ist.** *Isthmia* sp., **Lic**. *Licmophora* sp., **Mic**. *Microcystis* sp., **Nan**. *Nannochloropsis* sp., **Nav.** *Navicula* sp., **Neo.** *Neostreptotheca* sp (*subindica*), **Nit.** *Nitzschia* sp., **Ple**. *Pleurosigma* sp., **Pro**. *Prorocentrum* sp., **Rhi**. *Rhizosolenia* sp., **Str.** *Striatella* sp. (*unipunctata*), **Sur**. *Surirella* sp., **Tha.** *Thalassionema* sp., **Thal1**. *Thalassiosira* 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., *Nitzscha* sp., and *Pleurosigma* sp. and in depth, *Navicula* sp., *Nitzscha* sp., *Rhizosolenia* sp. and *Synechocystis* sp. (Fig. 9a, 9b). In zone 6, the dominant surface species are *Navicula* sp., *Nitzschia* sp., *Thalassiosira* sp. and *Pleurosigma* sp.. Those found at the bottom are *Ethmodicus* sp., *Navicula* sp. *Nitzschia* sp. and *Pleurosigma* sp. (Fig. 10a; 10b).

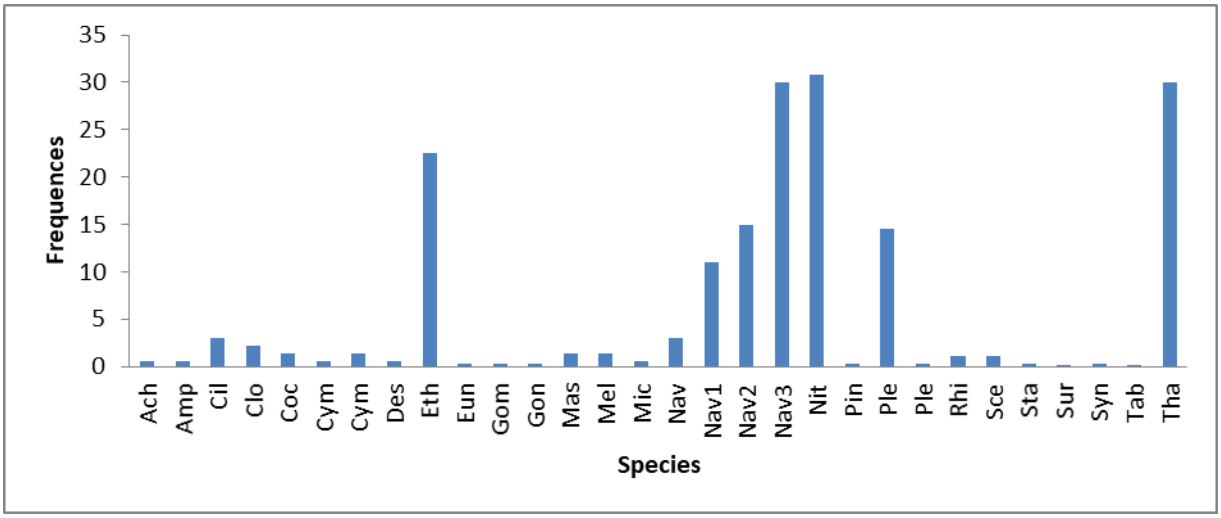

Fig.8a. Number of abundant species in Area 4 at the surface **Ach**. *Achnauthis* sp., **Amp**. *Amphora ovalis*, **Cil**. *Ciliophrys* sp. (*infusionum*), **Clo**. *Closterium* sp., **Coc**. *Cochlodinium* sp., **Cym**. *Cymatopleura solea*, **Cym**. *Cymbella* sp., **Des**. *Desmidium* sp., **Eth**. *Ethnodicus* sp., **Eun**. *Eunotica* sp., **Gom**. *Gomphonema* sp., **Gon**. *Goniochloris* sp., **Mas**. *Mastoglota* sp., **Mel**. *Melosiira* sp., **Mic**. *Microctinium* sp., **Nav**. *Navicula cryptocephalia*, **Nav1**. *Navicula cuspidata* **Nav2**. *Navicula pigmaea*, **Nav3**. *Navicula* sp., **Nit**. *Nitzschia* sp., **Pin**. *Pinnularia* sp., **Ple**. *Pleurosigma* sp., **Ple**. *Pleurotenium* sp., **Rhi**. *Rhizosolenia* sp., **Sce**. *Scennedesmus* sp., **Sta**. *Stauroneis* sp., **Sur**. *Surirella* sp., **Syn**. *Synedra ulma*, **Tab**. *Tabellaria floculosa*, **Tha**. *Thalassiossira* sp.

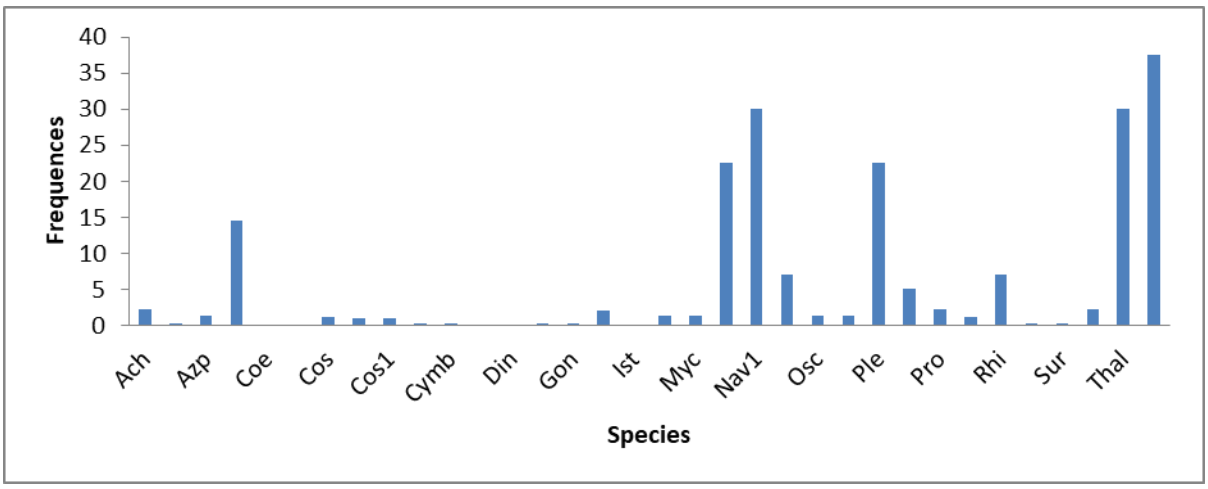

Fig.8b. Number of abundant species in zone 4 at depth **Ach**. *Achnauthes exignoides*, **Amp**. *Amphora ovalis*, **Azp**. *Azpeita* sp., **Clo**. *Closterium* sp., **Coe**. *Coelastrum* sp., **Col**. *Colacium cyclopicola*, **Cos**. *Coscinodiscus rudolfti*, **Cos** *cosmarium caudianum*, **Cos**. *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**. *Mycrocystis* 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**. *Rhicosolema* sp., **Rhi**. *Rhizosolenia* sp., **Ste**. *Stephanodiscus astraea*, **Sur**. *Surirella linearis*, **Tet**. *Tetraedron* sp. (*muticum*), **Thal**. *Thalassiosira pseudonana*, **Thal1**. *Thalassiosira* sp.

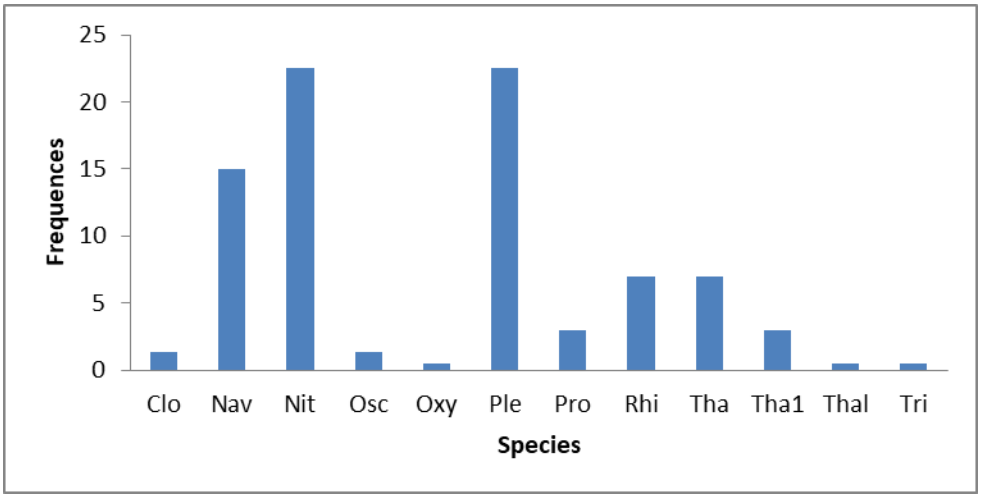

Fig.9a. Number of abundant species in Area 5 at the surface

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,* **Tha1**. *Thalassiosira* sp., **Thal**. *Thalassiothrix* sp. (*longissima*), **Tri**. *Trichodesmium* sp.

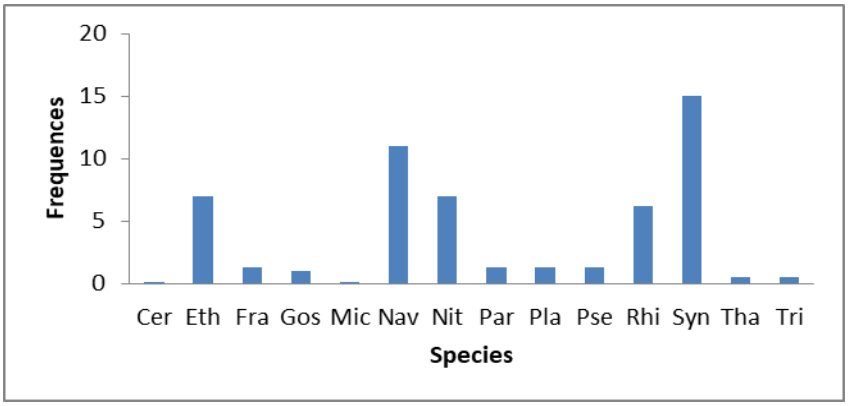

Fig.9b. Number of abundant species in zone 5 at depth

Cer. *Ceratium* sp., **Eth**. *Ethmodiscus* sp., **Fra.** *Fragilariopsis* sp.(*pseudonana*), **Gos.** *Gosslerialla* sp., **Mic**. *Microctinium* sp. (*pusillum*), **Nav**. *Navicula* sp. bout 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.

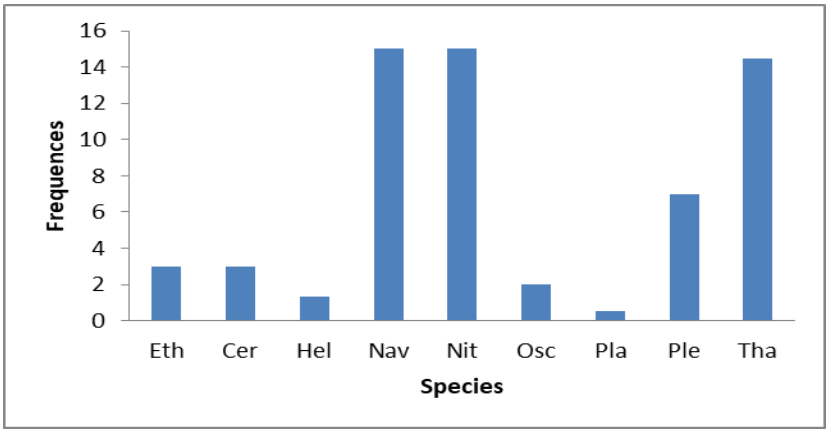

Fig.10a. Number of abundant species in Area 6 at the surface

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**. *Thalassiossira* sp.

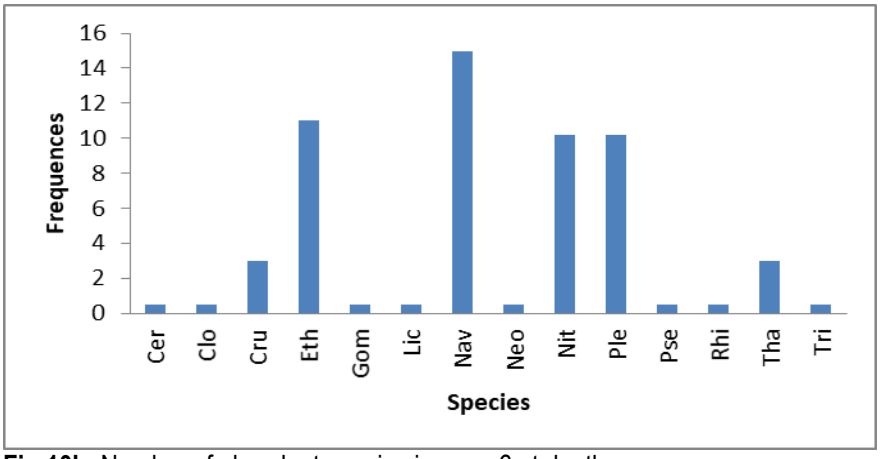

Fig.10b. Number of abundant species in zone 6 at depth

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**. *Rhicosolema* 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	B	S	B
1	2442667	3102667	330000	360000	18	27	3,967766	4,434289	4,169925	4,754888	0,95152	0,932196
2	1626667	2143000	360000	360000	15	13	3,493321	3,573636	3,906891	3,70044	0,894143	0,965733
3	1782667	2528333	330000	360000	12	22	3,395083	4,157148	3,584963	4,459432	0,947034	0,932215
4	2816667	3092667	460000	360000	30	34	4,224251	4,344434	4,906891	5,087463	0,860881	0,853949
5	1531667	1157000	360000	230000	12	14	3,269713	3,378867	3,584963	3,807355	0,912064	0,887458
6	1165000	1320333	330000	260000	9	14	2,944553	3,486606	3,169925	3,807355	0,928903	0,915755

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)	1	2	3	4	5	6
Number of common species at surface and bottom	13	9	8	15	4	6
Sørensen index	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), 6.85 ± 0.76 in zones 5 and 6. 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).

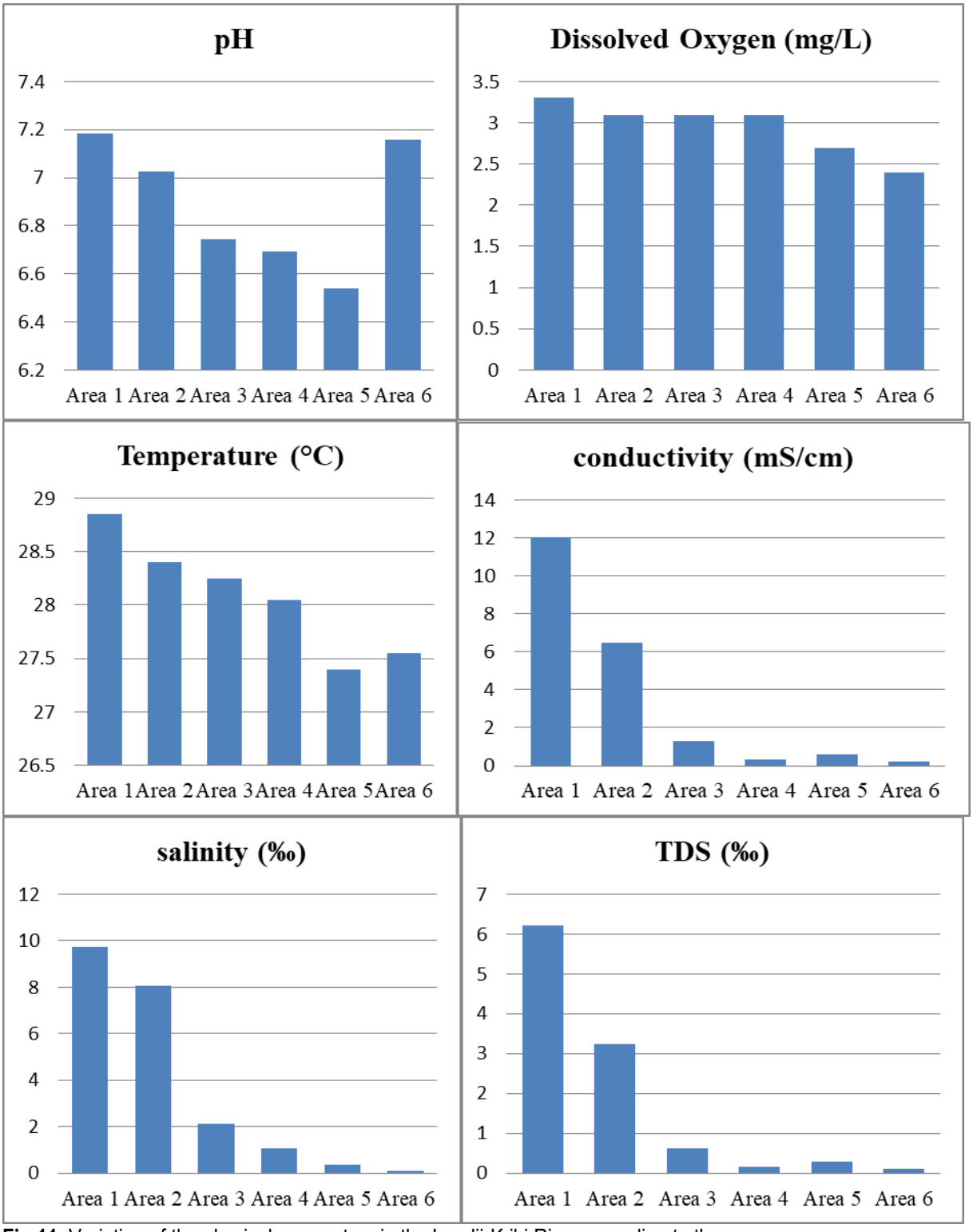

Fig.11. Variation of the physical parameters in the Londji-Kribi River according to the areas

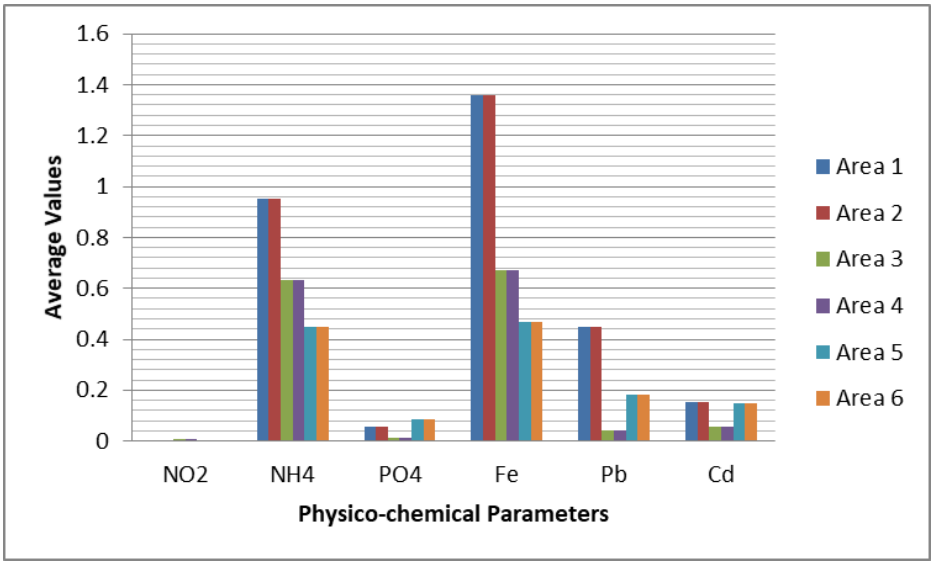

Fig.12. Variation of the physico-chemical parameters (NO2, NH4, PO4, Fe, Pb and Cd) according to the areas

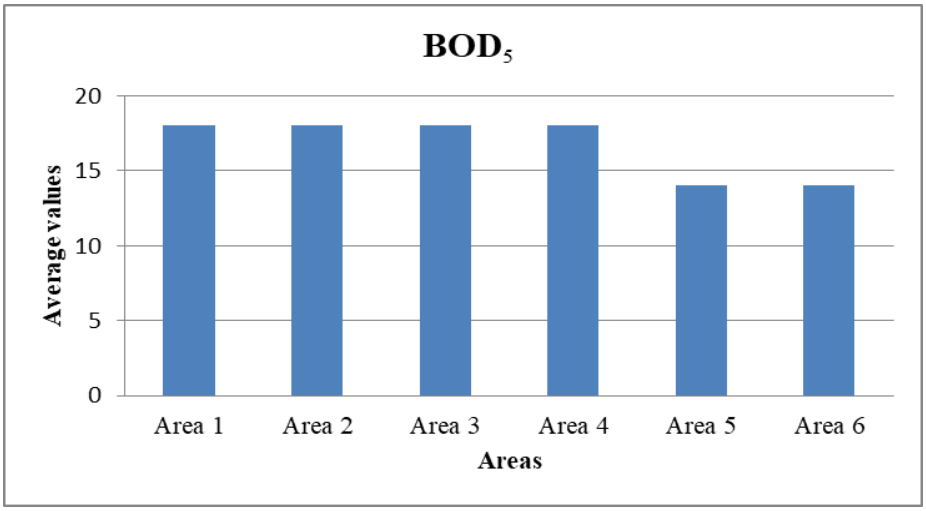

Fig.13. Concentration in BOD5 according to the zones

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 off-shores in the sea and the construction of the deep-water 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-Ebrottié *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).

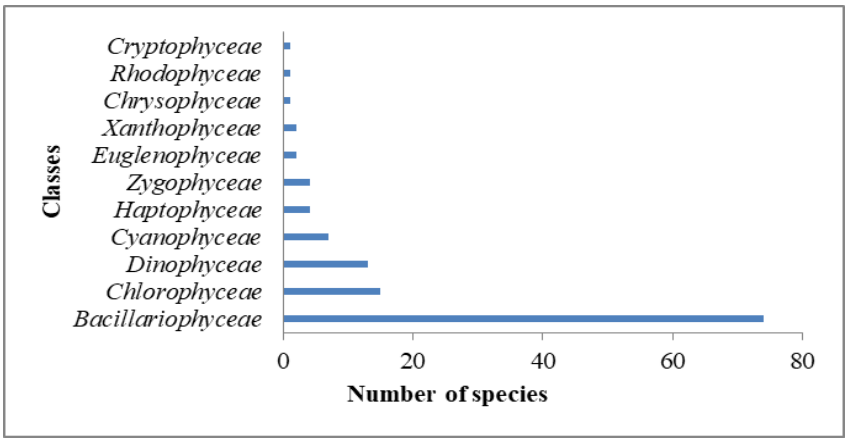

Fig.14. Percentage of the 11 classes inventoried in the six zones and at different levels

In addition, it appears from the surveys of the different zones (Fig. 5a to 10b) that zones 1 and 4 have more species than the other zones. Indeed, the places favourable to the development of the great diversity of plant plankton are the mouths of rivers and rivers, as well as the estuaries that receive the nutrients provided by watersheds.

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.

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REFERENCES

Ba N. 2006. La communauté phytoplanctonique du Lac de Guiers (Sénégal). Types d'associations fonctionnelles et approches expérimentales des facteurs de régulation. Thèse de Doctorat de 3ème Cycle de l'Université Cheikh Anta Diop de Dakar (Sénégal), 144 p.

Benoit–Chabot V. 2014. Les facteurs de sélection des bio-indicateurs de la qualité des écosystèmes aquatiques: élaboration d'un outil d'aide à la décision. Essai présenté au centre universitaire de formation en environnement et développement durable en vue de l'obtention du grade de maître en environnement. Université de Sherbrooke. 118 p.

Blais S. 2008. Guide d'identification des fleurs d'eau de Cyanobactéries. Comment les distinguer des végétaux observés dans nos lacs et nos rivières, 3e édition, Direction du suivi de l'état de l'environnement, Ministère du Développement durable, de l'Environnement et des Parcs, ISBN: 978-2-550-5240 8-3 (version imprimée), 54 p.

Botes L. 2001. Phytoplankton Identification Catalogue–Saldanha Bay, South Africa, April 2001. *GloBallast Monograph* Series No. 7, IMO London, U.K., 88 p.

Bouzille J.B. 2007. Gestion des habitats naturels et biodiversité-concepts, méthodes et démarches. Lavoisier, Paris, 331 p.

Carmelo R.T. 1997. Identifying marine phytoplankton. *Academic Press*. 867 p.

De Villier. 2005. Qualité physico-chimique et chimique des eaux de Surface: cadre général. Institut Bruxellois pour la Gestion de l'Environnement / Observatoire des Données de l'Environnement: "L'eau à Bruxelles" 16 p. Fiche 2.

Envirep. 2014. Stratégie nationale de gestion durable des mangroves et des écosystèmes côtiers au Cameroun et son plan de mise en œuvre. Rapport Pré-validé MINEPDED, 111 p.

Folack J. 1989. Etude préliminaire du phytoplancton d'une zone côtière d'exploitation crevetticole (Kribi-Cameroun, Golfe de Guinée, Atlantique Centre Est). *Cameroon Journal of Biology and Biochemistry Sciences,* 2(1): 51-65.

Gagneux-Moreaux S. 2006 Les métaux (Cd, Cu, Pb et Zn) dans la production des micro-algues sur différents milieux de culture: biodisponibilité, bioaccumulation et impact physiologique. Thèse de Doctorat. Discipline: Sciences de la Vie Spécialité: Biologie Marine, 273 p.

Gopinathan C.P., Rajagopalan M., Kaladharan P. and Prema D. 2007. Training manual on phytoplankton identification/taxonomy. Central Marine Research Institute, Cochin, US., 30 p.

Gueret. M. 2002. Méthode d'utilisation de la Cellule de Malassez. www.aquoa.net/spip.php article11.

Guiraud J.P. 1998. Microbiologie alimentaire, microbiologie des produits laitiers. Dunod, Paris. 651 p.

Herteman, M. 2010. Evaluation des capacités bioremédiatrices d'une mangrove impactée par des eaux usées domestiques: Application au site pilote de Malamani, Mayotte. Doctorat de l'Université de Toulouse, Toulouse, 330 p.

Huszar V.L.M., Silva L.H.S., Marinho M., Domingos P. and Sant'Anna C.L., 2000. Cyanoprokaryote assemblages in eight productive tropical Brazilian waters. *Hydrobiologia*, 424: 67–77.

Iltis A. 1980. Les algues. *Hydrobiologia.,* Tome 1 : 3-4. 61 p.

Karlson B., Cusack C. and Bresnan E. 2010.- Microscopic and molecular methods for quantitative phytoplankton analysis. - IOC Manuals and Guides, no. 55, IOC/2010/MG/5 UNESCO, Paris, France, 110 p.

Kengne I.M.N., Nya. J., Amougou A., Atanagana R.E., Ndikekro A., Fonkou T. and Brissaud F. 2005. Microphyte and macrophyte-based logoning in tropical regions. *Water science and Technology*, 51(12):267-274.

Laguerre H. 2008. Le plancton: applications environnementales. Fiche Agros Campus 18 p.

Laguerre H. 2009.La culture de phytoplancton. Fiche Agro Campus 29 p.

Lazur A. JIFSAN. 2007. Good Aquacultural practices program: Grow out Pond and Water Quality management. Joint institute for food safety and applied nutrition, University of Maryland.17 pp.

Lung'ayia H. B.O., M'Harzi A., Tackx M., Gichuki J. and Symoens J.J., 2000. Phytoplankton community structure and environment in the Kenyan waters of Lkae Victoria. *Freshwater Biology*, 43: 529-543.

FAO. P. 1996. Manual on the production and use of live food for aquaculture. FA0 *Fisheries Technical Paper* 361. 295 p.

Mama A.C., Oben L. M., Dongmo C.T., Motto I., Ndam JR N., and Ayina L.M. O. 2016. Tidal variations and its impacts on the abundance and diversity of Phytoplankton in the Nyong Estuary of Cameroon. *Journal of Multidisciplinary Engineering Science and Technology*, 3(1):3667-3675.

MDDEFP. 2013. Critères de qualité de l'eau de surface, 3ème édition, Québec, Direction du suivi de l'état de l'environnement. 510 p.

Mollo P. and Noury A. 2013. Le manuel du plancton. Essai N°195 Edition *Charles Léopold Mayer.* 201 p.

Muller-Feuga A. 1997. Micro-algues marines, les enjeux de la recherche. Rapport Ifremer n° 1092, 1279-8339.

Nguetsop, V.F. Fonkou, T. Lekeufack, M. and J.Y. Pinta. 2009. Assemblages d'algues et relations avec quelques paramètres environnementaux dans deux sites marécageux de l'Ouest-Cameroun. *Journal of Water Sciences*, 22(1) : 5-27.

Njine T., Kemka N., Zebaze S., Togouet H., Niyitegeka D., Nola M., Monkiedje J., Demanou J. and Foto M.S. 2007. Peuplement phytoplanctonique et qualité des eaux en milieu lacustre anthropisé : cas du lac municipal de Yaoundé (Cameroun). *African Journal of Science and Technology*, 8(1): 39-51.

Niamien-Ebrottié J.E., Konan K. F., Edia O.E., Ouattara A. and Gourène G. 2013. Composition et variation spatio-saisonnière du peuplement algal des rivières côtières du Sud-est de la Côte d'Ivoire. *Journal of Applied Biosciences,* 66 :5147–5161.

Priso R.J, Oum G.O. and Din N. 2012. Utilisation des macrophytes comme descripteurs de la qualité des eaux de la rivière Kondi dans la ville de Douala (Cameroun-Afrique central). *Journal of Applied Biosciences*, 53 : 3797-3811.

Radji R., Bandje A., Issifou L., Edorh T. and Kokou K. 2013. Diversité et dynamique des assemblages phytoplanctoniques dans les écosystèmes aquatiques au Sud du Togo. *Afrique Science*, 09(2) : 67-77.

Rodier J. 1996. L'analyse de l'eau : eaux naturelles, eaux résiduaires, eaux de mer. 8ème Edition, *Dunod,* Paris, France. 1384 p.

Siaebvelg. 2004. Territoire du SAGE des Lacs Médocains. Etude de la qualité des eaux superficielles. Consultants Asconit 110 p.

Talbot V. 1985. Relationship between cadmium in concentration in seawater and those in the mussel *Mytilus edulis*. *Marine Biology*, 85: 51-54.

Tomlinson P.B. 1986. The botany of mangroves. Cambridge University Press, 413 p.

Van Heurck H. 1899. Traité des Diatomées. Ifremer Bibliothèque de Brest. *J.-E. Buschmann, Anvers.* 53. 696 p.

Verlencar X.N. and Desai S. 2004. Phytoplankton Identification Manual. National Institute of Oceanography, Dona Paula, U.S., 35 p.