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Phytoplankton Dynamics of Mokolo and Mopa Ponds in Bertoua City (East-Cameroon)

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Abstract

This study aims to improve the understanding of algal community's dynamics in response to different environmental factors in two dam ponds (Mokolo and Mopa) in the city of Bertoua (East-Cameroon). Physicochemical and biological analyzes were carried out monthly by direct sampling at the surface and using Van Dorn bottle at 1 m depth. The organisms were collected using transparent glass vials of about 500 ml and fixed with 2.5 ml of a lugol solution, then analyzed using the Utermôhl method. Physicochemical analyzes show low transparency (<75 cm) of the ponds despite their shallow depth (≤150 cm), high levels of dissolved oxygen (>60%), BOD_5 (>30 mg/L) and chlorophyll "a" (>30 μg/L). These data made it possible to categorize the Mokolo and Mopa ponds as hypereutrophic with nitrogen as the limiting factor for eutrophication. Biological data show quite diversified ponds with 138 species identified in Mokolo Pond and strongly dominated by Diatoms with 2951 ind. representing 46% of the total abundance. In Mopa Pond, 147 species were identified, mainly represented by Chlorophyceae with 3629 ind. representing 52% of the total abundance. *Azpeitia africana* (Mokolo) and *Eresmophaera gigas* (Mopa) were the most represented taxa during the study. This study will have deduced that the structure and dynamics of algal communities are under the control of different factors or processes that interact simultaneously, namely ascending factors or bottom-up corresponding to nutrient resources and sunlight and descending factors or top-down that are exerted by grazing and active physiological substances produced by other algae that are known to influence phytoplankton.

Keywords

Bertoua, Dynamics, Hypereutrophic, Phytoplankton, Ponds

1. Introduction

Phytoplankton is made up of all micro-organisms plant living in water column, unable to resist the current and capable of developing their own organic substance by photosynthesis, from solar energy, water, carbon dioxide and nutrient salts [1]. In aquatic ecosystems, the different species of algae are distributed according to their biological and ecological requirements. Also, the study of the environmental variables of a biotope and the species that colonize enables to determine the relationships between environmental factors and organisms, and to identify the ecological factors that are appropriate for each species [2]. Phytoplankton organisms are widely considered to be the first biological community to respond to anthropogenic pressures and are the most direct indicator of nutrient concentrations in the water column of all biological elements [3]. Their metabolism is dominated by the autotrophic lifestyle based on photosynthesis [4]. A possible imbalance of intrinsic and/or extrinsic origin due to the control of nutrient resources can affect water quality and lead to a modification of the structure of biological community dependent on these hydrosystems, favouring the proliferation of certain algal species known as efflorescence [5]. These blooms can have many economic, ecological and even health consequences, because the massive growth of some phytoplankton populations can pose a risk to fish and therefore to consuming populations [6]. This work aims to contribute to the understanding of the mechanisms governing the distribution of algal communities through the study of the phytoplankton structure of two ponds (Mokolo and Mopa) in the city of Bertoua (East Region) in relation with some abiotic parameters.

2. Material and Methods

2.1. Presentation of the Studied Ponds

The city of Bertoua is located in the Department of Lom-and-Djérem, Eastern Region of Cameroon. The temperature is high all the year round and varies between 18˚C and 30˚C. Rainfall is relatively abundant (1500 to 2000 mm of rainfall per year) and the climate is subtropical with two seasons [7]. This study focuses on two dam ponds: Mokolo and Mopa in Bertoua city.

2.1.1. Mokolo Pond

Mokolo Pond is a dam pond located in the Mokolo district at the Northern end of the city of Bertoua. It is a pond with very little or no maintenance, abandoned to itself with geographical coordinates: 04˚36'065" North latitude and 013˚40'759" East longitude, with an altitude of 658 m (**Figure 1**). This pond is characterized by strong vegetation, trees and shrubs and many floating aquatic plants that proliferate along the banks all around the pond. The anthropization here is quite strong and the sources of pollution come mainly from a farm located upstream of the pond, domestic wastewater and plantations located in the watershed.

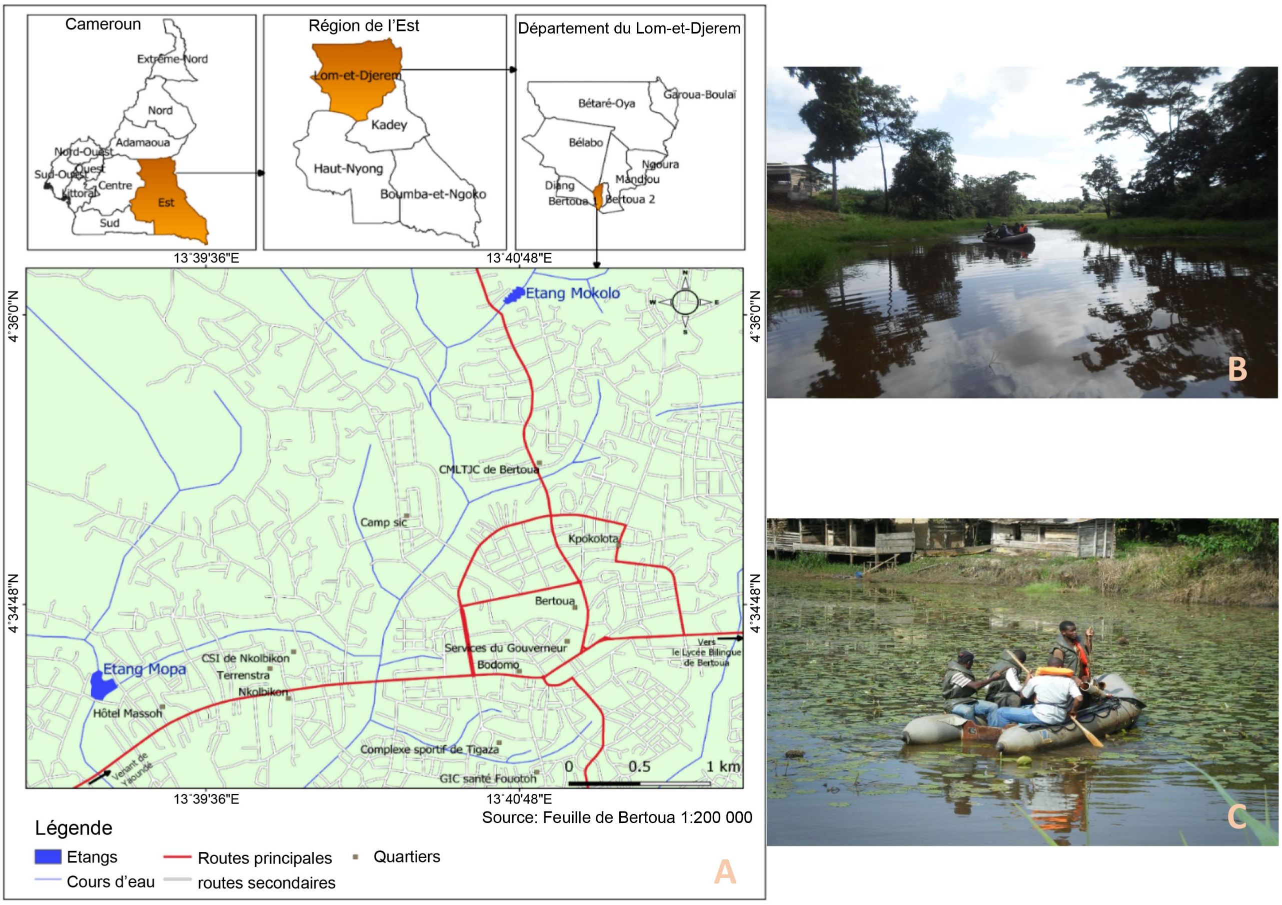

Figure 1. Geographical location of the two ponds study in Bertoua: (A) General situation; (B) Mokolo Pond and (C) Mopa Pond.

2.1.2. Mopa Pond

Mopa Pond is a dam pond located in the Nkolbikon district on the outskirts of the city of Bertoua, with geographical coordinates 04˚34'408" North latitude and 013˚39'188" East longitude, with an altitude of 650 m (**Figure 1**). It is an abandoned pond, not maintained, characterized by many plants mainly the species *Nymphaea lotus* and *Pistia stratiotes* which cover the water surface hinding a better penetration of light. The main sources of pollution in the pond are the strong macrophytic vegetation, trees and shrubs that surround the pond, as well as the plantations and dwellings located in the watershed.

2.2. Data Collection

Sampling was carried out from March 2016 to April 2017 followed a monthly frequency with surface and 1 m depth sampling for physicochemistry and biology. The movements on the ponds were possible using an inflatable Zodiac MR II.

2.2.1. Physicochemical Analysis

Samples for surface physicochemical analyzes were collected directly at the surface using polyethylene vials, while at 1 m depth, these samples were collected using a 6 L Van Dorn bottle. The physicochemical parameters measured in the field during this study were temperature measured using a 1/100th degree mercury column thermometer, transparency (Zs) measured using a 30 cm diameter black and white Secchi disc, depth measured using a weighted and graduated rope and dissolved oxygen measured using a HACH HQ14d oxymeter. The parameters measured in the laboratory included the nutrient salts (NO_3^-, NO_2^-, NH_4^+, PO_4^{3-}) measured using the colorimetric method with the HACH/DR 2010 spectrophotometer, the BOD_5 measured by respirometry using a LIEBHERR brand BOD meter and the chlorophyll "a" content measured by the Lorenzen spectrophotometric method [8]. These physicochemical analyzes were carried out using the AFNOR method [9].

The stoichiometric ratio [N]/[P] (nitrogen concentration/phosphorus concentration) was calculated for each pond and compared to the Redfield (1963) standard ratio value ([N]/[P] = 16) according to the following formulas:

$$[N] = [NO_3^-] + [NO_2^-] + [NH_4^+], \quad (1)$$

$$[P] = [PO_4^{3-}]. \quad (2)$$

Nitrogen or phosphorus or both nutrients elements will be limiting respectively if the N/P ratio is less than, greater than or equal to 16. To characterize the trophic state of the ponds, the system developed by the O.C.D.E. [10] and widely used internationally (**Table 1**), has been used.

2.2.2. Biological Analysis

Phytoplankton organism was collected by direct sampling at the surface and using a Van Dorn bottle at depth and then transferred to clean, transparent 500 ml glass vials and fixed with 2.5 ml of a lugol solution. After 48 hours of sedimentation, the supernatant was gently removed and the sub-sample of approximately 5 ml denser was preserved. After homogenization, 1 ml of the sub-sample was pipetted and observed in a Sedgewig-Rafter counting cell with an inverted microscope (Olympus CK2). The count was duplicated to minimize the risk of error and the identification of at least 400 individuals per sample was recommended for an accuracy of +/− 95% [11]. Due to the richness of some samples in particles and organisms, a dilution to 1/10th or 1/20th with distilled water was essential to facilitate enumeration. The count was carried out using an OLYMPUS CK2 inverted microscope with a 10X objective, with scans from left to right of the surface of the counting cell with alternating transects. Taxa have been identified

Table 1. Limit values of the trophic water classification system according to O.C.D.E. Ave.: average value; max.: maximum value; min.: minimum value.

Trophic state	PO_4^{3-} ave. (µg·L−1)	Chl "a"ave. (µg·L−1)	Chl "a"max. (µg·L−1)	Secchiave. (m)	Secchimin. (m)
Oligotrophic	<10	<2.5	2.5 - 8	>6	>3
Mesotrophic	10 - 35	2.5 - 8	8 - 25	3 - 6	1.5 - 3
Eutrophic	35 - 100	8 - 25	25 - 75	1.5 - 3	0.7 - 1.5
Hypereutrophic	>100	>25	>75	<1.5	<0.7

through the specialized literature of: Bourrelly [12] and [13]; Branco and Senna [14], as well as books and publications on phytoplankton taxonomy from Couté and Iltis [15]; Kemka [16] and Couté and Perrette [17]. The identified organisms will be grouped according to morphological, cytological, biochemical and reproductive criteria into 8 main phytoplankton Classes namely: Chlorophyceae, Chrysophyceae, Cryptophyceae, Cyanophyceae, Diatoms, Dinophyceae, Euglenophyceae and Xanthophyceae.

The determination of the density was calculated by the following formula:

$$D = N_i \times S \times 1000 / (v \times s), \quad (3)$$

with D = total headcount/litre; S = area of the counting cell (100 mm^2); N_i = counted number of individuals of a species; s = area of the total counted field (200 mm^2) and v = volume of sedimented sample (5 ml). The Hill diversity index [18] has been used to highlight the overall stands diversity and their degree of organization [19] with a maximum diversity of 1 and a minimum diversity of 0 based on the formula:

$$\text{Hill} = 1 - \left[(1/D) / e^{H'} \right], \quad (4)$$

with $1/D$ = inverse of the Simpson index and $e^{H'}$ = exponential of the Shannon and Weaver index. Piélou's regularity index (E) which varies between 0 and 1, makes it possible to study the regularity of the distribution of species and reflects the quality of organization of a stand [20] according to the equation:

$$E = H' / \log_2 S, \quad (5)$$

with H' = Shannon and Weaver diversity index and S = specific richness. The frequency of occurrence provides information on the environment preferences of a species and has been used to count the number of times it appears in samples [21] using the formula:

$$F = (F_i / F_t) \times 100, \quad (6)$$

with F_i = number of records containing the species and F_t = total number of samples taken. Depending on the value of the frequency, five categories of taxa are defined according to the classification of Dufrêne and Legendre [21]: F = 100%: Omnipresents taxa; 75% ≤ F < 100%: Regulars taxa; 50% ≤ F < 75%: Constants taxa; 25% ≤ F < 50%: Accessories taxa and F < 25%: Rares taxa. The Rank-Frequency Diagram (RFD) was used to assess the maturity of the stand and the succession of the development stages. The Canonical Correspondence Analysis (CCA), used to determine the abiotic factors influencing abundance of taxa.

3. Results

3.1. Physicochemical Parameters

The ponds studied have relatively high temperatures, low water transparency and shallow depth, medium oxygenation, high levels of nutrients, organic matter and chlorophyll "a" (**Table 2**). All these characteristics show a very poor water

Table 2. Summary of the different environmental variables recorded in Mokolo and Mopa ponds during the study period. Min: Minimum value; Max: Maximum value.

Environmental variables	Mokolo			Mopa		
	Min	Average	Max	Min	Average	Max
Temperature (˚C)	23	24.46 ± 1.11*	28	26	28.57 ± 1.68*	33
Transparency (cm)	38	65.93 ± 15.73	100	35	72.50 ± 20.55	100
Depth (cm)	140	151.43 ± 8.42	170	100	144.29 ± 16.62	170
pH (UC)	5.15	6.54 ± 0.75	8.63	4.96	6.32 ± 0.68	7.36
O_2 dissolved (%)	31	60.98 ± 11.79	88.6	27.8	61.7 ± 12.52	87.8
CO_2 dissolved (mg/L)	0.07	3.79 ± 3.28	15.84	0.07	2.63 ± 2.23	8.8
NO_3^- (mg/l)	0	1.58 ± 1.65	9	0	1.06 ± 1.19	5.6
NO_2^- (mg/l)	0	0.003 ± 0.004	0.017	0	0.02 ± 0.03	0.1
NH_4^+ (mg/l)	0.01	0.88 ± 0.61	2.49	0.11	1.21 ± 1.15	4.21
PO_4^{3-} (mg/l)	0	6.61 ± 5.60	24.20	0	4.44 ± 3.35	10.70
BOD_5 (mg/l)	5	31.61 ± 34.62	185	5	32.32 ± 46.25	185
Chlorophyll “a” (µg/L)	1.4	28.4 ± 29.52	147.1	6.1	39.96 ± 27.16	93.6
N/P ratio	0	1.22 ± 2.44	12.5	0	2.32 ± 4.88	18.73

*significant difference ($P < 0.05$).

quality of the ponds. The average of N/P ratio are very low comparatively to Redfield standard ratio (N/P = 16). The physicochemical parameters measured in this study didn’t vary significantly ($P > 0.05$) from the surface to the depth showing a homogeneous quality of water. Only the water temperature varies significantly ($P < 0.05$) between the two ponds during the study period (Table 2).

The parameter values for determining the trophic status of the Mokolo Pond give an average of orthophosphate content of 6605 µg/L, an average of chlorophyll “a” content of 28.4 µg/L while its maximum value is 147.1 µg/L, an average value of transparency of 0.66 m while its minimum value is 0.38 m. These parameters for trophic status in Mopa Pond have an average of orthophosphate content of 4437.86 µg/L, an average of chlorophyll “a” content of 40 µg/L while its maximum value is 93.6 µg/L, an average value of transparency of 0.73 m while its minimum value is 0.35 m.

3.2. Phytoplankton Dynamics of Ponds

3.2.1. Distribution of Phytoplankton Taxonomic Units in Ponds

During this study, 138 Species of phytoplankton were identified in Mokolo pond belonging to 61 Genus, 56 Families, 37 Orders and 6 Classes while in Mopa pond, the diversity was 147 Species of phytoplankton grouped into 55 Genus, 49 Families, 28 Orders and 5 Classes (Table 3).

3.2.2. Structure of Phytoplankton Groups

In Mokolo Pond, the specific richness was dominated by Chlorophyceae group

Table 3. Taxonomic units of phytoplankton in ponds.

Ponds	Classes	Orders	Families	Genus	Species
Mokolo	6	37	56	61	138
Mopa	5	28	49	55	147

with an average at the surface of 6 ± 4 species and at depth of 5 ± 4 species. Diatoms have an average at the surface of 5 ± 4 species and at depth of 4 ± 3 species. Euglenophyceae have an average at the surface of 4 ± 3 species and at depth of 3 ± 2 species. Cyanophyceae have an average at the surface of 3 ± 2 species and at depth of 2 ± 2 species. Cryptophyceae and Dinophyceae have been weakly diversified with an average of 1 ± 1 species both at the surface and at depth (**Figure 2(A)**). In Mopa Pond, the Diatoms group was the most diversified, with an average at the surface of 7 ± 4 species and at depth of 8 ± 4 species. Chlorophyceae have an average at the surface of 7 ± 5 species and at depth of 5 ± 4 species. Euglenophyceae have an average at the surface of 3 ± 3 species and a depth of 1 ± 1 species. Cyanophyceae have an average at the surface of 3 ± 3 species and at depth of 1 ± 1 species. Dinophyceae was low diversified with an average of 1 ± 1 species both at the surface and at depth (**Figure 2(B)**). The abundance in Mokolo Pond was dominated by Chlorophyceae group with an average at the surface of 143 ± 109 ind. and at depth of 68 ± 61 ind. Diatoms have an average at the surface of 76 ± 58 ind. and at depth of 40 ± 35 ind. Euglenophyceae have an average at the surface of 43 ± 37 ind. and at depth of 16 ± 22 ind. Cyanophyceae have an average at the surface of 43 ± 40 ind. and at depth of 17 ± 18 ind. Cryptophyceae have an average at the surface of 7 ± 10 ind. and at depth of 3 ± 8 ind. Dinophyceae have a low abundance in this pond with an average at the surface of 4 ± 9 ind. and at depth of 2 ± 4 ind (**Figure 2(C)**). In Mopa pond, the Diatoms were the most abundant group with an average at the surface of 123 ± 117 ind. and at depth of 137 ± 161 ind. Chlorophyceae have an average at the surface of 86 ± 69 ind. and at depth of 63 ± 66 ind. Euglenophyceae have an average at the surface of 21 ± 23 ind. and at depth of 14 ± 21 ind. Cyanophyceae have an average at the surface of 29 ± 28 ind. and at depth of 13 ± 17 ind. Dinophyceae was low abundant in this pond with an average at the surface of 7 ± 9 ind. and at depth of 4 ± 10 ind (**Figure 2(D)**). The specific richness and the abundance of the different phytoplankton groups doesn't vary significantly ($P > 0.05$) from the surface to the depth of the two ponds studied.

In mokolo pond, the density was dominated by Chlorophyceae with an average at the surface of 14,300 ± 10,889 ind./L and at depth of 6779 ± 6076 ind./L. Diatoms have an average at the surface of 7515 ± 5777 ind./L and at depth of 3943 ± 3465 ind./L. Euglenophyceae have an average at the surface of 4300 ± 3685 ind./L and at depth of 1579 ± 2104 ind./L. Cyanophyceae have an average at the surface of 4293 ± 3999 ind./L and at depth of 1629 ± 1778 ind./L. Cryptophyceae have an average density at the surface of 658 ± 997 ind./L and at depth of 265 ± 750 ind./L, while Dinophyceae have an average of 385 ± 826 ind./L at

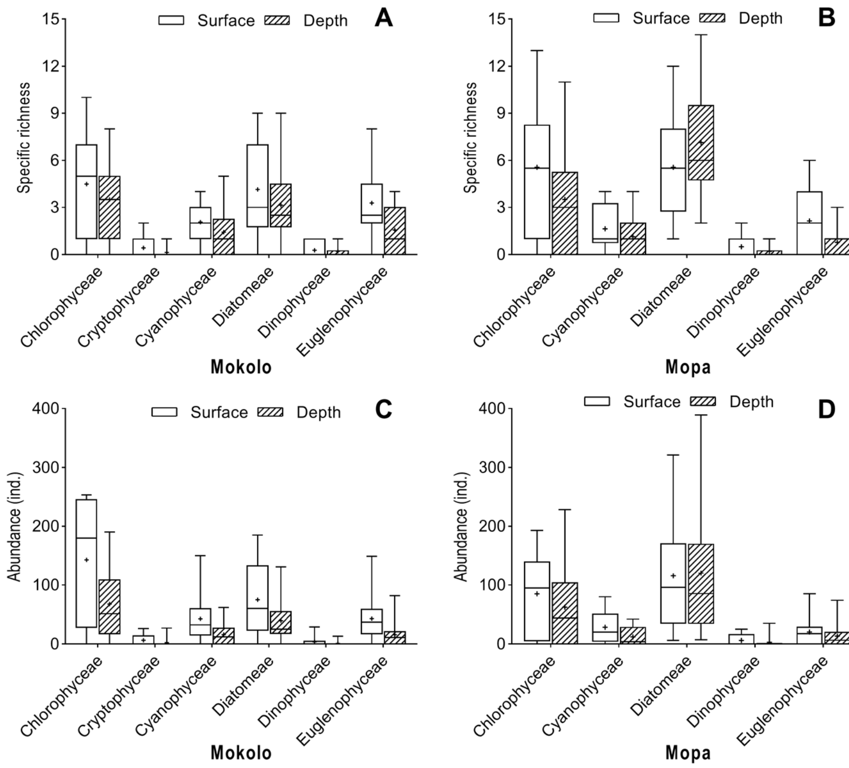

Figure 2. Spatial variations of specific richness (A and B) and abundance (C and D) respectively in Mokolo and Mopa ponds.

the surface and 122 ± 347 ind./L at depth (**Figure 3(A)**). In mopa Pond, the Diatoms have the highest density with an average at the surface of 12285 ± 11681 ind./L and at depth of 13636 ± 16017 ind./L. Chlorophyceae have an average at the surface of 8508 ± 6873 ind./L and at depth of 6236 ± 6850 ind./L. Euglenophyceae have an average of 2058 ± 2235 ind./L at the surface and 1350 ± 22055 ind./L at depth. Cyanophyceae have an average at the surface of 2865 ± 2716 ind./L and at depth of 1222 ± 1607 ind./L, while Dinophyceae have an average of 629 ± 868 ind./L at the surface and 315 ± 933 ind./L at depth (**Figure 3(B)**). The density of the different phytoplankton groups doesn't vary significantly ($P > 0.05$) from the surface to the depth in the two ponds studied. The dominants taxa were mainly represented in Mokolo Pond at the surface by the species *Azpeitia africana* with 45 ind. in June 2016 representing 44.55% of the total abundance while at depth the same species dominated with 15 ind. in June 2016 representing 36.59% of the total abundance (**Figure 3(C)**). In Mopa Pond at the surface, the species *Eresmophaera gigas* with 62 ind. in March 2017 represent 44.44% of the total abundance while at depth, the species *Thalassiosira subtilis* with 35 ind. in April 2016 corresponding to 32.71% of the total abundance (**Figure 3(D)**).

3.3. Data Analysis

The Rank-Frequency Diagram curves plotted across the ponds have all the same

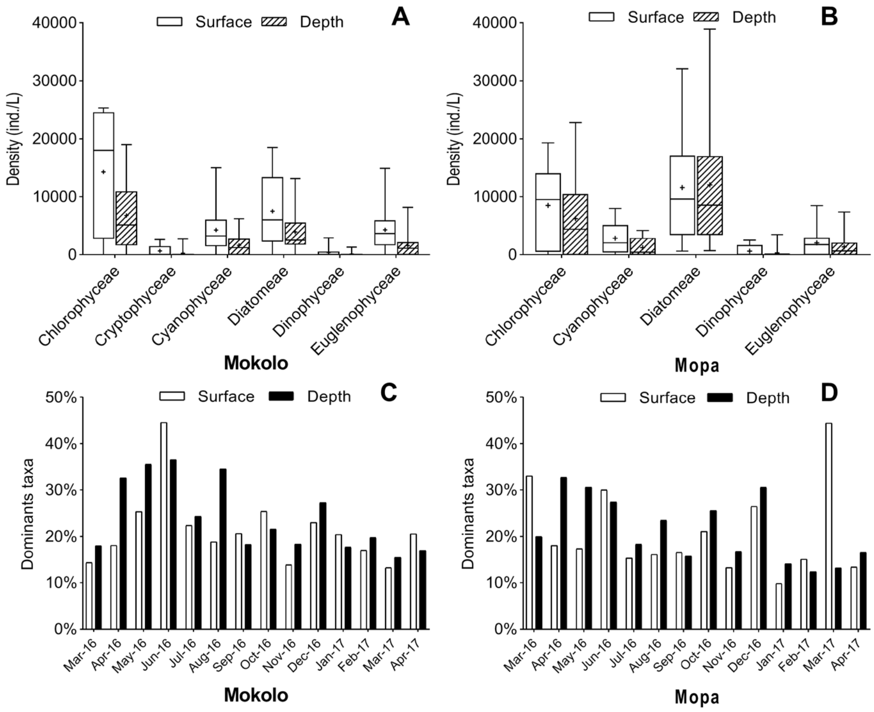

Figure 3. Spatial variations of density (A and B) and dominants taxa (C and D) respectively in Mokolo and Mopa ponds.

convex shape representing stage 2 of the evolution of planktonic communities (**Figure 4(A)**). The structure of the frequency of occurrence is the same in the two ponds studied. Rares taxa were the most dominant (>75%), followed by accessories taxa (>15%) and constants taxa (>4%). Regulars taxa (<2%) and omnipresents taxa (<1%) were poorly represented (**Figure 4(B)**).

The Hill diversity index in Mokolo Pond at the surface changes from 0.89 bits/ind. to 0.98 bits/ind. with an average of 0.95 ± 0.02 bits/ind. and at depth from 0.85 bits/ind. to 0.97 bits/ind. with an average of 0.92 ± 0.04 bits/ind. This index varies in Mopa Pond at the surface from 0.87 bits/ind. to 0.98 bits/ind. with an average of 0.95 ± 0.04 bits/ind. and at depth from 0.9 bits/ind. to 0.98 bits/ind. with an average of 0.94 ± 0.03 bits/ind. (**Figure 5(A)**). The regularity of Pielou was low in the ponds going into Mokolo Pond at the surface from 0.35 to 0.58 with an average of 0.47 ± 0.06 and at depth from 0.3 to 0.52 with an average of 0.41 ± 0.07. In Mopa Pond, this index varies at the surface from 0.32 to 0.58 with an average of 0.47 ± 0.08 and at depth from 0.35 to 0.57 with an average of 0.45 ± 0.08 (**Figure 5(B)**). The Hill diversity index and the Piélou regularity doesn't vary significantly ($P > 0.05$) from the surface to the depth and from one pond to another in the study period.

4. Discussion

4.1. Physicochemical Parameters

The temperature average values recorded in Mokolo (24.46˚C) and Mopa (28.57˚C) ponds are relatively high and depend strongly on the amount of sunlight. In this

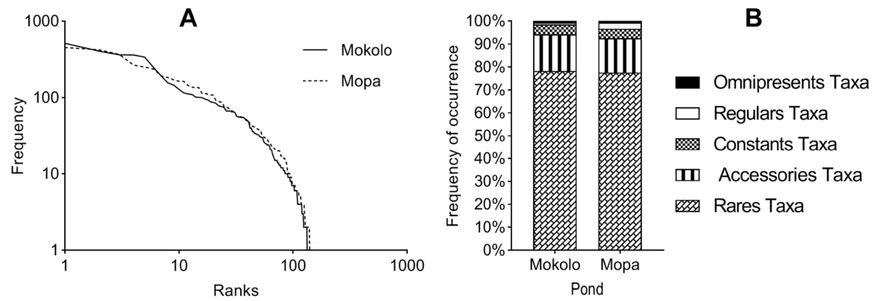

Figure 4. Variations of rank-frequency diagram (A) and frequency of occurrence (B) in Mokolo and Mopa ponds.

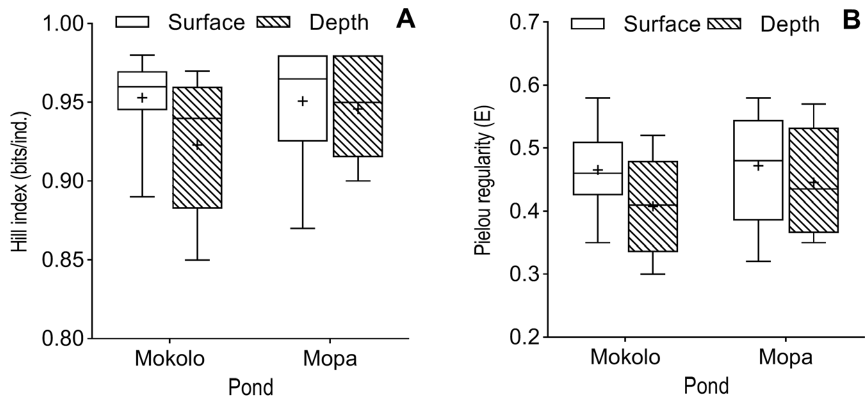

Figure 5. Spatial variations of Hill diversity index (A) and Piélou regularity (B) in Mokolo and Mopa ponds.

connection, Żukowski [22] affirms that the temperature of surface waters depends closely on the amount of sunshine and exchanges with the atmosphere. The low transparency values obtained in the ponds studied can be attributed to the action of winds combined with their shallow depths. Winds cause turbulence that, coupled with the shallow depth of the ponds, constantly suspend particles matter and phytoplankton that reduce the transparency of the pond water [23]. The shallow depth of the ponds allows light to penetrate to the bottom of all ponds and sometimes justifying the high phytoplankton abundances recorded at depth during the study. Dissolved carbon dioxide evolves in the opposite of oxygenation and the observed fluctuations in levels are undoubtedly linked to CO_2 using for photosynthesis and to the activity of aerobic bacteria that degrade fermentable organic matter, consuming dissolved oxygen while releasing carbon dioxide. The salts nutrient analysed were all raised in the ponds, reflecting a high degree of anthropisation. The high contents of nitrogenous elements in ponds are due to inputs of organic matter and nitrogenous metabolic waste from human activity, mainly from residential areas or from agricultural activities in the watershed of ponds. The high ammonium contents could be explained by the significant decomposition of organic matter accompanied by a high consumption of dissolved oxygen, favouring its production by ammonification [24]. High levels of orthophosphates in ponds show advanced trophic status and would be derived from runoff from the watershed. The high levels of oxidizable matter reflect a high presence of organic matter in the ponds from human activities in the watershed and therefore a high degree of oxidation of this organic matter by microorganisms that release humic acid, which contributes to reduce the pH values [25]. The high levels of chlorophyll "a" in ponds may be due to the high levels of nutrients (nitrogen and phosphorus) that can boost algal productivity. In this regard, Wurtz [26] argues that nutrients stimulate the growth of phytoplankton organisms, which are then used as food for microscopic animals such as zooplankton.

The average of N/P ratio in Mokolo (1.22) and Mopa (2.32) ponds are lower than Redfield ratio (N/P = 16), showing that nitrogen is the limiting factor of eutrophication and that rehabilitation measures should focus on controlling the flow of nitrogen compounds in ponds [27]. The most visible manifestation of the anthropization of a water body is the phenomenon of eutrophication. The two ponds studied have a very high content of orthophosphate and chlorophyll "a" with a very low transparency. According to the criteria established by the O.C.D.E. all these ponds are hypereutrophic. The signs of this hypereutrophication are quite noticeable because there is a gradual increase of phytoplankton biomass, a decrease of water transparency, siltation of the water body by accumulation of undegraded organic matter on the bottom and low oxygenation of the deep areas of the ponds.

4.2. Phytoplankton Dynamics

The relatively high specific richness of phytoplankton recorded in Mokolo (138) and Mopa (147) ponds is due to the anthropisation of the watershed of the ponds with organic and mineral materials containing high levels of nutrients and dissolved substances that promote the rapid and continuous growth of algae and aquatic plants. In this regard, Findlay and kling [28] point out that the low water volume associated with high nutrient levels is favourable to the development of phytoplankton organisms. The high abundance of Diatoms in the two ponds despite their low motility could be explained by the cosmopolitan nature of these organisms with a strong capacity to adapt to variations of environmental conditions and to various environments. Their distributions throughout the water column are related to winds and rains that generate strong turbulence, allowing the resuspension of Diatoms and other algae that tend to sink because of their densities, which are always slightly higher than the water, and to be found in the euphotic zone when they are below [29]. The high abundance of Chlorophyceae is explained by the very high levels of nitrogen elements recorded during the study period, making this nutrient the limiting factor in all the ponds studied. In this regard, Berube *et al.* [30] attests that a large number of Chlorophyceae belonging to the Chlorococcal class can reduce and metabolize up to 70% of the nitrogen compounds present in the biotope. The average abundance of Euglenophyceae is explained by the hypereutrophic nature of the ponds studied, this group affecting eutrophic environments [31]. The average abundance of Cyanophyceae is thought to be due to the fact that these organisms prefer environments where phosphorus is limiting and are generally found in shallow hydrosystems rich in nutrient [32]. The low abundance of Dinophyceae and Chrysophyceae is believed to be due to the particular flowering conditions of the organisms belonging to these two groups. Dinophyceae blooms are generally associated with salty or poor nutrient environments [33] while Chrysophyceae tend to form blooms in oligotrophic environments [34]. Algae densities have been high in the ponds, making them highly productive. These high densities result from the combined action of the different elements of abiotic origin on the development of microalgae. For example, Carpenter *et al.* [35] reports that dissolved organic matter can have both positive and negative effects on phytoplankton growth. The significance of these effects may vary depending on the source of this dissolved organic matter and the composition of the phytoplankton community. Phytoplankton density and biomass are in fact controlled mainly by nutrient availability [36].

The analysis of dominants taxa shows that *Volvox tertius, Eresmophaera gigas, Pleurotaenium trabecula, Microcystis aeruginosa, Aphanocapsa incerta* and *Azpeitia africana* are bioindicator species most characteristic of the hypereutrophic state of these ponds during the study period. The frequency of occurrence follows the same structure in all the ponds studied with a very high abundance of rare taxa about 80% in all ponds and a very low presence of regular taxa about 2% and omnipresent taxa (<1%). These data can be explained by the constant and irregular nutrient inputs to ponds that do not provide standard conditions for the growth and sustainability of a greater number of species. The convex shape of the Rank-Frequency Diagram curves representing stage 2 of evolution demonstrates the maturity of the phytoplankton communities in the ponds, which are fairly well diversified with a small number of species whose dominance is much higher than the other species [37]. These strong and constant recolonization of the environment by "r" strategy species that rely on reproduction with a high growth rate and very high mortality, adapting to unstable, unpredictable and highly polluted environments. Hill's diversity index have an average of 0.94 bits/ind (Mokolo) and 0.95 bits/ind (Mopa) showing well diversified ponds. This high diversification can be explained by the ideal photosynthetic conditions offered by ponds for the growth and development of phytoplankton species, namely high temperature, high solar energy, high nutrient levels and high CO_2 content [38]. The regularity of Pielou, was low in ponds fluctuating between 0.44 (Mokolo) and 0.46 (Mopa). These low regularity values show phytoplanktonic populations that are not in equilibrium, favoured by the high dominance of a small number of species due to irregular inputs of pollutants offering favourable and permanent environmental conditions to this small number of species that proliferate in very large numbers at the detriment of other species [39].

5. Conclusions

The ponds studied (Mokolo and Mopa) are rich in nutrients, with high content of chlorophyll "a" and low transparency. These characteristics classify ponds as hypereutrophic. These ponds are highly diversified and are not in balance, because they are dominated by a small group of species. This study has shown that the dynamics of algal communities depends on ascending factors or "bottom-up" corresponding essentially to nutrient resources, CO_2 contents and sunshine, which are the main photosynthetic factors that determine species succession, and descending factors or "top-down" that are essentially exerted by grazing and physiologically active substances produced by other algae that are known to have an influence on phytoplankton.

The rehabilitation of these hydrosystems involves reducing exogenous nitrogen inputs to the ponds in order to control eutrophication, mowing and gathering aquatic plants that proliferate in the ponds in order to maintain good oxygenation of water, as well as cleaning the sludge in order to limit the release of nutrients from the sediments to the water.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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