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Comparative analysis of phytoplankton diversity of the Miana and Tongo'o Bassa rivers (Littoral, Cameroon)

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Abstract
Anarchic and galloping anthropization is degrading the hydro systems of coastal towns in Cameroon. Phytoplankton plays an important role in the maintaining of imbalance in these ecosystems. The aim of the study was to make a comparative analysis of phytoplankton diversity of the Tongo'o Bassa and Miana rivers with a view to propose measures to monitor these rivers for diversity conservation. Sampling took place monthly from March, 2020 to February, 2021. Phytoplankton was sampled in the pelagic zone of each watercourse. Total species richness of Miana river amounts to 10 classes divided into 41 genera and 46 species. Tongo'o Bassa river has 9 classes divided into 20 genera and 22 species. Shannon-Weaver Diversity Index is high to 3.21 bits to Miana river (station M3) and low to Tongo'o Bassa river of 1.35 bit (station T2). Class of Bacillariophyceae records the highest density at Miana river of 2400 ind/L obtained respectively to M1 and M3 stations. To the Tongo'o Bassa river, the densest class is Cyanophyceae with a maximum density of 4400 ind/L to station 2. Correspondence Factor Analysis (CFA) identifies 2 groups of species. Group 1 consists of 42 species, exclusive to Miana river. Group 2 consists of 15 species, exclusive to Tongo'o Bassa river. The phytoplankton diversity is poor in the Tongo'o Bassa river, very polluted area and rich in the Miana river, less polluted area. This analysis will be used to highlight a bio typology of phytoplankton population of these rivers from which management resources could be set up for a restoration of quality of Tongo'o Bassa river and a rational use of these resources rivers for sustainable development.

Keywords: human activities, biodiversity conservation, phytoplankton, river, sustainable development

Introduction
State of health of rivers in urban areas is permanently liable to be influenced by discharges of domestic sewage and industrial effluents. These discharges degrade water quality and modify biodiversity of these hydro systems (Menye *et al*., 2012; Ndjouondo *et al*., 2020a) [11]. In Cameroon, rivers serve as dumping grounds for liquid and solid waste, particularly in urban areas (Agendia *et al*., 2000; Ndjouondo *et al*., 2017a) [8]. However, running waters are focus for human activities such as food, agriculture, industry and recreation (Ndjouondo *et al*., 2016; Djegbe *et al*., 2018) [7, 14]. Maintaining quality of these waters is a major concern for available water resources. It is essential to provide the monitoring bodies with appropriate tools to understand and sustainably manage the running waters as a whole (Goaziou, 2004; Faye *et al*., 2020) [28, 21].
Phytoplankton are mainstay of river flora at base of aquatic food chains (Harding *et al*., 2005; Niamen-Ebrottié *et al*., 2013; Ndjouondo *et al*., 2017b) [9]. Despite, their importance in aquatic ecosystems, phytoplankton generally remain very little studied in the rivers of Littoral region (Cameroon). In addition, the existing data are embryonic and only refer to the Batika (Millo, 2014) [23], Kambo and Longmayagui rivers (Dibong and Ndjouondo, 2014a) [25]. Thus, composition of this algal community remains little known in the rivers of Cameroon and particularly in Littoral region. Therefore, floristic richness of phytoplankton of this region needs to be characterized. General objective of the study is to make a comparative analysis of phytoplankton of the Tongo'o Bassa and Miana rivers with a view to propose measures to monitor these rivers for sustainable development.

Materials and Methods
Presentation of Study Areas
Yabassi (9° 50' - 10° 10' N and 4° 20' - 4° 40' E) chief town of NKAM department, located in Littoral region is considered as study area housing Miana river (MINEPAT, 2010) [22]. Miana river (7 km) has its source in this locality more precisely to 3 km of Makolakola and crosses the villages Dibit, Bonanama, Banya I before throwing itself in Nkam river. Its watershed is dominated by evergreen forest in *Lophira alata* and less anthropized. There are activities such as fishing, hunting and subsistence farming on its banks (Fig. 1a).

Douala (3° 40' - 4° 11' N and 9° 16' - 9° 52' E) is a relatively flat city with dense hydrographic network constituted by marsh areas, housing Tongo'o Bassa river. It is the densest and most populated city of Cameroon with about 3 millions of habitants. As for hydrography, Wouri is a river which crosses the city of Douala in its North-West region and flows according to direction NE-SW. It is fed by many rivers used as drains (Fogwe and Tchotsoua, 2007) [29]. Tongo'o Bassa watershed is exposed to various risks, such as pollution by CIC CACAO, GUINESS S.A., household and agro-pastoral activities (Meva'a *et al*., 2010) [2]. It takes its source in Ndogbati and crosses CIC CACAO neighborhoods, Makepe Missoke, Bepanda small market, mature Bepanda in the 5th district of city of Douala (Fig. 1b).

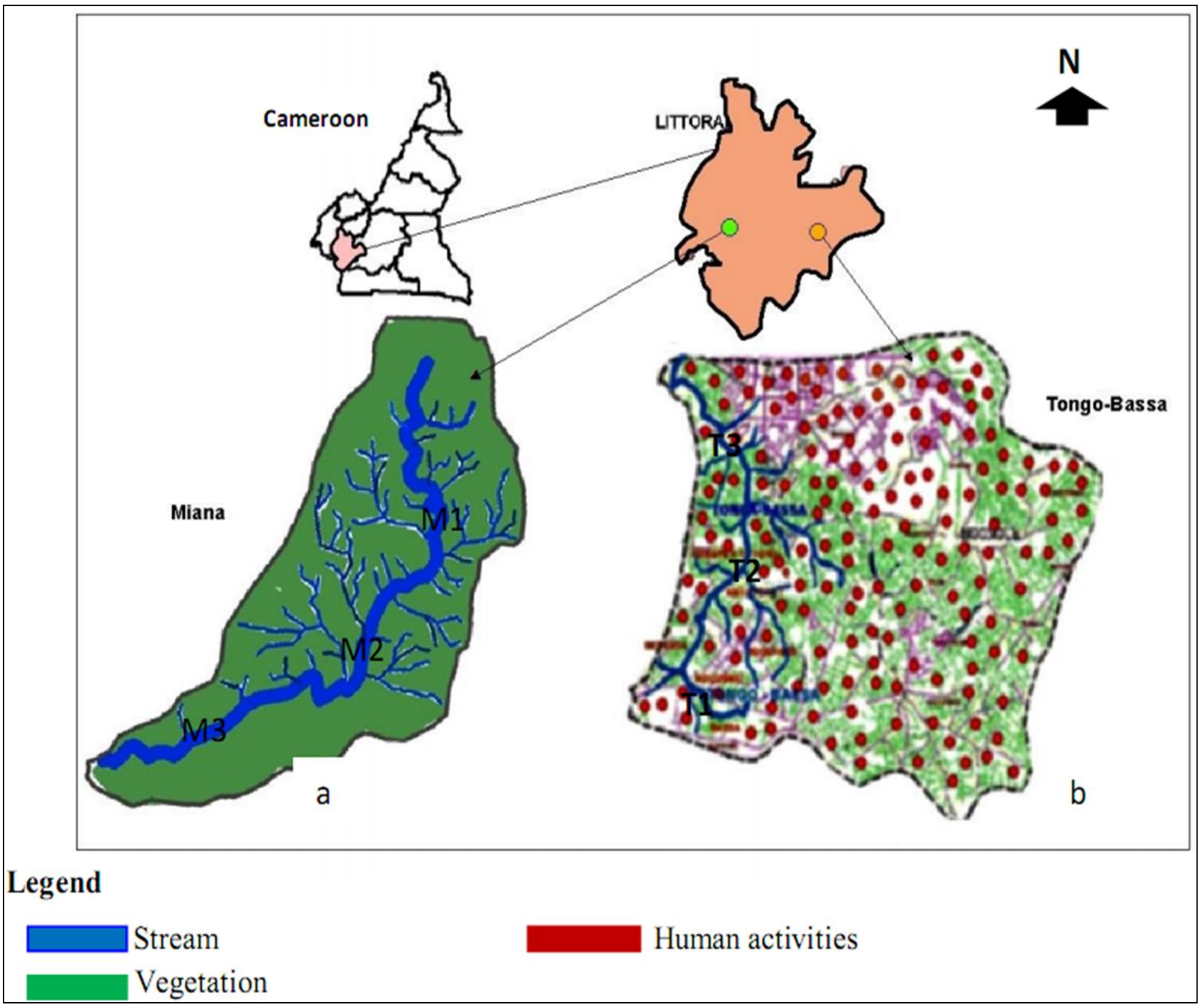


Fig 1: Location of Miana (a) and Tongo'o Bassa (b) rivers in watersheds

Choice of Sampling Stations

After watershed prospecting, 6 sampling stations were chosen, 3 stations per river depending on accessibility, light intensity, but especially by locating the slow-flowing portions. It is: M1 (04° 27' 792" N and 009° 57' 096" E, altitude: 24 m), M2 (04° 27' 712" N and 009° 56' 996" E, altitude: 33 m), M3 (04° 27' 591" N and 009° 56' 791" E, altitude: 19 m) for Miana river and T1 (3° 51' 30" N and 11° 30' 090" E, altitude: 19 m), T2 (3° 51' 34" N and 11° 29' 45" E, altitude: 19 m), T3 (3° 51' 23" N and 11° 29' 45" E, altitude: 9 m) for Tongo'o Bassa river.

Data Collection

Data were collected between March 2020 to February 2021. The water samples were taken monthly (12 campaigns) between 7:30 a.m. and 9:00 a.m., along the diagonal of each sampling station. Thus, during each campaign, 200 L water samples were taken and filtered using a 20 µm plankton net. After filtration, the water sub-samples were collected in the 60 mL pill boxes and immediately fixed with formaldehyde at 5% concentration.

Phytoplankton Stand Analysis

The algal cells were observed with the OAKON photomicroscope according to the technique of Ndjouondo *et al*. (2020b) [12] and photographed. The identification of the taxa photographed was carried out by combining key works (Iltis, 1980; Bourrelly, 1985; Krammer and Lange-Bertalot, 2000; Lavoie *et al*., 2006; Guiry and Guiry, 2021) [3, 24, 19, 15]. The cell count was carried out using an inverted microscope of the OAKON type according to the method of Utermöhl (1958) [30]. To evaluate phytoplankton community, algal density and various indices such as species richness, Shannon's diversity, Pielou's equitability and Sorensen's similarity indices were used (Ndjouondo *et al.*, 2017c) [10].

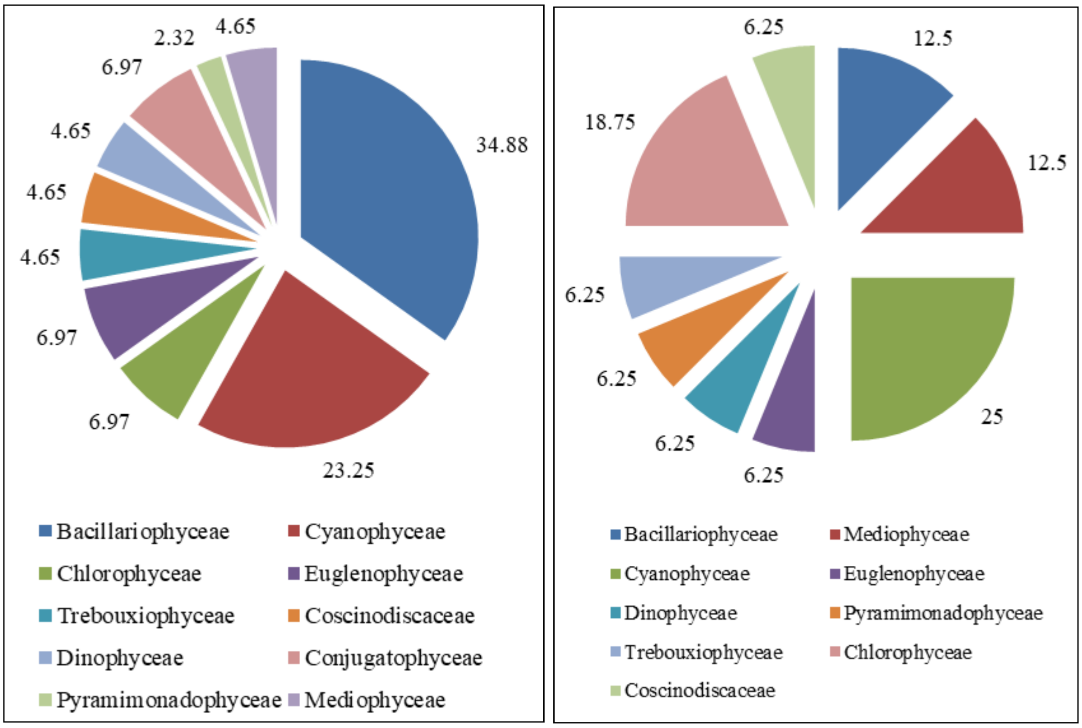
Statistical Analysis

Processing of the different data collected in each of the stations were carried out by Excel spreadsheet of Microsoft Office 2010 pack. A correspondence factor analysis (CFA) was applied to composition of the stand in order to group the sampling stations according to their floristic similarities. These analysis were carried out with software Xlstat 2014. Calculation of the indices of diversity was carried out by software Past 3.

Results

Floristic Wealth of Frequent Species

Total specific richness of Miana river is 10 classes divided into 41 genera and 46 species (Fig. 2a). It is dominated by Bacillariophyceae class, which accounts for 34.88% of total wealth. This class is followed by that of Cyanophyceae (23.25%). Pyramimonadophyceae class is a minority (2.32%). Tongo'o Bassa river has a total species richness of 9 classes divided into 20 genera and 22 species (Fig. 2b). Class of Cyanophyceae is also the most dominant with 25%. This class is followed by that of Chlorophyceae with 18.75% of total.



a b

Fig 2: Contribution of the different classes of seaweed to total specific richness of phytoplankton stand of the Miana (a) and Tongo'o Bassa (b) rivers

Shannon-Weaver's Diversity Index and Pielou's Regularity

Miana river has the highest diversity indices with a maximum of 3.21 bits to M3 (Table 1). On the other hand, the low values of index are observed at Tongo'o Bassa river with a minimum of 1.35 bits to T2. Pielou's regularity is lower to Tongo'o Bassa river and ranges from 0.69 (T2) to 0.98 (T3). Miana river has a nearly equitable distribution at all stations of 0.99.

Table 1: Shannon-Weaver's diversity index (H') and Pielou's regularity (J) for the Miana and Tongo'o Bassa rivers (M = Miana and T = Tongo'o Bassa)

Indices	Stations					
	M1	M2	M3	T1	T2	T3
H' (bits)	3.07	2.70	3.21	2.27	1.35	2.58
J	0.99	0.99	0.99	0.98	0.69	0.98

Similarity Index of Sorensen

In the Miana river, the highest similarity index is obtained between M1 and M3 (0.25) with 8 common species (Table 2). The lowest index is obtained between M1 and M2 (0.17) with 4 common species. On the other hand, in the Tongo'o Bassa river, the highest similarity index is obtained between T2 and T3 (0.27) with 4 common species. The lowest index is obtained between T1 and T3 (0.25) with 4 common species.

Table 2: Similarity indices of Tongo'o Bassa (T) and Miana (M) rivers

Stations	M1	M2	M3	T1	T2	T3
M1	1					
M2	0.17	1				
M3	0.25	0.20	1			
T1	0.00	0.07	0.05	1		
T2	0.06	0.15	0.11	0.26	1	
T3	0.10	0.12	0.13	0.25	0.27	1

Phytoplankton Population Density of Frequent Classes of Miana and Tongo'o Bassa Rivers

Bacillariophyceae class records the highest density to Miana river of 2400 ind/L obtained respectively at M1 and M3, followed by Chlorophyceae with a maximum value of 1200 ind/L obtained at M3 (Fig. 3). The classes of Trebouxiophyceae are the least dense with 200 ind/L obtained at M3. In the Tongo'o Bassa river, the densest class is that of Cyanophyceae with a maximum density of 4400 ind/L obtained at T2. This is followed by Bacillariophyceae with 800 ind/L obtained at T3.

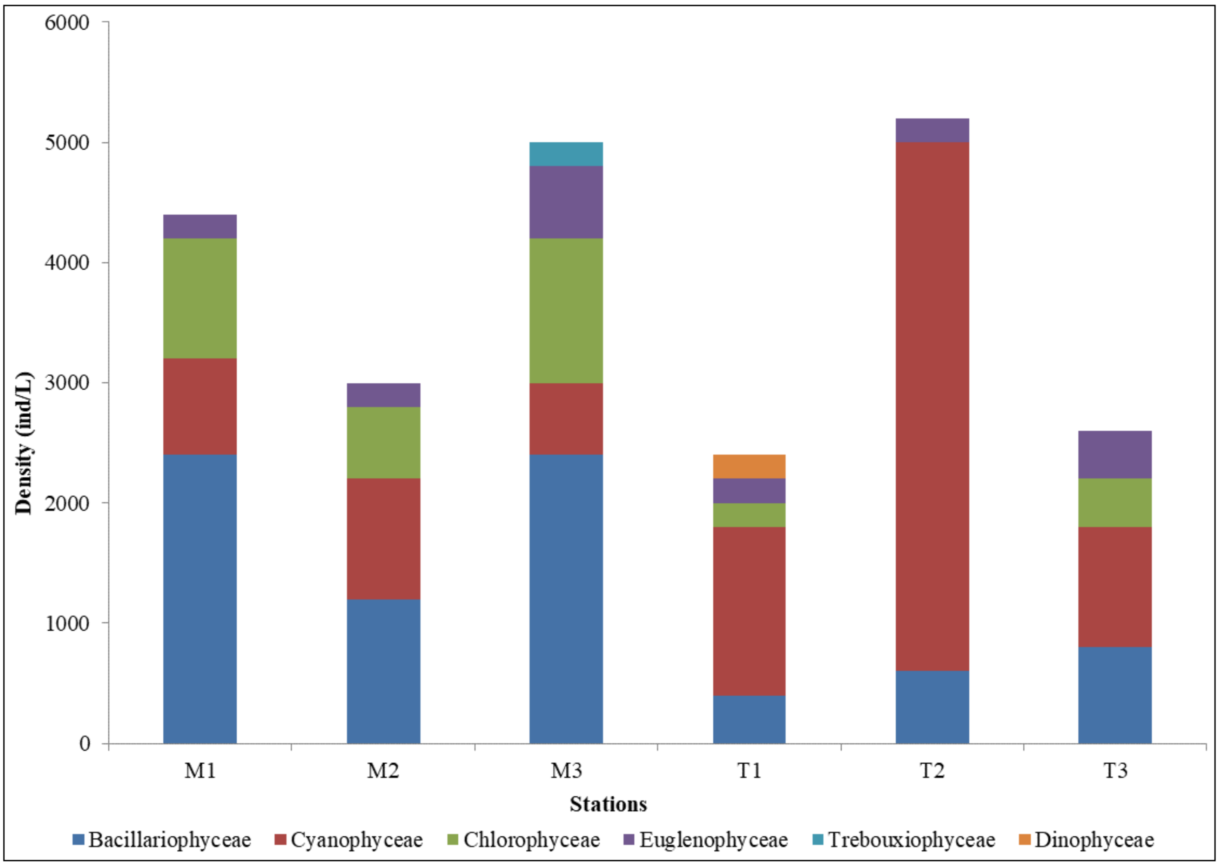


Fig 3: Phytoplankton density at the Miana (M) and Tongo'o Bassa (T) rivers stations

Variation of phytoplankton density in the study stations over time shows a gap between June and November characterized by a significant drop in density (Fig. 4). High densities are observed in the dry season between December and May. This density varies from 8150 ind/L to M1 in March to 2100 ind/L to T3 in September. Density is highly represented during all year at T3.

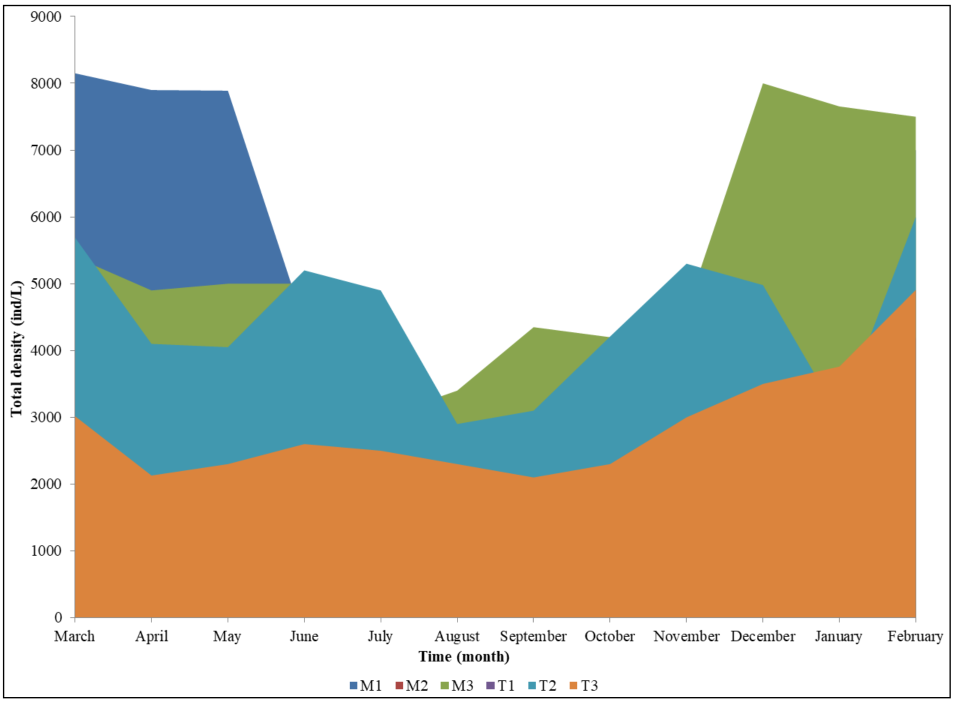


Fig 4: Spatiotemporal variation in phytoplankton density in the Miana and Tongo'o Bassa rivers

Factorial Analysis of Matches

The axes 1 (30.13% of inertia) and 2 (21.15% of inertia) of the plane 1-2 of the correspondence factor analysis (CFA) individualize 2 groups (Fig. 5). Group 1 consists of 42 exclusive species to the Miana river. Group 2 is made up of 15 exclusive species to the Tongo'o Bassa river.

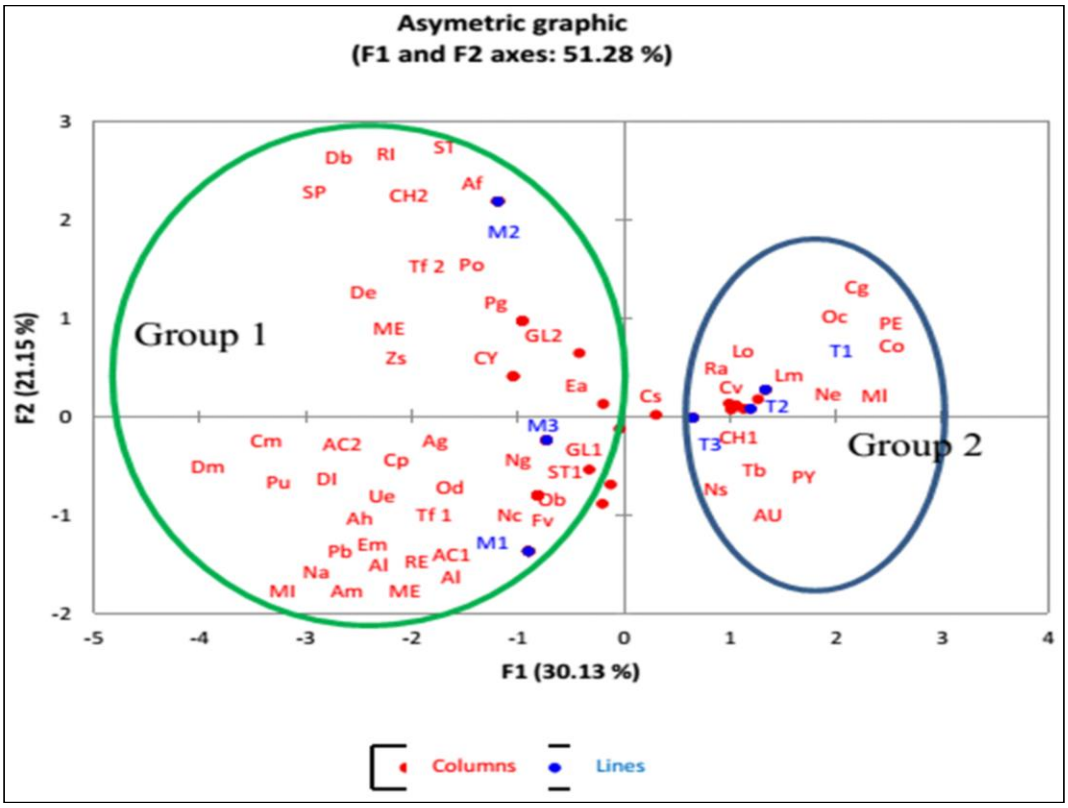


Fig 5 : Factorial correspondence analysis performed on abundance matrix of the taxa identified in the main groupings: Fv: *Fragilariforma viriscens*, CY: *Cyclostephanos* sp., Ea: *Epithemia adnata*, Nc: *Navicula cryptocephalla*, RE: *Reineria* sp., Ah: *Aphanocapsa holsatica*, ST1: *Stigeoclonium* sp., Al: *Aphanocapsa littoralis*, Em: *Euglena mutabilis*, Na: *Navicula atomus*, MI: *Microspora* sp., Al: *Achnanthidium linearis*, Pb: *Pinnularia brébissonii*, Cv: *Cymbella ventricosa*, Co: *Chlamydomonas ovata*, CH1: *Chlorella* sp., Pg: *Pinnularia gibba*, Tb: *Tabellaria binalis*, RI: *Rivularia* sp.1, Af: *Aphanizomenon flos-aquae*, Db: *Diatomella balfouriana*, Po: *Phacus onyx*, CH2: *Chlamydomonas* sp.1, Ob: *Oscillatoria boryana*, Ne: *Nostoc endophytum*, GL: *Gloeocystis* sp., Ng: *Navicula gregaria* AC: *Actinella* sp., Pu: *Phacus undulatus*, Dm: *Diatoma mesodon*, AU: *Aulacoseira* sp., Lo: *Lepocynclis ovum*, GL1: *Gloeotrichia* sp.2, Ml: *Microcoleus lacustris*, Cs: *Cyclotella stelligera*, Lm: *Lyngbya martensiana*, PE: *Peridinium* sp., Ra: *Rivularia aquatica*, PY: *Pyramimonas* sp.2, Ns: *Nitzschia sigma*, Ue: *Uronema elongatum*, Od: *Oedogonium* sp., Tf1: *Tabellaria flocculosa*, ME: *Melosira* sp., Am: *Achnanthes minutissima*, Zs: *Zygnema stellinum*, ME: *Merismopedia* sp., Tf2: *Tabellaria fenestrata*, SP: *Spirogyra* sp.1, ST: *Staurastrum* sp., De: *Diploneis eliptica*, Cm: *Cosmarium margaritatum*, DI: *Diatomella* sp., Ag: *Aulacoseira granulata*, AC: *Actinastrum* sp., Oc: *Oscillatoria chalibae*, Cg: *Cyclotella gamma*, Cp: *Cocconeis placentula*.

Discussion

Number of classes and species obtained from the Miana and Tongo'o Bassa rivers are different from the 192 taxa obtained by Niamien-Ebrottié *et al*. (2013) in 4 rivers of Ivory Coast. Dibong and Ndjouondo (2014a) [25] obtained 105 species in the Kambo and Longmayagui rivers of Douala. These results found at Miana river (Yabassi) on species richness (46 species) are greater than those obtained by Millo (2014) [23] who found 35 species at Batika river (Yabassi). In his work, he has shown that the low phytoplankton diversity is due to the speed of the flow of water too strong preventing phytoplankton development. This factor would also be involved in the low abundance observed in Miana river, which is less polluted. Fokou (2015) [27] in his work found a low specific richness at Tongo'o Bassa river. This river exposed in one of its branches upstream to Guiness S.A. which receive liquid pollutants that prevent penetration of light into water and thus limit multiplication of phytoplankton species. High species richness obtained at Miana river compared to Tongo'o Bassa river is confirmed by Ndjouondo *et al*. (2020c) [13] who have shown that the more the environment is degraded the less it is diversified. Diatoms constitute 45.65% of the taxa harvested at Miana river and 36.36% to Tongo'o Bassa river. This dominance of diatoms in taxonomic composition was also observed by Round (1993) [6] in European rivers, Ouattara (2000) [4] in Agneby river and in the fluvial areas of Bia river; Niamien-Ebrottié *et al*. (2013) in the coastal rivers of South-East of Ivory coast; Dibong and Ndjouondo (2014) in the Kambo and Longmayagui rivers (Douala, Cameroon) and Motto (2014) [16] in Londji river (Kribi, Cameroon). Diatoms are the most diversified autotrophic organisms in rivers since they have possibility of colonizing all the available surfaces (Dibong and Ndjouondo, 2014). Moreover, this dominance could be justified by the fact that diatoms can be detached supports and end up drifting in column water. This detachment is due to uprooting by current water (Ndjouondo *et al*., 2017b) [9]. High specificity of Diatom species in Miana river and lower in Tongo'o Bassa river is linked to the low anthropization of Miana river watershed, thus confirming the results of Motto (2014) [16] which shows that high number of diatoms in Londji river reflects the fact that this river is less polluted. For this author, microscopic algae are particularly sensitive and responsive to changes in nutrient concentration in water, and organic and mineral loads from fertilizers that run off farmland. Similarity of algal stand is low with minimum observed at Miana river, of 0.17 between M1-M2 and strong in Tongo'o Bassa river, of 0.27 between T2-T3. This difference would be related for first one of a weak resemblance this because of strong plant cover at station M2 and for second to the chemical characteristics of water rather close. Diatom class is denser in Miana river because it has great diversity and also presence of genera such as *Cocconeis*, *Cymbella* and *Navicula* that thrive in clear and oligotrophic streams (Ndjouondo *et al*., 2017c) [10]. On the other hand, high density of Cyanophyceae in the waters of Tongo'o Bassa river is linked to an excessive intake of organic matter by Guiness S.A., households and agropastoral activities along river. Diversity indices are higher in less polluted sites compared to highly polluted sites (Dibong and Ndjouondo, 2014b; Ndjouondo *et al*., 2017c; Coulibaly-Kalpy *et al*., 2017) [26, 10, 17]. Difference between the results of the Shannon-Weaver's index and Pielou's regularity obtained in the Miana and Tongo'o Bassa rivers is related to the low anthropization of the banks of Miana and a strong anthropization of those of Tongo'o Bassa.

Conclusion

This study on diversity of phytoplankton populations in the Tongo'o Bassa (Douala) and Miana (Yabassi) rivers provided information on wealth of these polluted and unpolluted waters in Littoral region (Cameroon). The said study showed a diversity of organisms strongly influenced by human activities in Tongo'o Bassa river. However, Miana river has a higher specific richness in phytoplankton (46 species) than Tongo'o Bassa river (22 species). Diatoms are dominant in these rivers (46.50%). In terms of density, Diatom class is dominant to Miana river from 2400 ind/l (station M1), while Cyanophyceae is more abundant to Tongo'o Bassa river of 4400 ind/l (station T2). Sorensen's similarity index records the highest value in Tongo'o Bassa river (0.27 between T2 and T3). Correspondence Factor Analysis was used to demonstrate biotypology of phytoplankton population of these rivers. This biological typology turns out to be dependent on hydromorphological and chemical factors of each river.

Competing Interests

The authors declare that there are no competing of interests.

Authors' Contribuitions

Ndjouondo Gildas Parfait: conceptualization, data collection, statistical analysis, writing and original draft. Nwamo Roland Didier and Muyang Rosaline Fosah: data collection, statistical analysis, writing and original draft.

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