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Structure and determinism of phytoplankton of the Bandama River in the Marahoué region (West-central, Côte d'Ivoire)

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Abstract

The high anthropogenic pressure Bandama River is undergoing is relatively of concern. Considering that the aforementioned actions could constitute a factor of imbalance in the functioning of the ecosystem, this study was carried out with the aim of determining the effect of anthropogenic pressure on the phytoplankton community. We analyzed the spatial variation of phytoplankton biovolume and its relationship with abiotic factors by sampling in six stations established on the two mains tributaries of Bandama river once a month from October 2019 to August 2020. The results showed that except dissolved oxygen, conductivity and water depth, the other physicochemical parameters did not vary significantly from one station to another. The total biovolume was dominated by the phyla of Chlorophyta $2.81.10^7 mm^3/L$, Charophyta and Euglenozoa $1.63.10^7 mm^3/L$ and $1.53.10^7 mm^3/L$ respectively. The lowest average biovolume ($5.34.10^4 \pm 3.67.10^4 mm^3/L$) was determined at station S6 and the highest ($3.15.10^5 \pm 3.03.10^5 mm^3/L$) at the station of lake Kossou upstream of the dike (S1). Station S6, which is located at the confluence of the two arms of Bandama river although having the lowest biovolume, presents the greatest regularity and stability of phytoplankton communities. From the redundancy analysis (RDA), it appears that the largest biovolumes are weakly linked to the high concentrations of nitrogen, phosphorus, nitrate and nitrite in the environment. However, the transparency of the water and the dissolved oxygen are the factors discriminating the quantity of biomass. Phytoplankton, although having environmental preferences, this study made it possible to establish a negative correlation between a high phytoplankton biomass and the concentration salts.

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Introduction

Aquatic ecosystems are essential components of the global environment. In addition to being essential contributors to biodiversity and ecological productivity, they also provide various services to humans, including drinking water, agricultural irrigation water, fisheries as well as recreational opportunities. Unfortunately, this system is increasingly threatened by anthropogenic industrial and urban activities leading to an imbalance in its functioning (Riquier *et al.*, 2015). In Côte d'Ivoire, the Bandama river does not remain isolated from these anthropogenic pressures. Indeed, housing two large hydroelectric dams (Kossou and Taabo) as well as numerous hydro-agricultural dams, this river is among the natural environments strongly participating in the socio-economic development of Côte d'Ivoire thanks to the development of fishing activities and agriculture (Avit *et al.*, 1999). The part of this river in Marahoué region, is particularly subject to acute anthropogenic activities such as clandestine gold panning, industrial and domestic discharges. Moreover, the Kossou hydroelectric dam is settled on this region (Konan *et al.*, 2015). For such a crucial ecosystem in the socio-economic development of Côte d'Ivoire, continuous and sufficient monitoring seems important for its preservation. Indeed, several studies, including those related to the phytoplankton community have been carried out in this watershed Lozo *et al.* (2013), Konan *et al.* (2015) and Adon *et al.* (2017). The trophic status and biological functioning still remain relatively poorly to characterize the structure of phytoplankton assemblages and determine the effect of anthropogenic pressure on this phytoplankton community.

Materials and methods

Sampling stations

Sampling was carried out monthly from October 2019 to August 2020. Six (6) stations were sampled on two tributaries of the Bandama river (Bandama Blanc and Bandama Rouge) covering the Marahoué region and at their melting zone. The sampling stations were chosen taking into account the accessibility, the anthropization level of the streambanks, and human activities in the vicinity of the stream such as gold panning and presence of industrial or domestic waste. Sampling station S1 is located on Lake Kossou, close to the Kossou hydroelectric dam. This station is bordered by fishing camps and is subject to domestic activities. Station S2 is located on the riverine section just after the dam of Kossou hydroelectric dam. This station is overgrown with more or less well-preserved vegetation. There are also plantations and gold panning activities on the left bank downstream of this station. Station S3 is located near the village of Bambakro. In addition to the domestic activities that take place there (washing, doing the dishes) and bathing, this station is also the site of intense gold panning activity. These three stations (S1, S2, S3) are located on the Bandama Blanc tributary. Stations S4 and S5 are located on the Bandama Rouge tributary. Station S4 is located near Zuénoula beneath the bridge settled on the Bandama river. Plantations and sparse forest can be seen all along this station. This station is receiving industrial discharges further in upstream. Station S5 is located between Zuenoula and Bouaflé. The banks of this station are occupied by stretches of forest and plantations. No gold-panning activity was noted at this station, station S6 is located at the confluence of the two tributaries (Bandama Blanc and Bandama Rouge). This site is bordered by an open forest and an area developed for leisure activities. However, on the opposite bank to this recreation area, gold-panning activities have been carried out on the streambank. The study area and stations are shown in Fig. 1.

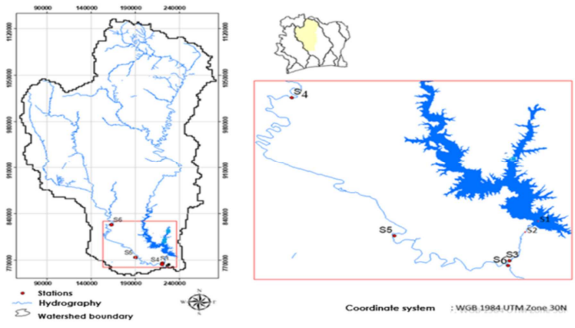


Fig. 1. Map showing sampling stations

Measurement of abiotic parameters

Temperature (°C), pH, conductivity (µS/cm), and oxygen (mg/l) were measured *in situ* at each station using a Hanna multiparameter. Water transparency was determined using a Secchi disc. The depth of the stations was estimated using a graduated weighted rope. The water samples for the nutrients analysis were taken in 1L polypropylene bottles at each station, carefully labelled and kept cool in a cooler containing ice so that they could be kept at optimum temperature in the field. These samples were then sent to the laboratory for determination of the nutrients such as nitrite (mg/l), nitrate (mg/l), total phosphorus (mg/l) and ammonium (mg/l) in accordance with AFNOR standards (1997).

Phytoplankton sampling

The integrated sampling using device has been used applying the pipe technique in the euphotic zone. All the samples taken were collected and stored in pillboxes, then identified and fixed with formaldehyde at a final concentration of 5% before being sent to the laboratory for further analysis (Laplace-Treyture *et al.*, 2009).

Phytoplankton analysis in the laboratory

In the laboratory, the analysis consisted in identifying and counting the phytoplankton in water samples. In order to determine the phytoplankton diversity, slides were mounted and observed under an Optika upright optical microscope. The taxa observed were measured with a micrometer, then identified and photographed to validate the identification. Counting was carried out under an Optika inverted optical microscope using the Utermöhl method (1958) after sedimentation of the samples in 10 and 25 ml tanks with sedimentation times of 12 and 24 hours respectively. Individuals were counted in 35 randomly selected fields without repetition. In accordance with AFNOR standard NF EN 15204/T 90-379, a counting accuracy of 5% was achieved by counting at least 400 algal individuals, wherever possible. Taxa were identified using a combination of identification books and scientific articles: Bourrelly (1981, 1985, 1990), Compère (1974, 1975, 1977), Couté and Bernard (2001), Couté and Chauveau (1994) Komárek and Anagnostidis (2000, 2005), John *et al.* (2002) and a taxonomic check on the Algaebase website consulted on 21 June 2023.

Determination of biovolume

Biovolume was obtained using the following formula: Biovolume (mm^3/L) = (specific biovolume (μm^3/ind) x density (ind/mL))*10^{-6}. It reflects the occupancy of the different species in the environment (Laplace-Treyture *et al.*, 2009). Individual biovolume was calculated using the method of Gábor *et al.* (2021).

Determination of the Shannon diversity index and the Pielou equitability index

The Shannon diversity index (H') for measuring the degree of organization of the population, it calculated according to the relation

$$H' = -\sum_{i=1}^{s}\left(\frac{ni}{N} * \ln(\frac{ni}{N})\right)$$

S: the species richness of the sample; N: total biovolume; ni: biovulume of species i, the Pielou evenness it calculated to the relation

$$E = \frac{H'}{\ln(S)}$$

H': Shannon diversity index; S: the species richness

It is between 0 and 1. It tends towards 0 when almost all the numbers are concentrated on one species and towards 1 when all the species have the same abundance.

Statistical treatments

Descriptive analyzes were carried out on abiotic parameters, biovolumes as well as alpha diversity indices for their spatial characterizations. Subsequently, a Redundancy Analysis (RDA) was carried out to relate the phytoplankton biovolumes to environmental variables. Statistical analyzes were carried out using Paleontological Statistics (PAST) v4.11 software and CANOCO for Windows 4.5.

Results

Physico-chemical analysis results

The physicochemical data recorded during this study did not vary significantly with the exception of dissolved oxygen, conductivity and depth. Stations S1, S2 and S3 were significantly more oxygenated than stations S4, S5 and S6 (Kruskal-Wallis $p > 0.05$). For conductivity, stations S1, S2, S6 and S3 have significantly lower conductivity than stations S4 and S5 (Kruskal-Wallis $p<0.05$). Regarding depth, the stations with significantly higher depths were S1 and S2 (Kruskal-Wallis $p < 0.05$) (Table 1).

Analysis of total phytoplankton biovolume in the whole study area

The total biovolume of phytoplankton determined was $7.54.10^6 mm^3/L$. The Chlorophyta phylum with $2.81.10^7 mm^3/L$ (34,07%) dominate the total phytoplankton biovolume. they followed by Charophyta and Euglenozoa with $1.63.10^7 mm^3/L$ and $1.53.10^7 mm^3/L$ respectively (20% and 19%). The Cyanobacteria phylum, with $9.71.10^6 mm^3/L$, contribute to 11,76% of the total biovolume. The biovolume of Bacillariophyta is $9.39.10^6 mm^3/L$ (11.33%). The lowest biovolumes were obtained from Miozoa $3.62.10^6 mm^3/L$ (4,38%) and Ochrophyta $4.77.10^4$ mm^3/L (0,05%) (Fig. 2).

Spatial variation of phytoplankton biovolume in Bandama river

There is no significant difference between the phytaplankton sample medians (Kruskal-Wallis $p> 0.05$). The highest median biovolume was obtained at station S1 ($2.30.10^6$ mm^3/L). This was followed by stations S5, with biovolume of 1.66.106 mm^3/L. The lowest average biovolume was recorded at station S6 ($6.66.10^5 mm^3/L$) (Fig. 3).

Table 1. Spatial variation in physico-chemical parameters

Parameters	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	P	Significantly (K-W)
O_2 (mg /L)	5,93 ^{a}	5,60 ^{a}	5,47 ^{a}	4,36 ^{b}	4,44 ^{b}	4,98 ^{a}	0,007442	SD
Cond(µS/cm)	30,63 ^{a}	28 ^{a}	36,36^a	58,27 ^{b}	51,72 ^{b}	40,54 ^{b}	0,000206	SD
Depth (m)	5,23 ^{a}	5,06 ^{a}	3,47 ^{a}	1,63 ^{b}	3,06 ^{c}	3,09 ^{c}	0,00001	SD
T°C	26,87	27,05	26,52	26,60	27,07	26,87	0,98	NSD
Transparency (m)	0,65	0,82	0,557	0,40	0,55	0,33	0,56	NSD
pH	6,97	6,81	6,85	6,90	6,84	6,78	0,39	NSD
NO_2^-(mg /L)	0,04	0,03	0,03	0,02	0,03	0,03	0,1	NSD
NO_3^-(mg /L)	4,52	3,54	4,19	6,11	7,93	6,22	0,35	NSD
Pt (mg /L)	7,30	11,25	10,51	12,69	11,29	14,47	0,49	NSD
Nt (mg /L)	23,54	29,45	41,76	51,34	43,38 ^{a}	42,36	0,3166	NSD

Median values with the same letters do not differ significantly (a, b, c) (Mann-Whitney $p>0.05$); P: probability; SD: significant difference; NSD not significant difference; K-W: (Kruskal-Wallis)

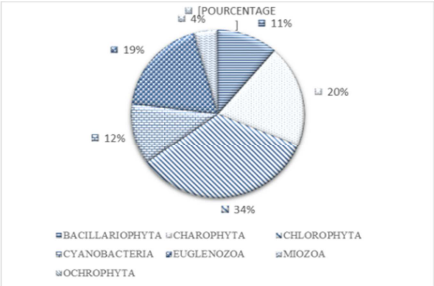


Fig. 2. Contribution of phytoplankton phyla at total biovolume

Spatial distribution of dominant species

The species used (*Pediastrum simplex, Peridinium cintum, Euglena polymorpha, Aulacoseira granulata, Closterium ehrenbergii, Staurstrum bulbosum Pediastrum duplex*) in this analysis are contributing to 65.93% of the total biovolume and those put in the "other" group are the contributors to the remaining biovolume. The species Pediastrum simplex appeared more dominant respectively at stations S3 (7.56 105 mm^3/L), S1 (6.24.105 mm^3/L) and S3 (5.12.105 mm^3/L). At stations S4, S5 and S6 its biovolume decreased to the advantage of the species *Peridinium cintum* (2.21.105 mm^3/L) at station S4, *Euglena polymorpha* (6.44.105 mm^3/L) at station 5 and *Aulacoseira granulata* (6.75.104 mm^3/L) at station S6. Furthermore, at station S1, the biovolumes of the species *Closterium ehrenbergii* (2.32.105 mm^3/L), *Euglena polymorpha* (1.72.105

mm³/L) appeared non-negligible despite the dominance of the species *Pediastrum simplex* (Fig. 4). Station S2 also has a slightly larger biovolume of *Staurstrum bulbosum* (1.75.105mm³/L) (Fig. 5). In addition, S6 is characterized by a codominance of biovolumes of the species *Aulacoseira granulata* and *Euglena polymorpha* as well as the low biovolume of *Pediastrum simplex* (Fig. 4).

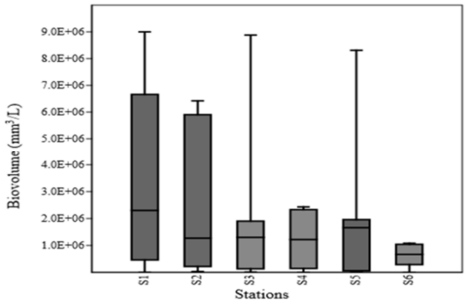


Fig. 3. Spatial variation of phytoplankton biovolume in Bandama river

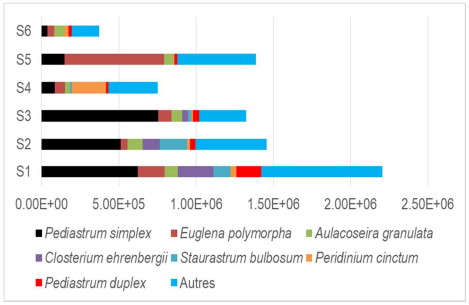


Fig. 4. Spatial variation of dominant species

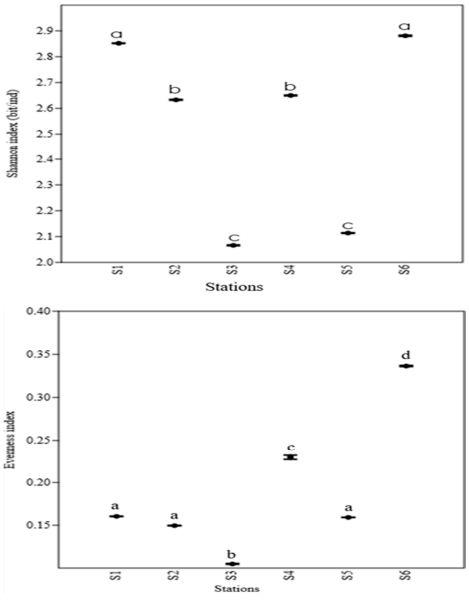


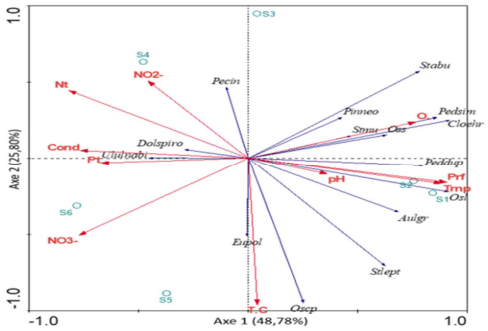
Fig. 5. Spatial variation of Shannon index (a) and Pielou index (b) based on phytoplankton in Bandama River.

Diversity analysis

The structure and specific diversity of phytoplankton were determined through the Shannon and equitability indices. The Shannon index is varied from 2.06 bits/ind (S3) to 2.88 bits/ind (S6). The indices of stations S1, S2, S4 and S6 are significantly higher (Kruskal-Wallis $p>0.05$) than those of stations S3 and S5 (figure 5-A). The fairness index varied from 0.14 (S3) to 0.33 (S6). A significant difference in the index was determined between stations. The equitability indices at stations S4 and S6 are significantly higher than those at other stations (Kruskal-Wallis $p>0.05$). Generally, the fairness index is closer to 0 than 1 (Fig. 5-B).

Relationship between phytoplankton and abiotic parameters

A Redundancy Analysis (RDA) allowed us to highlight the influence of abiotic parameters (temperature, pH, conductivity, dissolved oxygen, transparency, depth, nitrite, nitrate, total nitrogen, total phosphorus) on the phytoplankton biovolume. The main plan of the analysis expressing 74.59% of the total variance (axis 1: 48.78%; axis 2: 25.80%) was retained for the analysis (Fig. 6).



T.C : Temperature ; O. : oxygen ; Cond : Conductivity ; Prof : Depth ; NO2- : Nitrite ; NO3- : Nitrate ; Nt : Total nitrogen, Pt: Total phosphorus, Trnp: transparency Pedsim : *Pediastrum simplex ; Peddup : Pediastrum duplex ; Cloehr : Closterium ehrenbergii, Oss : Oscillatoria sp. ; Osl : Oscillatoria limosa ; Aulgr : Aulacoseira granulata ; Stmu : Staurastrum muticum ; Stabu :Staurastrum bulbosum ; Pinneo : Pinnularia neomajor ; Ulnnabi : Ulnaria ulnabiseriata ; Dolspiro : Dolichospermum spiroides ; Oscp : Oscillatoria princeps ;Eupol : Euglena polymorpha; pecin: Peridinium cinctum.*

Fig. 6. Redundancy Analysis (RDA) of dominant phytoplankton biovolumes and river environmental parameters.

The ordination along axis 1 presents in its positive part a strong positive correlation with transparency, depth and dissolved oxygen. In its negative part, a strong correlation is established with conductivity, total phosphorus and total nitrogen. Associated with high transparencies and depths and dissolved oxygen, as well as low conductivity concentrations of total phosphorus and total nitrogen along axis 1. Stations S1 and S2 favored high biovolumes of the species *Pediastrum duplex, Oscillatoria* sp, *Aulacoseira granulata*, to the detriment of *Ulnaria ulnabiseriata, Dolichospermum spiroides*. Species such as *Pediastrum simplex, Closterium ehrenbergii, Oscillatoria limosa, Staurastrum muticum, Staurastrum bulbosum, Pinnularia neomajor* in addition to being associated with high depth and transparency, are also distinguished by a high level of dissolved oxygen, also d a lesser presence of the nitrate level in the environment according to axis 1. A strong positive correlation was established between high temperatures and *Euglena polymorpha* and *Oscillatoria princeps* according to axis 2 unlike the species *Peridinium cinctum* characterized by low temperatures and high nitrite concentrations along axis 2.

Discussion

The results of this study show a spatial variation of a few physico-chemical parameters between the stations. The low variability in physico-chemical parameters is thought to be due to the more or less homogeneous climatic and anthropogenic factors affecting this environment. The average temperatures observed (26.5°C to 27.07°C) in the waters of the Bandama river during this study are thought to be due to the influence of ambient temperature. In fact, several studies carried out in the waters of warm tropical regions have shown that the average annual temperature of the rivers is about 28°C and rarely falls below 25°C (Konan *et al*., 2008). The waters of the river appeared very turbid, with average transparencies of less than one meter. This low water transparency is thought to be due to anthropogenic activities such as gold panning on the banks and in the riverbed, which cause sediments to be suspended. This range of variation is similar to the measurements made by Lozo (2019) and Soro *et al*. (2021) in Bandama river. Concerning pH, the values show that the water in the river is close to neutral and therefore optimal for the development of aquatic communities. According to Blinda (2007), pH values between 5 and 9 allow normal development of flora and fauna. For dissolved oxygen which is an important parameter in the evaluation of water quality, stations S1, S2, S3 presenting relatively high values than the others would indicate good photosynthetic activity of aquatic plants and micro-algae in the environment (Rodier 1984). The electrical conductivity, reflecting the level of mineralization of the medium, oscillated from 28µS/cm (S1) to 58.27 µS/cm (S4). The higher electrical conductivity of stations S4, S5 (Red Bandama) and station S6 (confluence) testifies to a higher level of mineralization of this arm compared to the Red Bandama. This high mineralization would come from exogenous inputs from surrounding agrosystems and also from industrial discharges along this arm, therefore leading to high concentrations of ions dissolved in the water (Tshibanda *et al*., 2021, Yao *et al*., 2022). From the analysis of the structure and phytoplankton composition, it emerged that the species *Pediastrum simplex*, *Peridinium cintum*, *Euglena polymorpha*, *Aulacoseira granulata*, *Closterium ehrenbergii*, *Staurstrum bulbosum* and *Pediastrum duplex* were dominant with varying proportions depending on the stations. These variable dominances per station, as well as the significant differences in biovolume observed between stations would be linked to the variability of environmental conditions which, according to Padial *et al.* (2014) affects the composition and abundance of taxa in an environment. The specific diversity and equitability of the distribution of species determined using the Shannon de Pielou indices revealed significant differences. The low values of the equitability index at stations S3 and S5 would be due to the dominance of *Pediastrum simplex* for station S3 and *Euglena polymorpha* for station S5. However, the values of the equitability index are all close to 0 and 1 testify to an inequality in the distribution of species in the environment.

Furthermore, station S6, although having the lowest biovolume, gives the greatest values of these indices, thus presenting greater specific diversity. The redundancy analysis (RDA) showed that each species reacts differently to environmental variations and that the highest biovolumes in our study are negatively linked to the high concentrations of nutrient salts such as nitrogen, nitrate, nitrite, phosphorus. This observation would reflect the use of these nutrients by phytoplankton in their proliferations, hence their low concentration (Tian *et al.*, 2000). Furthermore, a positive correlation of this distribution is favored by high temperatures, transparencies, dissolved oxygen and pH. In addition, the grouping of these species at stations S1 and S2, more transparent with the greater rate of dissolved oxygen, reassures this observation because it appeared to be the least impacted by human activities than the others. Indeed, studies by Reynolds (1984) demonstrated that the penetration of light would be an important factor for the achievement of photosynthesis and therefore good growth of phytoplankton. The "alpha" diversity indices calculated using the Shannon diversity index and Pielou equitability index presented different degrees of organization of the phytoplankton population. Stations S1, S2, S4 and S6 have higher taxonomic diversity than stations S3 and S5. Furthermore, the regularity of this taxonomic distribution is highest at station S6 and very low at station S3. In addition, the low values of the equitability index demonstrate an irregularity in the biovolume occupied by the species in the environment. This low degree of organization would find its origin in the cumulative effects of human activities, notably the domestic activities of villages and fishing camps, exogenous effluent from plantations and strong gold panning activity at this station as well as upstream.

Conclusion

In this work on the structure and determinism of the phytoplankton community in the waters of the Bandama River in the Marahoué region. The physicochemical parameters of the Bandama River present a certain homogeneity probably due to the combined influence of climatic conditions and human activities on the environment. However, the study of the structure and composition of phytoplankton as well as the redundancy analysis revealed dynamics and taxonomic complexity influenced by these parameters. The high phytoplankton biomass was positively influenced by transparency and dissolved oxygen and water depth as well as low nutrient salt concentrations. This sensitivity of phytoplankton species to react to environmental changes therefore offers a monitoring tool for environmental management.

References

Adon MP, Niamien -Ebrottie JE, Konan KF, Azah CN, Ouattara A, Gourene G. 2017. Qualité des eaux du Bandama-blanc (Côte d'Ivoire) et de ses affluents soumis à de fortes activités anthropiques à partir de la microflore algale. Agronomie Africaine **29**(2), 159-175.

AFNOR. 2006. Norme guide pour le dénombrement du phytoplancton par microscopie inversée (méthode Utermöhl) – NF EN 15204. 39p.

Avit JBLF, Pédia PL, Sankaré Y. 1999. Diversité biologique de la Côte d'Ivoire. Rapport de synthèse. Ministère de l'Environnement L. Krienitz, G. Gärtner, M. Schagerl (Eds.), Sübwasserflora von Mittelleuropa, **19** (2), 1- 759.

Blinda M. 2007. Pollution tellurique du littoral nord-ouest du Maroc entre Tanger et Tétouan : caractérisation, impact sur l'environnement et proposition de solutions [Land pollution of the northwest coastline of Morocco between Tangier and Tetouan: Characterisation, impact on the environment and proposed solutions]. PhD Thesis. Rabat. University of Mohammed V pp. 75.

Bourrelly P. 1981. Les algues d'eau douce. Initiation à la systematique. Tome II. Les algues jaunes et brunes : Chrysophycées, Phéophycées, Xantophycées et Diatomées. Société nouvelle des éditions Boubée, Paris (France), 517 p.

Bourrelly P. 1990. Les algues d'eau douce. Initiation à la systématique. Tome I: Les algues vertes. 2è edition, Société nouvelle des éditions Boubée, Paris (France): 1-572.

Bourrelly P. 1985. Les Algues d'eau douce. Tome III : Les Algues bleues et rouges. Les Eugléniens, Péridiniens et Cryptomonadines. Société nouvelle des éditions Boubée, Paris, 606p.

Compère P. 1974. Algues de la région du lac Tchad. II: Cyanophycées. Cahiers O.R.S.T.O.M., série Hydrobiologie **8** (3/4), 165-198.

Compère P. 1975. Algues de la région du lac Tchad. III: Rhodophycées, Euglénophycées, Cryptophycées, Dinophycées, Chrysophycées, Xanthophycées. Cahiers O.R.S.T.O.M., série Hydrobiologie **9** (3), 167-192.

Compère P. 1977. Algues de la région du lac Tchad. VII: Chlorophycophytes (3ième partie : Desrnidiées) (I). Cahiers O.R.S.T.O.M., série Hydrobiologie **11** (2), 77-177.

Couté A, Bernard C. 2001. Les cyanobactéries toxiques. In : Toxines d'algues dans l'alimentation. Ifremer, Brest (Biélorussie) : 21-37.

Couté A, Chauveau O. 1994. Algae. Encyclopaedia Biospeologica I. Edition Société de Biopédologie: 371-380.

Gábor Borics, Vérone Lerf, Enikő T-Krasznai, Igor Stanković, Levente Pickó, Viktória Béres, Gábor Várbíró. 2021. Calculs de biovolume et de surface pour les microalgues, à l'aide de modèles 3D réalistes. Science of the Total Environment 773 (2021), 145538.

John DM, Whitton BA, Brook AJ. 2011. The freshwater algal flora of the British Isles: an identification guide to freshwater and terrestrial algae. Second Edition. Cambridge University Press. 878 p.

Komárek J, Anagnostidis K. 2000. Cyanoprokaryota-1. Teil: Chroococcales Berlin: Spektrum Akademischer Verlag Heidelberg; ISBN 3-8274-0890-3p.

Komárek J, Anagnostidis K. 2005. Cyanoprokaryota 19/2. teil: Oscillatoriales. Elsevier GmbH 759p.

Konan KF, Bony KY, Adon MP, Potgieter J. 2015. Hydrobiological study of the Bandama Basin in Yaoure Gold Project's Area of Influence (Yaoure Gold Project, Côte d'Ivoire). Study report - Amara Mining Côte d'Ivoire SARL / Cabinet AMEC Foster Wheeler /Cabinet 2D Consulting Afrique, 99p.

Laplace TC, Barbe J, Dutartre A, Druart JC, Rimet F, Anneville O. 2009. Protocole standardisé d'échantillonnage, de conservation, d'observation et de dénombrement du phytoplancton en plan d'eau pour la mise en œuvre de la DCE : version 3.3.1. Cemagref, 44p.

Laplace TC, Derot J, Morin S, Tison JR. 2019. Bioindication d'état et de fonctionnement en plan d'eau : Utilisation des traits morpho-fonctionnels du phytoplancton pour définir des métriques de diagnostic Rapport final. IRSTE 79pp.

Lozo RN, Berté S, Ouattara NI, Kouamélan EP. 2019. Variation spatio-saisonnière des paramètres physico-chimiques des eaux du fleuve Bandama (Côte d'Ivoire) Revue de l'Environnement et de la Biodiversité -Pasres **4** (1), 34-43.

Lozo N, Berté S, Komoé K,Yao S, Kouamélan P. 2013. Bacillariophyceae (Heterokontophyta) from Bandana River in Côte d'Ivoire, West Africa. Journal of animal & plant sciences **20** (2), 3113 -3121.

Riquier J, Piégay H, Sulc MM. 2015. Hydromorphological conditions in eighteen restored floodplain channels of a large river: Linking patterns to processes. Freshwater Biology **60,** 1085-1103.

Rodier J. 1984. L'analyse de l'eau : Eaux naturelles, eaux résiduaires, eaux de mer. Chimie, physico-chimie, bactériologie, biologie. Édition Dunod Paris, (1984) 1356p.

Soro TA, Silué KD, Gogbé ZM, Coulibaly L, Gooré BG. 2021. Paramètres physico-chimiques des eaux du bassin du Haut-Bandama (Côte d'Ivoire). Synthèse: Revue des Sciences et de la Techonologie **1**, 33-48.

Utermöhl H. 1958. Zur Ver vollkommnung der quantitativen Phytoplankton-methodik. Internationale Vereinigung Fuertheoretische Undeamgewandte Limnologie **9**, 1-39.

Tshibanda JB, Malumba AM, Mpiana TP, Crispin K Mulaji, Jean-Paul Otamonga JP, Poté WJ. 2021. Influence of watershed on the accumulation of heavy metals in sediments of urban rivers under tropical conditions: Case of N'djili and Lukaya rivers in Kinshasa Democratic Republic of the Congo. Watershed Ecology and the Environment **3**, 30–37.

Yao Y, Vanderkelen I, Lombardozzi D, Swenson S, Lawrence D, Jägermeyr J, Grant L, Thiery W. 2022. Implementation and evaluation of irrigation techniques in the Community Land Model. Journal of Advances in Modeling Earth Systems **14(12)**, e2022MS003074.
DOI: 10.1029/2022MS003074.

Koné N, Amalan Sylvie N'da AS, Kien KB, Boguhé GFDH, Berthé S. 2022. Caractérisation physico-chimique des eaux du lac du barrage hydroélectrique de Kossou, fleuve Bandama, Côte d'Ivoire. Revue Ivoirienne des Sciences et Technologie. 39, 55 - 69.

Padial JM, Grant T, Frost D. 2014. Molecular systematics of terraranas (Anura: Brachycephaloidea) with anassessment of the effects of alignment and optimality criteria. Zootaxa **3825** (1), 1–132.
http://dx.doi.org/10.11646/zootaxa.3825.1.1.

Tian RC, Vézina AF, Legendre L, Ingéram RG. 2000. Effects of pelagic food-web interactions and nutrient remineralization on the biogeochemical cycling of carbon: a modeling approach. Deep-Sea Res II **47**, 637–662.