(RESEARCH ARTICLE)

Diversity and degree of organization of the Ichthyofauna of two branches of the Bandama river in the Marahoue region (Central West of Côte D'Ivoire)

Dramane Ouattara [1], Romuald Sonan Assi [2, *], Charles Koffi Boussou [2] and Séraphin Kouakou Konan [1]

[1] Environmental Science and Technology Laboratory, Faculty of Environment, Jean Lorougnon Guédé University, POB 150 Daloa, Côte d'Ivoire.
[2] Department of Biodiversity and Sustainable Management of Ecosystems, Faculty of Environment, Jean Lorougnon Guédé University, POB 150 Daloa, Côte d'Ivoire.

Abstract

Diversity and Degree of organization of the ichthyological population of two tributaries of the Bandama River in the Marahoue region located in the center-west of Côte d'Ivoire were studied. Indeed, the two tributaries of the Bandama River that are Marahoue and White Bandama Rivers draining this region are subject to numerous disturbances, the main one being gold panning. Data collection was conducted from September 2019 to November 2020 from experimental and artisanal fisheries. The mesh sizes of the gillnets used for the experimental fishery varied from 10 to 40 mm mesh size. The results showed a dominance of the order Siluriformes represented by 6 families and 18 species in the Marahoue River against 4 families and 13 species in the White Bandama River. Also, the Shannon Index (H') values obtained in the White Bandama River (H' fluctuates from 2.26 to 2.33 bits/ind) are lower than those obtained in the River Marahoue (H' fluctuates from 3.02 to 3.14 bits/ind). Our results also highlighted the equitability. This index appeared relatively high in the Marahoue River (E varies from 0.77 to 0.80) compared to the White Bandama River (E varies from 0.5 to 0.57). Consequently, the Marahoue River appears to be more stable and has a good degree of organization of the ichthyological population compared to the White Bandama River.

Keywords: Diversity; Degree of organization; Ichthyofauna; Marahoue and Bandama Rivers; Central West of Côte d'Ivoire

1. Introduction

The diversity of biological communities plays a key role in the functioning of ecosystems [1; 2]. However, man, through his activities, considerably threatens the survival of species and biological diversity.

In Côte d'Ivoire, the threats of anthropic activities on aquatic biodiversity are increasing [3; 4]. In the Marahoué region, the Bandama River is not immune to these anthropogenic pressures. Thus, the two main tributaries, the White Bandama and the Marahoué, which drain this region, are subject to numerous disturbances. The main anthropogenic activities likely to modify aquatic diversity in the Marahoue region are: the discharge of industrial effluents from the Société de limonadéries et de brasseries d'Afrique (SOLIBRA) in Bouaflé, and the untimely use of fertilizers and pesticides in the large sugarcane plantations of the SUCRIVOIRE integrated agricultural production unit (IAU) in Zuenoula. In addition, gold panning has intensified in recent years in the river basin in the Marahoue region. Among aquatic resources, fish are very vulnerable to the chemicals used in gold mining [5].

* Corresponding author: Romuald Sonan Assi
Department of Biodiversity and Sustainable Management of Ecosystems, Faculty of Environment, Jean Lorougnon Guédé University, POB 150 Daloa, Côte d'Ivoire.

Faced with all these threats to biodiversity, a policy for the preservation of ichthyological diversity in this Ivorian zone under strong anthropic pressure must be adopted. Most environmentalists agree that the establishment and implementation of any policy for the development and preservation of aquatic ecosystems must be preceded by knowledge of fish populations and their living environment [6].

The last survey mission on the Bandama River in general is that of Aboua DR [7]. This study only highlighted the relationships between ichthyological populations and environmental variables.

However, the results of research on the inventory and distribution of fish are subject to numerous changes. The reasons for these changes are taxonomic (systematic revisions), technical (diversification of sampling sites and sampling effort) and ecological (disappearance of specific habitats, extinction of species, hybridization etc.). [8]. Given this challenge, it is necessary to update the data on the ichthyofauna. It is in this context that the present study on the diversity and degree of organization of the ichthyological population was initiated on the two tributaries of the Bandama River. The results of this study will help decision makers in Côte d'Ivoire in the development and preservation of aquatic ecosystems in the Marahoue region.

2. Methodology

2.1. Study environment

The Marahoue region is located in central-western Côte d'Ivoire between longitudes 5°15 and 6°30 West and latitudes 6°00 and 8°00 North (Figure 1). This region has many advantages for the practice of continental fishing because it benefits from an important hydrographic network with the Bandama River [9]. Indeed, the Bandama River watershed is drained by two main tributaries, the White Bandama and Marahoue Rivers, which intersect in the vicinity of the town of Bouaflé. According to [10], the Marahoue Region is known for agriculture and fishing. In addition, in recent years, artisanal gold mining has been practiced in an abusive manner along the White Bandama in the southern part of the Bouaflé department. As for the Marahoue River, it receives industrial effluent discharges from the Société de limonadéries et de brasseries d'Afrique (SOLIBRA) in Bouaflé coupled with fertilizers and pesticides used in the large sugarcane plantations of the SUCRIVOIRE integrated agricultural production unit (UAI) in Zuenoula.
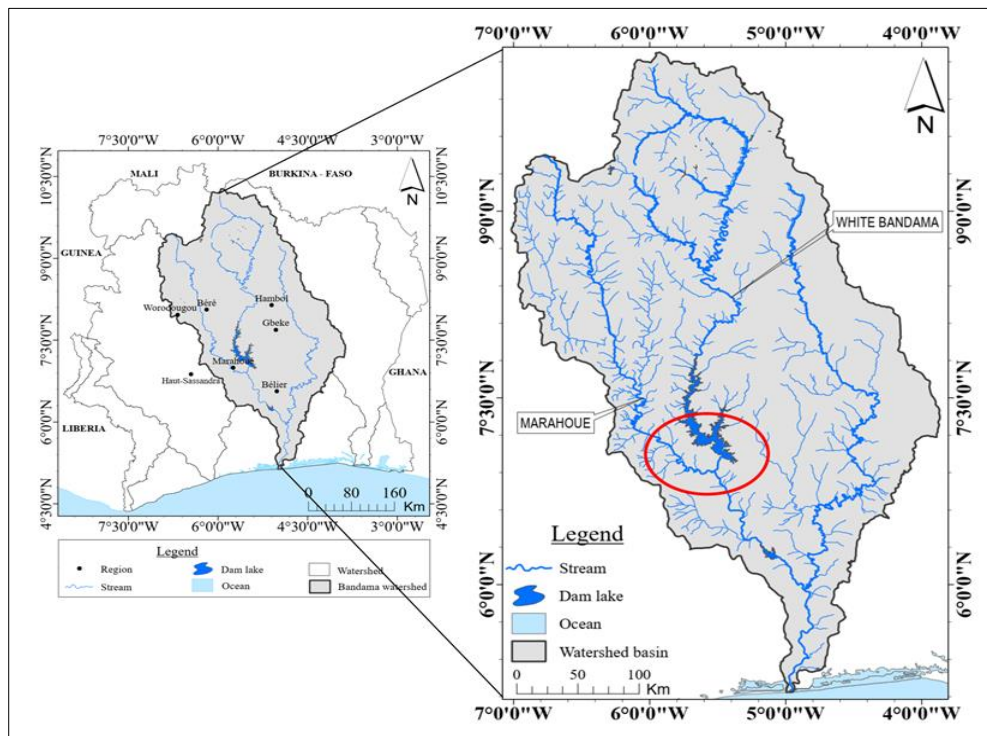

Figure 1 Mapping the study area

2.2. Data collection and analysis

2.2.1. Ichthyofauna sampling

For this study, ichthyofauna data collection was conducted from September 2019 to November 2020 using experimental and artisanal fisheries. The mesh sizes of the gillnets used in the experimental fishery ranged from 10 to 40 mm mesh size. Catches from artisanal fishermen were analyzed to complete the list of species actually present.

The identification guides proposed by [11, 12,13,14,15] were used to identify fish specimens encountered down to the specific level.

2.2.2. Sampling effort

The sampling effort was evaluated based on the expected species richness. Indeed, the expected species richness of the White Bandama and Marahoue Rivers was estimated using the Chao method from the experimental fishing data. This non-parametric estimator was estimated using the EstimateS (Statistica Estimation of Species Richness and Shared Species from Samples) software [16].

2.3. Degree of organization of the ichthyofauna

The degree of organization of the the ichthyofauna was evaluated using Shannon's diversity index (H') [17] and equitability index (E) [18]. These indices are calculated from the Paleotological Statistic (PAST) software (4.03) [19] and according to the following equations:

- H' = -Σqi Log$_2$(qi) : where qi is the relative abundance of each species;
- E = H' / Log$_2$ (S) : where H' is the Shannon's diversity index and S is the total number of species.

The Shannon Index (H') is commonly used to characterize the diversity of an environment based on taxonomic diversity. In natural environments, this index generally varies from 0.5 for low diversity to 4.5 for high diversity [20]. For these authors, it allows characterizing a stand and gives an unbiased estimate by measuring the degree of organization of this stand. The choice of this index is justified by the fact that it is independent of the sample size and instead takes into account the relative abundance of each species. The Shannon index is expressed in units of information per individual or bits / individual. As H' increases, so does the diversity.

Equitability or regularity (E) index [18] is used to study the regularity of species distribution in a given ecosystem. Equitability varies from 0 to 1 and reflects the quality of organization of a stand. If this index is close to 1, all species have the same abundance in an environment. Equitability (E) is equal to 0 when a single species dominates the stand.

The comparison t-test performed with PAST (4.03) software allowed us to compare the values of the Shannon and Equitability indices at the 5% significance level.

3. Results

3.1. Evaluation of the sampling effort

The sampling effort in terms of number of species as a function of the number of samples analyzed is shown in figure 2. At the end of the sampling campaigns, 57 and 51 fish species were identified in the White Bandama and Marahoue Rivers respectively. For the richness estimator considered during this study, the species accumulation curves show ascending trends at the end of the sampling period. The maximum species richness was estimated by the Chao 1 method at 65 and 53 species in the White Bandama and Marahoue rivers, respectively. The observed species richness in the White Bandama River corresponds to 87.69% of the richness predicted by the Chao 1 formula while it is 96.22% in the Marahoue River.
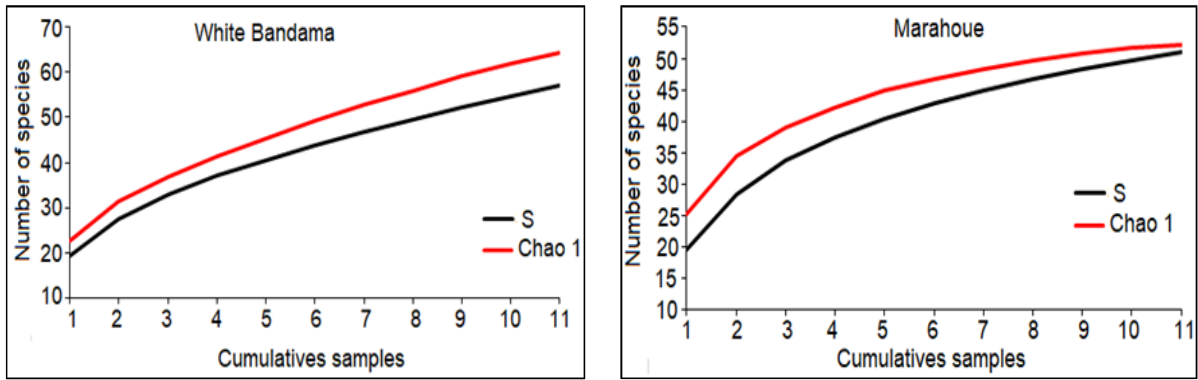
Figure 2 Accumulation curves for the number of fish species from the Bandama Blanc and Marahoue rivers using the method of Chao 1

3.2. Ichthyofauna composition

The ichthyological composition of the environment is recorded in Table 1. The work of the present study allowed the inventory of 57 and 51 species of fish in the White Bandama and Marahoué Rivers respectively. These species are divided into 15 families and 07 orders in the White Bandama and 19 families and 09 orders in the Marahoué River.

The orders observed are as follows: Characiformes, Anabantiformes, Carangaria, Cichliformes, Clupeiformes, Osteoglossiformes, Siluriformes, Polypteriformes and Synbranchiformes. The orders Polypteriformes and Synbranchiformes were obtained only in the Marahoué River while the other orders are common to both Rivers.

In terms of families, the order Siluriformes and Characiformes are the most diverse in both Rivers. The Siluriformes are represented by 4 families in the White Bandama River while they have 6 families in the Marahoue River. The orders Polypteriformes and Synbranchiformes consist of only one family.

Considering the species, the orders Cichliformes (14 species), Siluriformes (13 species) and Clupeiformes (12 species) are the most diverse in the White Bandama River. In the Marahoué River, Siluriformes (18 species), Cichliformes (11 species) and Osteoglossiformes (8 species) are the most diversified in the Marahoue River.

The proportions of the dominant orders differ from one River to another. Indeed, the Siluriformes has 18 species in the Marahoue River compared to 13 species in the White Bandama River. The order Clupeiformes is represented by 12 species in the White Bandama River compared to 3 species in the Marahoué River. The Cichliformes are dominant with 14 species in the White Bandama River while they are dominant with 11 species in the Marahoue River (Figure 3).
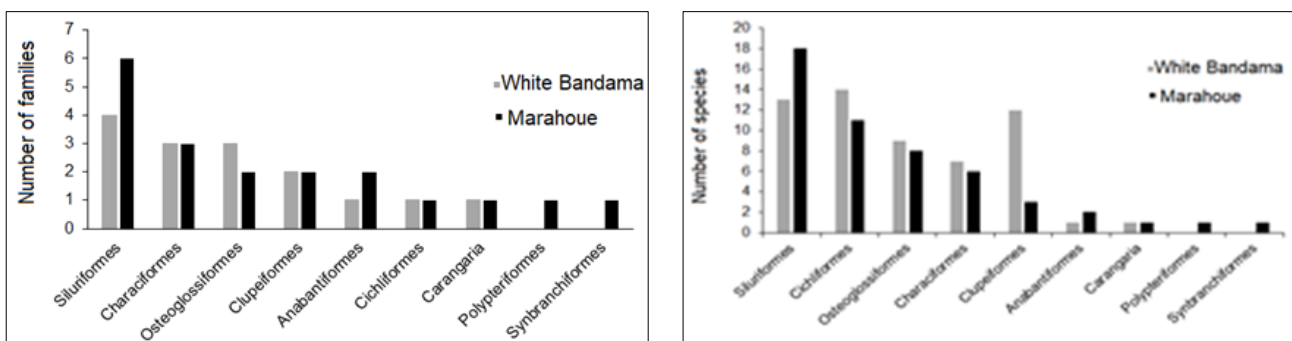

Figure 3 Classification of orders according to the number of families and the number of species

3.3. Degree of organization of the ichthyofauna

In the white Bandama River, the values of the Shannon index (H') varied between 2.26 and 2.33 bits/ind. However, these values ranged from 3.02 to 3.14 bits/ind at the Marahoue River (Figure 4). Equitability (E) appeared high in the Marahoue River compared to that obtained in the White Bandama River. These equitability values fluctuated between 0.56 and 0.57; between 0.77 and 0.80 for the White Bandama and Marahoue rivers respectively. According to the results of the comparative t-test, these index variations were significant across rivers (t-test ; $p < 0.05$) (Figure 4).
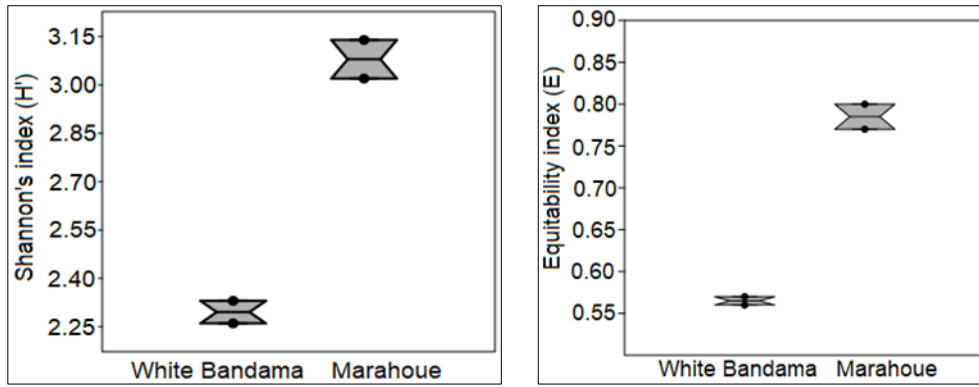
Figure 4 Variation of the shannon index (H') and Equitability (E) of the ichthyofauna of the White Bandama and Marahoue Rivers

Table 1 List of the ichthyofauna of white Bandama and Marahoue rivers (Marahoue Region; Central West of Côte d'Ivoire) from September 2019 to November 2020

Order	Family	Species	White Bandama	Marahoue
Characiformes	Alestidae	*Hydrocynus forskahlii*	1	1
		Alestes baremoze	1	1
		Brycinus imberi	1	1
		Brycinus macrolepidotus	1	1
		Micralestes occidentalis	1	0
	Distichodontidae	*Distichodus rostratus*	1	1
	Hepsetidae	*Hepsetus odoe*	1	1
Anabantiformes	Anabantidae	*Ctenopoma kingsleyae*	0	1
		Ctenopoma petherici	1	0
	Channidae	*Parachanna obscura*	0	1
Carangaria	Latidae	*Lates niloticus*	1	1
Cichliformes	Cichlidae	*Oreochromis niloticus*	1	1
		Pelmatochromis nigrofasciatus	1	0
		Chromidotilapia guntheri	1	1
		Hemichromis fasciatus	1	1
		Hemichromis bimaculatus	1	1
		Sarotherodon galilaeus	1	1
		Sarotherodon melanotheron	1	1
		Sarotherodon occidentalis	1	1
		Thysochromis ansorgii	1	1
		Tilapia busumana	1	1
		Pelmatolapia mariae	1	1
		Tylochromis jentinki	1	0
		Coptodon guineensis	1	0

Order	Family	Species	White Bandama	Marahoue
		Coptodon zillii	1	1
Clupeiformes	Clupeidae	*Pellonula leonensis*	1	0
		Pellonula vorax	1	0
		Labeo coubie	1	1
		Labeo parvus	1	1
		Labeo senegalensis	1	0
		Labeobarbus bynni	1	0
		Enteromius leonensis	1	0
		Enteromius macrops	1	0
		Enteromius pobeguini	1	0
		Enteromius sublineatus	1	0
		Enteromius trispilos	1	0
	Danionidae	*Raiamas nigeriensis*	1	0
		Raiamas senegalensis	0	1
Osteoglossiformes	Osteoglossidae	*Heterotis niloticus*	1	1
	Mormyridae	*Brienomyrus brachyistius*	1	0
		Petrocephalus bovei	0	1
		Marcusenius furcidens	1	1
		Pollimyrus isidori	1	0
		Marcusenius senegalensis	1	1
		Marcusenius ussheri	1	1
		Mormyrops anguilloides	1	1
		Mormyrus hasselquistii	0	1
		Mormyrus rume	1	1
	Notopteridae	*Papyrocranus afer*	1	0
Polypteriformes	Polypteridae	*Polypterus endlicherii*	0	1
Siluriformes	Clariidae	*Clarias anguillaris*	1	1
		Clarias buettikoferi	0	1
		Clarias gariepinus	0	1
		Clarias laeviceps	0	1
		Heterobranchus isopterus	0	1
		Heterobranchus longifilis	1	1
	Amphiliidae	*Amphilius atesuensis*	0	1
	Claroteidae	*Chrysichthys auratus*	1	1
		Chrysichthys maurus	1	1
		Chrysichthys johnelsi	1	1

Order	Family	Species	White Bandama	Marahoue
		Auchenoglanis occidentalis	1	1
		Auchenoglanis biscutatus	1	0
	Mochokidae	*Chiloglanis occidentalis*	1	1
		Synodontis bastiani	1	1
		Synodontis koensis	0	1
		Synodontis punctifer	1	1
		Synodontis schall	1	1
	Schilbeidae	*Parailia pellucida*	1	0
		Schilbe mandibularis	1	1
	Malapteruridae	*Malapterurus electricus*	0	1
Synbranchiformes	Mastacembelidae	*Mastacembelus nigromarginatus*	0	1

4. Discussion

The sampling effort evaluated by the Chao 1 richness estimator predicts an expected species richness of 65 and 53 species respectively in the White Bandama and Marahoue Rivers compared to 57 and 51 species respectively observed in these Rivers. The species richness observed in the White Bandama River corresponds to 87.69% of the richness predicted by the Chao 1 formula, whereas it is 96.22% in the Marahoue River. This result indicates that more fish species could be recorded with a higher sampling effort. This is also confirmed by the upward trend of the species accumulation curves at the end of the sampling period in both rivers. Thus, the sampling methodology used during this study based on the combination of experimental and artisanal fishing proves very satisfactory [21]. The species richness of the Bandama River in the Marahoue region (71 species obtained during this study) represents 95% of the total species richness of the Bandama River. Indeed, previous work by Aboua DR, reported the presence of 74 species throughout the Bandama River [7].

The proportions of the dominant orders differ from one river to another. The order Siluriformes is represented by 6 families and 18 species in the Marahoue River compared to 4 families and 13 species in the White Bandama River. This result could be explained by the rate of canopy closure which would influence the abundance and distribution of Siluriform species. Indeed, the rate of coverage is practically lower than 10% at the level of the White Bandama River due to artisanal gold mining practiced in an abusive manner all along this tributary in the department of Bouafle. In addition, Siluriformes are detritivorous species that feed on dead material that has fallen to the bottom [14; 15]. In addition, the order Cichliformes with the family Cichlidae alone is dominant with 14 species in the White Bandama River while it is dominant with 11 species in the Marahoue River. The dominance of the family Cichlidae is due to the food flexibility of this family. In addition, the creation of dam lakes in general is followed by their colonization by species of the family Cichlidae [22]. Indeed, the white Bandama River is the site of the construction of the Kossou hydroelectric dam, thus creating the Kossou dam lake.

The Shannon Index (H') values obtained in the White Bandama River (H' fluctuates from 2.26 to 2.33 bits/ind) are lower than those obtained in the Marahoué River (H' fluctuates from 3.02 to 3.14 bits/ind). Thus, the species identified in the White Bandama River are represented by a low abundance. Moreover, the ichthyological population of the White Bandama River is dominated by a high abundance of individuals belonging only to the families of Cichlidae (*Oreochromis niloticus* and *Coptodon zillii*) and Claroteidae (*Chrysichthys auratus* and *Chrysichthys johnelsi*). In contrast, in the Maharoue River all species inventoried are codominant. According to Ndiaye M, the Shannon index is higher when the individuals found are distributed over several species, which corresponds to a stable population, not subject to the action of abiotic factors or pollution factors [23]. Consequently, the Marahoue River appears to be more stable.

Equitability appeared relatively high in the Marahoue River (E ranged from 0.77 to 0.80) compared to the White Bandama River (E ranged from 0.5 to 0.57). This result shows that the Marahoue River has a good degree of ichtyofauna organization compared to the White Bandama River. The White Bandama is subject to uncontrolled, clandestine gold mining. Intense, uncontrolled illegal mining along a waterway promotes the erosion of biodiversity [24].

5. Conclusion

The present study allowed the inventory of 57 and 51 species of fish in the white Bandama and Marahoue rivers respectively. These species are divided into 15 families and 07 orders in the white Bandama River and 19 families and 09 orders in the Marahoue River. Marahoue River appears to be more stable and has a good degree of ichtyofauna organization compared to the white Bandama River.

Compliance with ethical standards

Acknowledgments

The authors of this work are grateful to the Research Group on Hydrobiology and Ecological Engineering (GRHIE) of Faculty of Environment, Jean Lorougnon Guédé University (Côte d'Ivoire).

Disclosure of conflict of interest

The authors have not declared any conflict of interests.

References

[1] Cucherousset J, Fried G, Cote J, Renault D. Biological invasions and ecosystem functioning; characterizing ecological impacts associated with invasive species. Journal of Ecology, Earth and Life, National Society for the Protection of Nature. 2015; 70 (12): 49-52.

[2] Mbete VC, Mbete P, Ibala-Zamba A, Mamonekene V. Diversity of the benthic macroinvertebrate fauna in the Loya Lagoon, in the extreme south of Congo Brazzaville. Journal of Animal & Plant Sciences. 2021; 47 (3): 8518-8526.

[3] Simmou YJ, Bamba M, Konan YA, Kouassi KP, Koné T. Impact of anthropogenic activities on the distribution of benthic macroinvertebrates and water quality of four small rivers in Côte d'Ivoire. European Journal of Scientific Research. 2015; 136(2): 122-137.

[4] Monney AI, Ouattara NI, Etilé NR, Aka NM, Bamba M, Koné T. Distribution of zooplankton in relation to environmental characteristics of four coastal rivers in southeastern Côte d'Ivoire (West Africa). Journal of Applied Biosciences. 2016; 98: 9344-9353.

[5] Affessi AS, Affessi A. Uncontrolled migration, resilience practices and the weakening of social relations in clandestine gold mining in Nyan (Côte d'Ivoire). International Journal of Innovation and Applied Studies. 2019; 28(1): 191-202.

[6] Myriam T, Pierre F, Justin D. From local knowledge to naturalist experts: The recognition of the knowledge of artisanal fishermen in Martinique. Journal of ethnoecology. 2017; 11: 1-19.

[7] Aboua DR, Konan NG, Kouamelan EP, Berté S, Bamba M. Spatial organization of the fish population in the Bandama. International Journal of Biological and Chemical Sciences. 2010; 4(5): 1480-1493.

[8] Leclercq V. Conservation issues of wild bees (Apoidea: Anthophila) on a network of nature reserves Statistical analysis (Master Biodiversity, Ecology, Evolution (B.E.E)). National Institute of Agronomic Research. 2019.

[9] Gouzile AP, Soro GE, Kouadio ZA, Goula Bi TA. Assessment of hydro-climatic and environmental risks related to the occurrence of Buruli ulcer in the Marahoue region (Cote d'Ivoire). International Journal of Biological and Chemical Sciences. 2016; 10(4): 1637-1650.

[10] Diarra A. Kossou: a fishing pole in decadence. Journal Espace, Territoires, Sociétés et Santé. 2020; 3(5): 79 -91.

[11] Paugy D, Lévêque C, Teugels GG. Fresh and brackish water fishes of West Africa, complete edition. Volume I. Edition IRD-MNHN-MRAC, Paris-Turvuren. 2003a.

[12] Paugy D, Lévêque C, Teugels GG. Fresh and brackish water fishes of West Africa, complete edition. Volume II. Edition IRD-MNHN-MRAC, Paris-Turvuren. 2003b.

[13] Sonnenberg R, Busch E. Description of a new genus and two new species of killifish (Cyprinodontiformes: Nothobranchiidae) from West Africa with a discussion of the taxonomic status of *Aphyosemion maeseni* Poll. 1941. Zootaxa. 2009; 2294: 1-22.

[14] Fricke R, Eschmeyer WN, van der Laan R. Catalog of fishes: genera, species, references. Electronic version; 2021 (accessed 19/07/2021).

[15] Froese R, Pauly D. Fish Base. World Wide Web electronic publication. Version 02/2019; 2020. (accessed 19/07/2021).

[16] Colwell RK. Estimate S. Statistical estimation of species richness and shared species from samples. Version 9. 1. 0. 2013.

[17] Shannon CE, Weaver W. The mathematical theory of communication. Urbana University Press, Illinois. 1963.

[18] Pielou EC. An introduction to mathematical ecology. Wiley Intersci., New York. 1969.

[19] Hammer O, Harper DAT, Ryan PD. Paleontological statistics software package for education and data analysis. Palaeontologia Electronica. 2001; 4(1): 1-9.

[20] Sarr SM, Ndiaye M, Faye E, Diedhiou DK. Species richness and abundance of the fish population of the Joal-Fadiouth Marine Protected Area in Senegal. Vertig O. 2018; 18(1): 1-21.

[21] Assi SR, Konan KF, Kouamé KM, Boussou KC, Aliko NG, Gourène G. Diversity and trophic guilds structure of fish assemblages from Aghien Lagoon (Côte d'Ivoire). Aquaculture, Aquarium, Consevation & Legislation (AACL Bioflux). 2019; 12(3): 977-988.

[22] Koné T, Teugels GG, N'douba V, Gooré Bi G, Kouamélan EP. First data on the inventory and distribution of the ichthyofauna of a small West African coastal basin: Gô River (Côte d'Ivoire). Cymbium. 2003; 27(2): 101-106.

[23] Ndiaye M. Biodiversity and bioecological structures of the fish fauna of the Cayar marine protected area (Senegal). 2014.

[24] Doffou RJO. Influence of gold panning on the diversity of the ichthyological population and the feeding ecology of an endemic species (*Micralestes eburneensis* Daget, 1964) in the Cavally River (West of Ivory Coast) (Thesis Ecology, Biodiversity and Evolution). University Jean Lorougnon Guédé. 2020.