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Inventory of ichthyological population and on some physicochemical parameters characteristics of a drinking water supply dam: the Ehuikro lake (Bongouanou, Côte d'Ivoire)

Akissi Nathalie Kouadio[1*], Kouakou Barthélemy Koffi[2], Stanislas Silvain Yao[1], Gouli Gooré Bi[1], Etilé Raphaël N'Doua[1], Yao Aristide Konan[1]

[1]Laboratoire d'Hydrobiologie et d'Ecotechnologie des Eaux, URF Biosciences, Université Felix Houphouët Boigny, 22 BP 582 Abidjan 22, Cote d'Ivoire

[2]Département des Sciences et Technologie, Ecole Normale Supérieure, 08 BP 10 Abidjan 08, Côte d'Ivoire

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Abstract

A study of the qualitative and quantitative inventory of the ichthyological population as well as on some physicochemical parameters were carried out in the Ehuikro lake in Bongouanou (Côte d'Ivoire), from July 2017 to June 2018. Monthly experimental fisheries with monofilament nets help register 462 individuals classified into 12 species, including *Oreochromis niloticus* and *Heterotis niloticus* (two introduced species). These species are divided into nine genera, six families and three orders. Qualitatively, the Cichlidae was the dominant family (n = 4 species); followed by Clariidae (n = 3) and Claroteidae (n = 2) families. The Anabantidae, Arapaimidae and Channidae families are monospecific. Quantitatively, *Hemichromis fasciatus* and *Heterotis niloticus* have respectively the highest numerical (64%) and weight (45%) percentage. This lake, because of its diversified population and good organization, seems to be stable and balanced. Thus, the first qualitative and quantitative inventory of the ichtyological population of the Ehuikro lake, as well as the knowledge of the characteristics of some environmental parameters, will serve as references for the subsequent investigations of this fish fauna and the development of appropriate measures to ensure sustainable protection and exploitation of the services of this lake environment.

* **Corresponding Author:** Akissi Nathalie Kouadio ✉ anniemarial58@gmail.com

Introduction

In Africa, the study of the ichthyological population of aquatic ecosystems has aroused the interest of many scientists (Gourène *et al.*, 1999 ; Ahouansou, 2003 ; Lalèyè *et al.*, 2003). Also, studies on the biology and knowledge of freshwater and brackish African fish continue (Lalèyè, 1995 ; Crespi, 1998 ; Koffi, 2015 ; Kouakou, 2017). In Côte d'Ivoire, several studies have been carried out on the ichthyological population of different rivers in different regions. There are, among others, the studies of Yao (2006) in the Comoé river; Aboua (2012) in the Bandama river; Kamelan *et al.* (2013) in the Dodo river ; Koffi *et al.* (2014) in the lagoon complex Aby-Tendo-Ehy ; Konan (2014) in the Tanoé-Ehy marsh forest and Adou *et al.* (2017) in the lake of Ayame 2. These various studies mainly interested in large river basins, rivers, lagoons and hydroelectric lakes. However, the ichthyological fauna of small dams, in this case that of Drinking Water Supply dams (DWS), remains little known to the scientific world : this is the case of the Ehuikro lake in the department of Bongouanou. This lake plays important roles such as the supply of drinking water and fish products. However, it is subject to several human activities, which could cause disruption in its biodiversity in general and its ichthyological diversity in particular. To this end, this study aims to make the qualitatively and quantitatively inventory of the ichthyological fauna of the Ehuikro lake and to estimate the annual averages of some environmental parameters of that lake.

Materials and methods

Study area

The Ehuikro Drinking Water Supply Dam (Figure 1) was built in 1973 on the sacred Yakpo River as part of the National Water Program. Its surface area is 733455 m². It is located between latitude 6 ° 38'24 "North and longitude 4 ° 10'12" West.

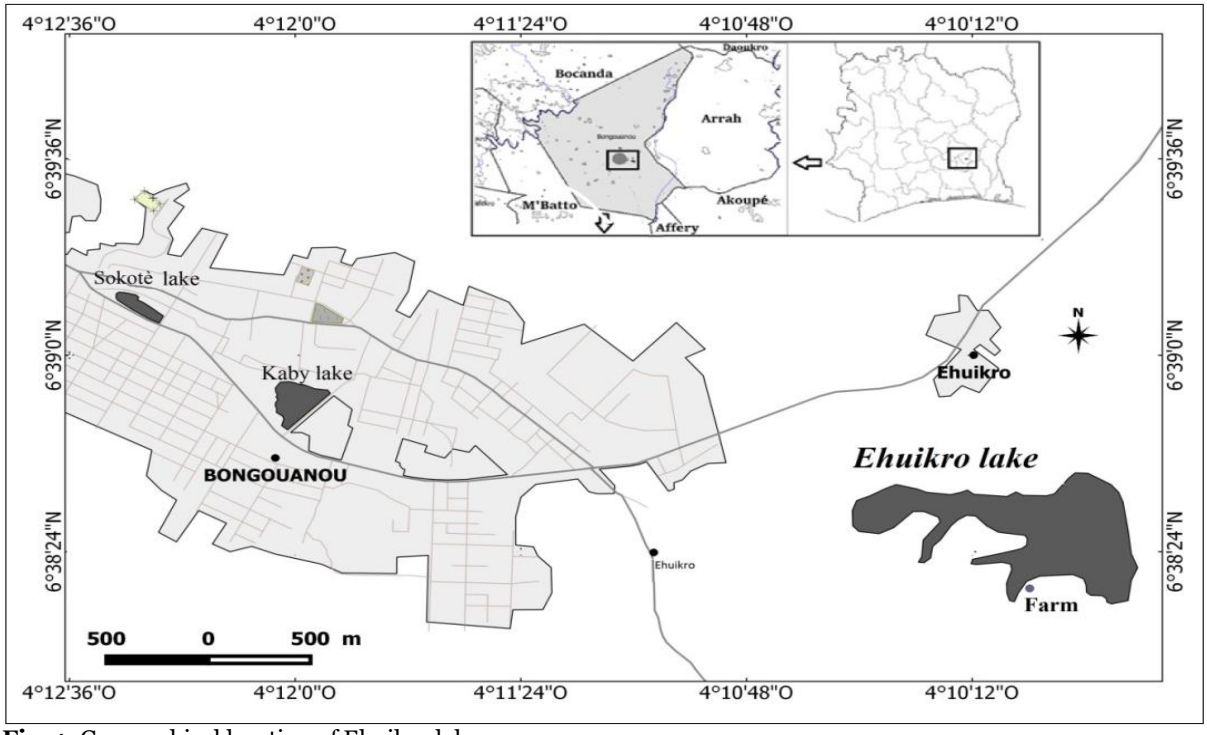

Fig. 1. Geographical location of Ehuikro lake.

The rate of flow of this dam mainly depends on that of the sacred river Yakpo and partly on another lake called Lake Kaby. It also receives water runoff from the village of Ehuikro located upstream. The Ehuikro Dam is bordered to the south by a poultry farm, a pig farm and agricultural crops (rubber tree nurseries, maize, tomato and okra) and to the east by the village of Ehuikro. The North and West are occupied by plantations of cassava, cocoa and also by crops like tomatoes, peppers and okra.

Several plants grow in this lentic environment [*Mimosa invisa* (Mimosaceae), *Cassia siamea* (Caesalpiniaceae), *Polygonum lanigerum* (Polygonaceae), *Nymphaea lotus* (Nymphaeaceae), *Rhynchospora corymbosa* (Cyperaceae) and *Ipomoea aquatica* (convolvulaceae)].

Fish fauna sampling

To evaluate the state of the fish fauna, experimental fisheries were carried out monthly over a period of 12 successive months (July 2017 to June 2018) using monofilament nets of 15, 20, 25, 30, 40, and 60 mm mesh. They were set at 5 pm and visited the next morning by 6 :30 am for the night fishing and set again. They were definitively removed at 2 pm for daytime fishing. The fish caught were identified according to Paugy *et al.* (2003a, b) and Dunz and Schliewen (2013), grouped and counted. Each fish is measured (standard length, total length) using a millimetric ichthyometer and then weighed using an ADAM HCB 123 electronic scale.

The physicochemical parameters were monthly measured *in-situ* between July 2017 and June 2018 in the lake in the morning between 7 am and 10 am using a multiparameter.

Analysis and data processing

The data collected were analyzed using the occurrence (F), numerical (N) and weight (P) percentages on the one hand, and on the other hand, using Shannon-Weaver's biological indices and Equitability. These indices were calculated from the numbers of the fish recorded thanks to the software Past. The Shannon and Weaver (H ') diversity index measures the degree of the population organization. It is a value between 0 and 5 (Ludwig and Reynolds, 1988). The Equitability (E) helps assess the quality of this organization (Dajoz 2000, Barbault 2000). It varies between 0 and 1. All these analyzes were respectively carried out according to the following formulas:

Occurrence percentage (%): $F = (Pi / Pt) \times 100$

With Pi = number of samples where species i has been identified;

Pt = total number of samples in an environment.

The classification of Dajoz (2000) is based on the value of F as follows:

- $F \geq 50\%$: constant species;
- $50\% < F \leq 25\%$: accessory species;
- $F < 25\%$: accidental species.

Numerical Percentage (%): $N = n / Nt \times 100$

With n = number of individuals from a taxonomic group (species, family, order);

Nt = Total number of individuals in an environment.

Weight Percentage (%): $P = p / Pt \times 100$

With p = Mass of individuals of a taxonomic group (species, family, order);

Pt = Total mass of individuals from a sample

Shannon and Weaver's diversity index: $H' = -\sum_{i=1}^{s} pi \times \log_2 ft$

With S = Total number of species;

Pi = probability of capture of species i in the sample ($Pi = Ni / N$)

N = total number of individuals;

Ni = number of individuals of a species, ranging from 1 to 5 (number and species).

Equitability: $E = H' / \text{Log}_2 S$

With H '= Shannon and Weaver specific diversity index;

S = Specific wealth.

Results

Qualitative inventory

The fish population inventoried in the lake of Ehuikro is recorded in Table 1. In total, 462 individuals divided into 12 species of which two introduced (*Oreochromis niloticus* and *Heterotis niloticus*), were caught from July 2017 to June 2018. These species belong to three orders that are: Perciformes, Siluriformes and Osteoglossiformes. These orders are divided into six families and nine genera.

The Perciformes are the most diversified with six species (50% of inventoried species). They are followed by Siluriformes with five species (42%) and Osteoglossiformes represented by a single species (8%) (Figure 2). The percentage in number of species of the families of fish caught (Figure 3) shows that the family more diversified with four species is that of

Cichlidae; that is 34%. This family is followed by Clariidae families with three species (25%), and Claroteidae families with two species (17%). The other three families namely, Channidae, Anabantidae and Arapaimidae with a numerical proportion of 8% of the ichthyological population are represented by one species each.

Table 1. List, frequency and seasonal variation of fish species recorded in Ehuikro lake (Bongouanou, Côte d'Ivoire) between July 2017 and June 2018.

Famillies	Genera	Species	F (%)	D. S.	R. S.
Cichlidae	*Coptodon*	*Coptodon zillii* (Gervais, 1848)	50	+	+
		Coptodon guineensis (Günther, 1862)	35.71	+	+
	Oreochromis	*Oreochromis niloticus* (Linné, 1758)	35.71	+	+
	Hemichromis	*Hemichromis fasciatus* Peters, 1857	78.57	+	+
Channidae	*Parachanna*	*Parachanna obscura* (Günther, 1861)	35.71		+
Anabantidae	*Ctenopoma*	*Ctenopoma petherici* Günther, 1864	14.28		+
Clariidae	*Clarias*	*Clarias anguillaris (*Linnaeus, 1758)	21.42		+
		Clarias buettikoferi Steindachner, 1894	7.14		+
	Heterobranchus	*Heterobranchus longifilis* Valenciennes, 1840	21.42		+
Claroteidae	*Chrysichthys*	*Chrysichthys nigrodigitatus* (Lacepède, 1803)	42.85	+	+
		Chrysichthys maurus (Valenciennes, 1840)	7.14		+
Arapaimidae	*Heterotis*	*Heterotis niloticus* (Cuvier, 1829)	71.48	+	+
6	9	12		6	12

F (%) = Frequency of occurrence; D.S = Dry Season ; R.S = Rainy season.

It should be noted that *Hemichromis fasciatus* is the most common species with an occurrence of 78.57%. It is followed by *H. niloticus* with an occurrence of 71.48%. These two species are qualified for constant species in this environment. *Coptodon zillii*, *C. guineensis*, *O. niloticus*, *Parachanna obscura* and *Chrysischthys nigrodigitatus*, which have a frequency of occurrence of between 25% and 50%, are the accessory species in this lake.

All other species whose frequency of occurrence is less than 25% represent accidental species (Table 1).

Table 2. Averages of the physicochemical parameters of the Ehuikro lake (Bongouanou, Côte d'Ivoire) between July 2017 and June 2018.

Physico-chimical parameters	Conductivity (µS/cm)	pH	Temperature (°C)	Dioxygen (O_2) (mg/l)
Annual average value	273.97	7.57	28.05	4.89

Quantitative inventory

Quantitative analysis indicates that in Ehuikro lake, *Hemichromis fasciatus* is the most abundant species with 64% of the population number.

It is followed by Heterotisniloticus (16%), *Coptodon zillii* (8%) and *C. guineensis* (3%). Other species have a numerical abundance of less than or equal to 2%. These species are: *Chrysischthys nigrodigitatus*, *P. obscura*, *O. niloticus*, *C. buettikoferi*, *C. anguillaris*, *Heterobranchus longifilis*, *Ctenopoma petherici* and *Chrysichthys maurus* (Figure 4).

With regard to biomass (Figure 5), *H. niloticus* dominates the population of this lake with a weight percentage of 45%. It is followed by *H. fasciatus* (P = 30%). Other species have weight percentages less than or equal to 5%.

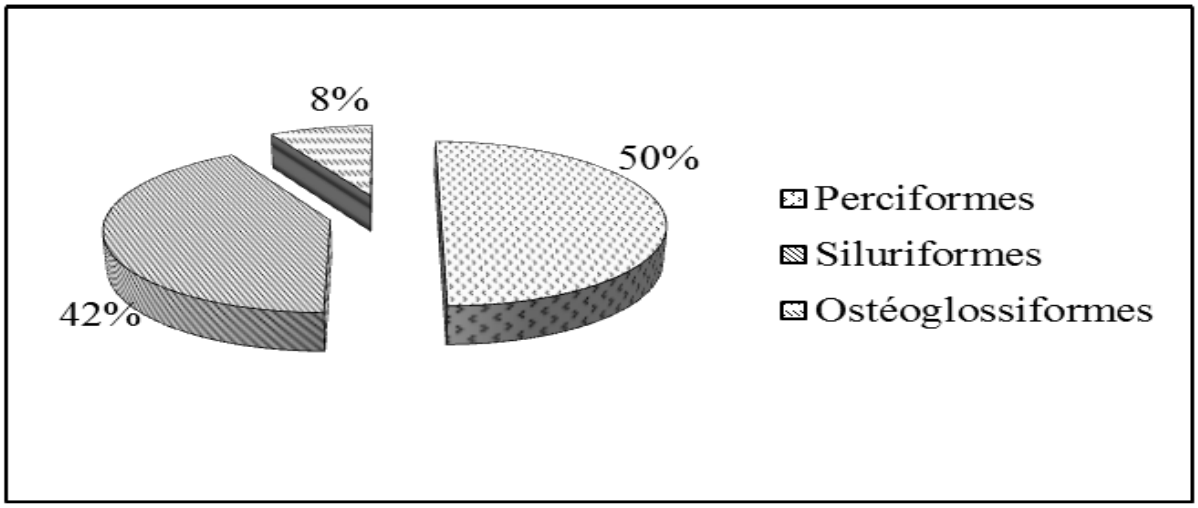

Fig. 2. Percentage of fish orders inventoried in Ehuikro Lake (Bongouanou, Côte d'Ivoire) from July 2017 to June 2018.

The Shannon-Weaner diversity and Equitability indices were calculated. They are respectively 1.26 and 0.5.

Seasonal variation

On a numerical level, the analysis according to the climatic seasons in this lake has shown that the fish caught are more numerous in the rainy season (330 individuals) than in the dry season (132 individuals). Specifically, six species were caught during the dry season while 12 species were caught during the rainy season. The comparison of the data obtained during the two seasons indicates that there is no significant difference (Mann-Whitney U test, $P < 0.05$) between climatic seasons.

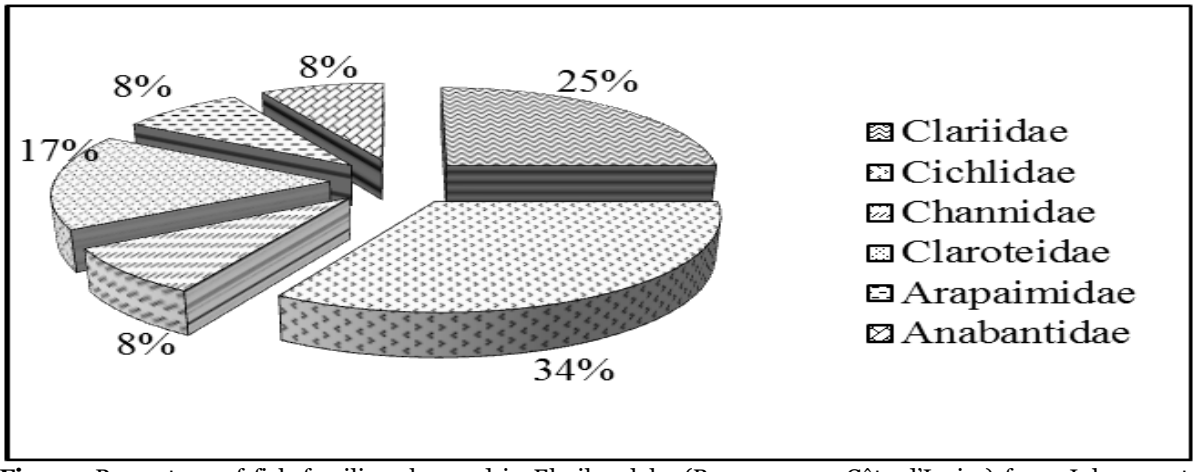

Fig. 3. Percentage of fish families observed in Ehuikro lake (Bongouanou, Côte d'Ivoire) from July 2017 to June 2018.

Physicochemical parameters

The average values of physico-chemical parameters of Ehuikros lake are given in Table 2. The low conductivity value was measured in June (227.4 µS / cm) and the highest value in February (389 µS / cm) with an average of (273.97 µS / cm). The Hydrogen potential (pH) varies between 7.04 (January) and 8.13 (June) with an average annual value 7.57.

The minimum (26.8 ° C) and maximum (29.73 ° C) temperature values were recorded in June and February, respectively. The average value of this parameter is 28.05 ° C. Regarding the values of dissolved oxygen, the lowest value (2.64 mg / l) in the month of January and the

highest 8.23 mg / l in the month of February with a (4.89 mg / l).

Discussion

Sampling conducted during this study in Ehuikro lake helped identify 12 species of fish. This specific richness obtained in this lake could be explained either by its origin, its source of supply, its surface area which is not large or its environment. Indeed, Ehuikro lake was built on a small river (Yakpo) and it is also connected to Kaby lake from which it gets populated. This richness is high compared to that obtained in Kaby lake (four species) by Kouadio *et al.* (2018). However, it is very low compared to the other studies carried out on the population in the lakes Ayamé 1 (Tah *et al.*, 2009, Konan *et al.*, 2013), Kossou (Aboua *et al.*, 2010) and Ayamé 2 (Adou *et al.*, 2017). These authors recorded respectively 41, 47, 37 and 40 species.

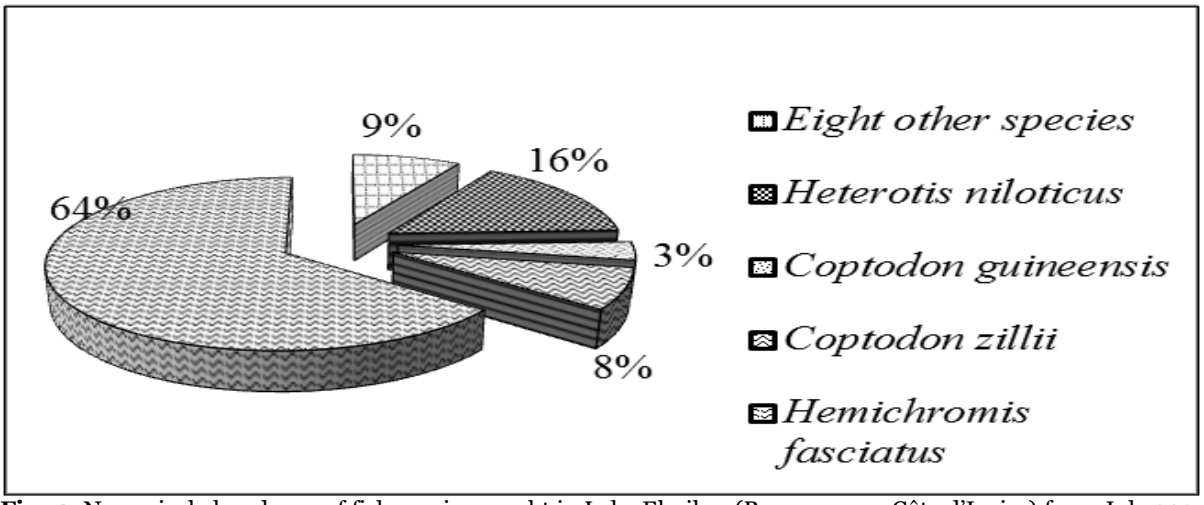

Fig. 4. Numerical abundance of fish species caught in Lake Ehuikro (Bongouanou, Côte d'Ivoire) from July 2017 to June 2018.

These lakes, unlike Ehuikro lake, were built on a large river (Bia) for the lakes of Ayamé 1 and 2 and also on a river (Bandama) for Kossou lake. These aquatic environments on which these lakes were built receive tributaries enriching these environments in fish. Some authors like Gourène *et al.* (1999), Kouamélan *et al.* (2003), Yao *et al.* (2005) and Yao (2006) argue that parameters such as the basin size, environmental variables of habitats and some anthropogenic activities can influence both species diversity and the distribution of fish species in streams. This result would also be due to an environmental stress indicator. In fact, the Ehuikro lake is influenced by several human activities including fishing and agricultural activities (market gardening, rubber tree and cocoa nurseries). This implies that chemicals are used. These products are drained in that environment, thus influencing the respiration of certain species of fish. In addition, there are poultry and pig farms. Yet, the excessive presence of certain ions in water has harmful effects on the growth of aquatic fauna (Bremond and Vuichard, 1973). Some anthropogenic activities can influence both species diversity and distribution of fish species in rivers (Kouamélan *et al.*, 2003 ; Yao *et al.*, 2005).

Furthermore, the inventory of the population revealed that the Cichlidae family is predominant in species and individual number. This is could be because of their food plasticity (Blaber, 2000) and their ability to resist stress (Philippard and Ruwet, 1982). This result is in line with those of Da Costa (2003) in the case of the Ayamé 1 lake, Ouédraogo *et al.* (2015) in the lake of Sahelian of Higa and Adou *et al.* (2017) in the dam of Ayamé 2. Also, Koné *et al.* (2003) have indicated that the creation of the lake is often accompanied by the colonization of the environment by Cichlidae species. In addition,

Winemiller *et al.* (1995) state that most species of Cichlidae are adapted to live along riverbanks or in water in the presence of higher plants.

Although the Mann-Whitney U-test revealed no significant differences in the individuals caught between the two climatic seasons, the results of the qualitative analysis indicated that there is a difference in the number of fish individuals according to seasonal variation. Indeed, there are more individuals caught in the rainy season in this lake than in the dry season. These results could be explained by the increase of the submerged surfaces and by the submersion of the surrounding vegetation. In fact, these lakes are surrounded or inhabited by abundant vegetation that would provide fish with a significant amount of immigrant organic matter and nutrients for their development during periods of heavy rainfall (Aboua, 2012 ; Castillo-Rivera, 2013).

In addition, during the rainy seasons, the waters are more oxygenated because of agitation movements and also because of the photosynthesis of aquatic plants, thus offering better oxygenation and fish life conditions. Our results are in line with those obtained by Konan (2014) in the FMTE.

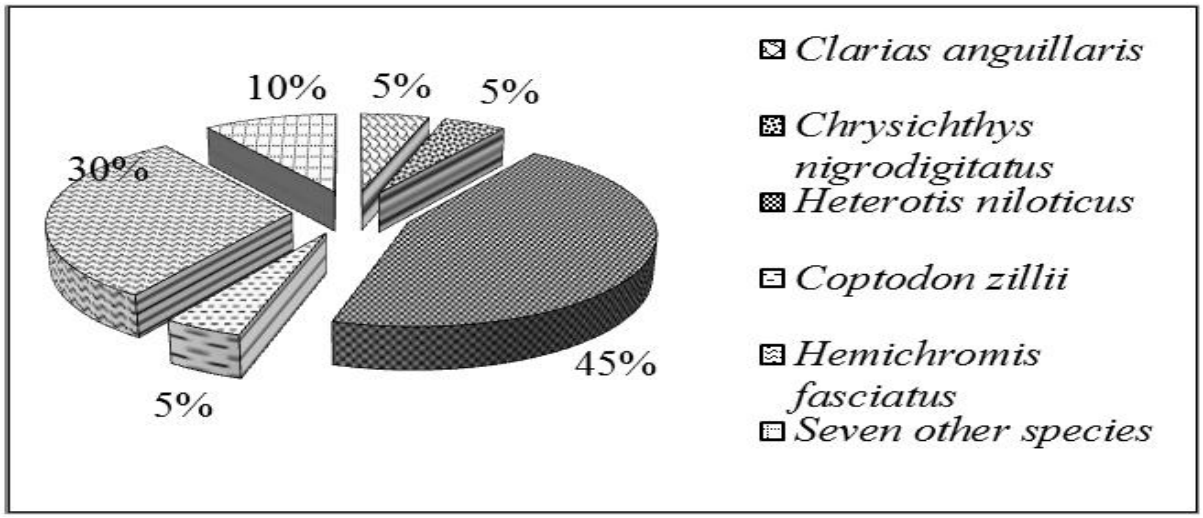

Fig. 5. Weight percentage of fish species sampled in Ehuikro lake (Bongouanou, Côte d'Ivoire) from July 2017 to June 2018.

The analysis of the degree of organization of the fish population shows that the Ehuikro lake with a Shannon and Weaver diversity index of 1.26 is stable because of its diversified population and good organization. This result differs from the Kaby lake result with a Shannon and Weaver diversity index of 0.39 by Kouadio *et al.* (2018). Indeed, Ehuikro lake, located on the outskirts of the town of Bongouanou, is home to more species (12) than Kaby lake (4) located in the town of Bongouanou. The high species diversity of this lake could be explained by the constant arrival of freshwater from the Yakpo River. Moreover, the Ehuikro Lake was built on this river to make a reservoir of water to feed the population. Besides, this lake contains lots of aquatic plants. It can provide a spawning ground and an important food source for most fish species because plants are the source of high primary productivity. The results of this study are similar to those reported by Kouamé (2010) on the Buyo lake and by Aboua (2012) on the Taabo lake. As for the analysis of the Equitability index, it indicates that the Ehuikro lake with an index of 0.5 has more or less a balanced population. Also, its ecological state is not disturbed insofar as several species belonging to different trophic forms live there. According to Barbault (2000) and Dajoz (2000), the more the Equitability is closer to 1, the more the population is balanced and stable. In addition, low Equitability reflects the predominance of some species over all the other taxa and an imbalance of population due to a natural or anthropogenic event.

In terms of environmental parameters, it is known that human activities related to lakes have very often caused eutrophication (Ogutu-Oluvayo *et al.*, 1997 . Mama, 2010). Also, the growth of water hyacinths is often determined by seasonal variations and various environmental factors (Hadj *et al.*, 2008). It is due to those reasons that it has been estimated the average of some parameters and nutrients in the Ehuikro drinking water supply lake.

Conductivity indicates the ability of the water to conduct the current, which depends on the mineral content of the water. Taking into account the normal value of 400µS / cm, the average conductivity value measured (273.97 µS / cm), is lower than normal. This low value of the conductivity is favorable for the maturation of fish (Vincent and Saïdou, 1990).

The potential of Hydrogen (pH) reflects the concentration of ion H^+ and measures the acidity or alkalinity of the water read on a scale from 0 to 14. The average pH value (7.57) of the Ehuikro lake noted shows a slight basicity of this lacustrine environment. The guidelines set by the World Health Organization (WHO) are 6.5 <pH <9.5. This leads to the conclusion that the average value obtained is within the tolerable value. According to Merceron (1999), a pH that tends to be basic is not very favorable for the development of fish that lose their flesh at maturity and become skeletal.

The average value of the temperature (28.05 ° C) is within the range that is tolerated by aquatic species of hot water (25 ° C to 30 ° C). In order to reproduce, most Cichlidae, the dominant family in Ehuikro lake, need a temperature of at least 20 ° C (Barnabé, 1986). We therefore deduce that the temperature of the waters of Ehuikro lake is favorable to the life of these fish.

The oxygen level provides information on the health of rivers and allows, among other things, to assess the quality of fish habitats (Chouti *et al.*, 2010). It must be pointed out that the presence of dissolved oxygen in water is important for aquatic life.

It promotes the process of self-purification of rivers with the participation of microorganisms (Le Pimpec, 2002). The Ehuikro lake oxygen level (4.89 mg / l) is lower than the value of 7 mg / l considered as the normal value but is higher than the limit value of 2 mg / l below which fish mortality is common (Francis-Floyd, 2003). This average value of dissolved dioxygen recorded in the Ehuikro lake is acceptable for the initial stage and for other life stages in tropical ecosystems (CCREM, 1987). It is due to the presence of fish species, most of which are species known for their algivorous power (Foutlane *et al.*, 1997). This action can contribute to reducing the fall of organic matter in the deep layers from the production areas and whose oxidation could lead to an undersaturation of the dissolved oxygen content of the body of water.

Conclusion

The inventory identified 12 species of fish, belonging to nine genera, six families and three orders. The results about the physicochemical parameters show that the water in Ehuikro lake is relatively of good quality but some limiting factors such as the pH and the dissolved oxygen have to be controlled to avoid pollution.

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