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Spatial and seasonal variation of ichtyofauna in the littoral zone of Lake Buyo (South-west Côte d'Ivoire) using video surveillance

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Abstract

Video surveillance techniques are increasingly being used for aquatic research purposes because they are non-extractive and cause less disturbance to fish habitats. The aim is to use video surveillance as a sampling method to inventory fish in the littoral zones of Lake Buyo. Six baited cameras were used to sample the fish. Analysis of the video recordings enabled 18 species of fish to be identified, divided into 13 genera, 9 families and 7 orders. The best represented families were the Cyprinidae with 2102 individuals, the Cichlidae (1892 individuals) and the Alestidae (1772 individuals). *Enteromius macrops* (2057 individuals), *Coptodon zillii* (1387 individuals), *Brycinus macrolepidotus* (858 individuals), *Brycinus longipinnis* (831 individuals) and *Oreochromis niloticus* (469 individuals) were the most abundant species. Depending on the hydrological season, significant differences in species richness were observed between high water and low water seasons at all the stations. Analysis of the structure of the fish assemblages revealed a environment was more diverse and stable during periods of high water than during periods of low water. The use of video surveillance as a sampling method thus represents a important alternative for the collection of ichthyological data.

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Introduction

As transition zones between terrestrial and aquatic environments, littoral zones represent the most heterogeneous, diverse and productive physical environment in lakes (Brind'Amour, 2005; Zohary and Gasith, 2014). The complexity and diversity of nearshore habitats provide more food resources for fish, stimulate spawning behaviour and generate refuges for many nearshore aquatic species (Schmieder, 2004 ; Kyle *et al.*, 2014).

Unfortunately, these ecosystems are subject to numerous anthropogenic pressures that considerably alter their role in the renewal of fish stocks. These pressures are mainly linked to intensive fishing, the use of chemical substances in agriculture, the destruction of forests and the reduction in the surface area or quality of habitats (Jones, 2002 ; Onana *et al.*, 2014 ; Monney *et al.*, 2016).

In Côte d'Ivoire, the Buyo dam lake is no exception to these pressures. Anthropogenic activities (fishing and agriculture) have harmful consequences for fish habitats and fish stocks, sometimes leading to the disappearance of fish species (N'Dri *et al.*, 2020). The fishing techniques and gear used by some fishermen are largely unregulated and very often considerably destroy the lake's coastal habitats, remove spawners from nests and catch all sizes of fish. Excessive variations in water level also threaten the lake's fish populations by altering feeding conditions through the reduction in prey populations (Anderson *et al.*, 2021), or by eliminating fish spawning sites (N'Dri, 2020).

However, although numerous studies have been carried out on Lake Buyo (Kouamé, 2010; Goli Bi *et al.*, 2019; Kouassi *et al.*, 2019), few investigations have focused specifically on the littoral zones of this lake, in particular the zone incorporating the Taï National Park, even though the latter is known to be an important spawning ground for fish (N'Dri, 2020). Hence the need to monitor the dynamics of fish in coastal areas in order to identify and even anticipate possible degradation that could affect them. Such monitoring can also help to understand the causes inherent in these changes. The heritage and economic importance of Lake Buyo in Côte d'Ivoire alone justifies the introduction of such monitoring. The observation methods traditionally used to monitor aquatic ecosystems are based on experimental fishing. However, this extractive technique is destructive, which is undesirable in sensitive or protected areas (Pelletier, 2003 ; Kimball and Able, 2012; Sheaves *et al.*, 2016).

In this context, video surveillance is an interesting alternative, although it is still relatively little used for monitoring aquatic ecosystems (Pelletier *et al.*, 2006 ; Favaro *et al.*, 2012). Visual techniques have largely proved their worth and provide a fairly complete picture of fish populations. The general aim of this study is to use video surveillance to determine the composition of the ichthyofauna at different time and space scales in the littoral zone of Lake Buyo with a view to efficient management. Specifically, the aim is to determine the diversity and abundance of fish that frequent the littoral habitats of Lake Buyo.

Materials and methods

Study area

Located in the southwest of Côte d'Ivoire, Lake Buyo (1°14'-7°034 N, 6°54'-7°31'W) is the result of the construction of a hydroelectric dam on the Sassandra River, drowning approximately 8,400 hectares of forest (OIPR, 2006). It has an area of 920 km² and a watershed of 75,000 km². The hydrological conditions of Lake Buyo during the year 2020 are marked by a season of high water (HW) (September to February 2020) and a season of low water (LW) (March to August 2020). Four sampling stations located in the coastal zone of Lake Buyo (Fig. 1), in the integral part of Taï National Park, were visited during 12 campaigns (January to December 2020). These stations were selected based on their accessibility and common characteristics. Station PK15 is closer to the hydroelectric dam and is subject to slow drying during low flow seasons. On the other hand, station PK28, less close to the hydroelectric dam than station Pk15, is characterized by rapid drying during low water periods. The Dera station is an intermediate zone between the Pk28 station and the Beablo station and is subject to slight drying out during low water seasons. As for the Beablo station, it is located in an overflow zone of the Sassandra River and is characterized by very rapid drying during low water seasons.

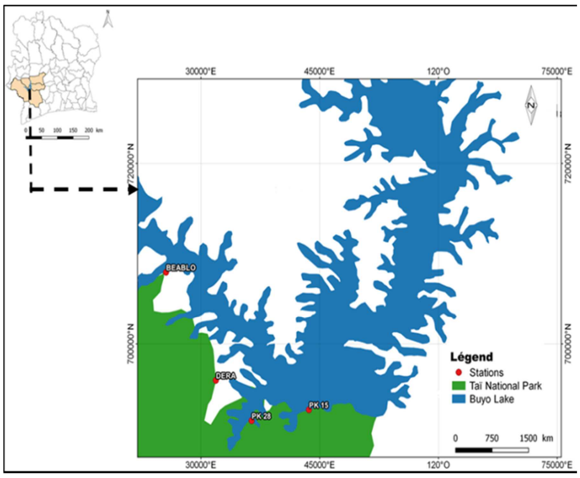

Fig. 1. Location of Lake Buyo sampling stations

Data collection

Sampling fish using baited cameras

The study of fish diversity and abundance in Lake Buyo was carried out using six baited devices separated from each other by at least 20 metres (Sheaves *et al.*, 2016). Each device consisted of an Apexcam Pro EIS Action model M 80 camera (supplied with a waterproof protective box and fitted with a 64 Gigabyte memory card), a bait pot and metal supports of the same type to which the camera and pot were attached. On each support, the cameras were placed horizontally (Fig. 2) so that the bait was in the camera's field of vision, making it easier to identify and count the fish (Cappo *et al.*, 2004). Each pot was perforated before being baited with 300g of food to accelerate the release of the odour into the environment. Of these devices, three contained rice bran and the other three contained maize bran. The optimum distance chosen between the camera and the bait pot was 30 cm (Abo *et al.*, 2021) (optimum distance obtained after the visibility test for good quality images). The choice of these baits and of this optimal distance was based on the results obtained after the bait test and the fish visibility test by the cameras (Abo *et al.*, 2021). The food was pre-cooked with a litre of water until a strong-smelling, water-resistant paw was obtained. A series of 1h30 recordings was made from 7am to 5.30pm.

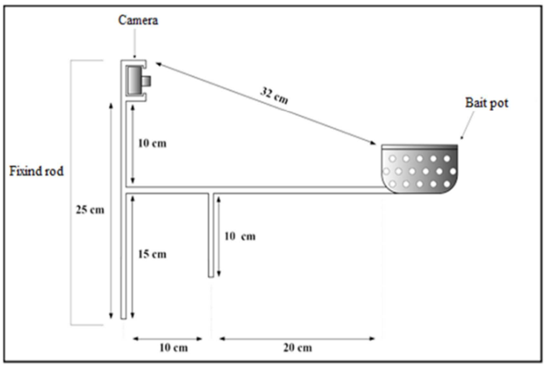

Fig. 2. Diagram of the experimental baited camera system used to sample fish in Lake Buyo

Analysis of video sequences

In the laboratory, the video sequences were viewed on a computer using players (Gom Player and VLC). These players are capable of low-speed playback and image optimisation (contrast, brightness and colour saturation) to make it easier to identify and count the fish. Fish were identified using the identification keys of Paugy *et al.* (2003 a and b) and species names were updated in Fishbase (Froese and Pauly, 2021). When it was not possible to identify the individual clearly, identification was made at least at family level, and if possible at genus level. The total recording time of an underwater camera (1 h 30 min) was first sequenced into 15 minutes. Each 15 minutes sequence was then subdivided into 30 seconds intervals (i.e. 30 30 second intervals). For each number of fish counted in 30 seconds, an average value for each set (MaxNA) over 15 minutes was calculated. This measurement provides an index of fish abundance through repeated observations of the same individuals (Stoner *et al.*, 2007). When there were too many individuals in the field of view of the cameras, images were captured to count the fish individuals present. Only visible fish were counted.

Data analysis

The fish population captured by the video surveillance system was characterised using the following indices: species richness, Shannon and equitability indices, percentage of occurrence and abundance.

The Shannon index (Shannon, 1948) was used to measure the degree of organisation of the stand. It was calculated according to the following equation: H' = - Σ (ni/N) ln (ni/N), where H' = Shannon and Weaver (1949) index; ni = number of individuals of species i; N = total number of individuals of all species.

Pielou's equitability index (1966) was used to assess the quality of the distribution of individuals within species in the environment. It is calculated using the formula: E = H'/Log2Rs where E = equitability index; H' = Shannon-Weaver index; Rs = number of species.

The percentage of occurrence (F) provides information on the environmental (habitat) preferences of a given species. It is obtained using the formula F = (Fi × 100) / Ft. Depending on the value of F, the following classification is adopted (Dajoz, 2000): constant species (F ≥ 50 %), accessory species (25 ≤ F ≤ 50 %) and accidental species (F < 25 %).

The non-parametric Mann-Whitney test was used to assess the importance of hydrological variations (high and low water) on fish populations. The test was significant at $p < 0.05$. The tests were carried out using STATISTICA version 7.1 software.

Results

Qualitative analysis of fish community in the littoral zone of Lake Buyo

This study identified 18 species of fish divided into 13 genera, 9 families and 7 orders (Table 1). Analysis of the species composition showed that the best represented families in terms of species were the Cichlidae (5 species representing 27.77%); the Cyprinidae (4 species representing 22.22%) and the Alestidae (3 species, or 16.66%) (Fig. 3). The other families (Clariidae, Claroteidae, Clupeidae, Schilbeidae, Latidae and Osteoglossidae) were each represented by a single species (i.e. 5.55% per family) (Fig. 3). Fig. 4 shows images of some of the fish species observed by the video surveillance system. The highest species richness was recorded during the high water seasons at all stations.The Beablo station recorded the highest diversity (14 species) during the high-water period. However, during the low-water period, the lowest diversity (3 species) was recorded at the Pk28 and Pk15 stations (Fig. 5). Significant differences in species richness were observed between the low and high water seasons at each sampling station (Mann-Whitney U test; $p < 0.05$).

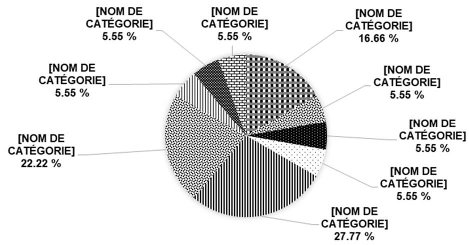

Fig. 3. Contribution (%) of families to the species richness of fish observed in the littoral habitats of Lake Buyo between January and December 2020

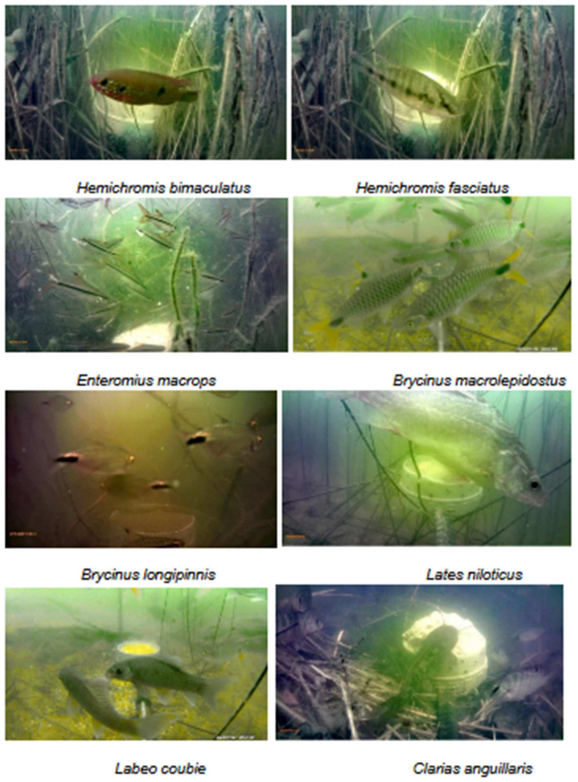

Fig. 4. Image captures of some fish species observed in the field of view of the cameras deployed on Lake Buyo

Occurrence of sampled species

The analysis of occurrence indicates 9 very frequent species including 5 species recorded on 4 stations, i.e. 100 % and 4 species recorded on 3 stations out of 4, i.e. 75 %, 4 fairly frequent species listed in 2 out of 4 stations, i.e. 50 %, 4 species recorded at 1 station, i.e. 25 % (Table 1).

Table 1. List of fish species observed in Lake Buyo from January to December 2020 using the video surveillance system at the various sampling stations in Lake Buyo

Order	Family	Species	Beablo	Dera	Pk15	Pk28	F(%)
Characiformes	Alestidae	*Brycinus longipinnis*	+		+	+	75
		Brycinus macrolepidotus	+	+	+	+	100
		Brycinus sp.	+		+		50
Siluriformes	Claroteidae	*Chrysichtys nigrodigitatus*	+	+	+		75
	Clariidae	*Clarias anguilaris*	+			+	50
	Schilbeidae	*Schilbe mandibularis*	+				25
Cichliformes	Cichlidae	*Coptodon zillii*	+	+	+	+	100
		Hemichromis bimaculatus	+	+	+	+	100
		Hemichromis fasciatus	+		+	+	75
		*Oreochromis niloticus**	+	+	+	+	100
		Sarotherodon melanotheron	+		+		50
Cypriniformes	Cyprinidae	*Enteromius macrops*	+	+	+	+	100
		Enteromius sublineatus	+	+	+		75
		Labeo coubie	+	+			50
		Labeo parvus		+			25
Osteoglossiformes	Osteoglossidae	*Heterotis niloticus**	+	+	+		75
Atheriniformes	Latidae	*Lates niloticus*				+	25
Clupeiformes	Clupeidae	*Pellonula leonensis***		+			25
7	9	18	15	11	12	9	

+: presence; *: introduced species; **: estuarine or marine species ; F : Frequency of occurrence.

Table 2. Shannon-Weaver diversity and Pielou equitability index for fish community on the littoral zone of Lake Buyo at different hydrological seasons

Seasons	Beablo		Dera		PK15		PK28	
	H'	E	H'	E	H'	E	H'	E
High water	1.85	0.72	1.51	0.63	1.47	0.67	1.61	0.67
Low water	1.3	0.93	1.06	0.66	0.76	0.62	0.68	0.69

Shannon index= H' ; Equitability = E

Quantitative analysis of fish community in the littoral zone of Lake Buyo

A total of 6148 fish specimens were observed at all the stations sampled. Analysis of the data showed that the most abundant families in terms of individuals were the Cyprinidae (2102 individuals or 34.18%), the Cichlidae (1892 individuals or 30.77%) and the Alestidae (1772 individuals or 28.82%). The other families (Clariidae, Claroteidae, Clupeidae, Osteoglossidae and Centroponidae) represented a total of 382 individuals or 6.21 % (Fig. 6). The species *Enteromius macrops* (2057 individuals or 33.46 %), *Coptodon zillii* (1387 individuals or 22.56 %), *Brycinus macrolepidotus* (858 individuals or 13.95 %), *Brycinus longipinnis* (831 individuals or 13.51 %) and *Oreochromis niloticus* (469 individuals or 7.63 %) were the most abundant in the present study (Fig. 7). The 13 other species totalled 546 individuals, or 8.88% of the fish observed (Fig. 7). The greatest abundance of fish was observed during the high-water season at all stations. The Beablo station recorded the extreme values (HW = 80.9%; LW= 19.1%) for this abundance (Fig. 8). Significant differences were observed between hydrological seasons at each station (Mann-Whitney U test; $p < 0.05$).

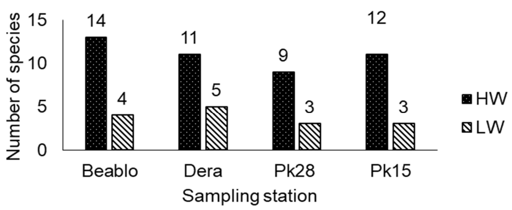

Fig. 5. Variation in specific richness according to the hydrological seasons in Lake Buyo sampling stations

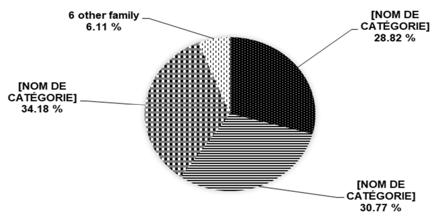

Fig. 6. Relative abundance (%) of fish families recorded in the littoral zone of Lake Buyo from January to December 2020

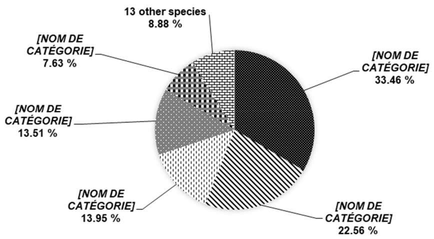

Fig. 7. Relative abundance (%) of fish species inventoried in the littoral zone of Lake Buyo from January to December 2020

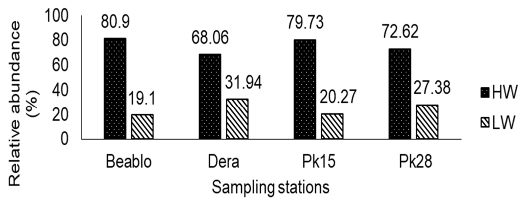

Fig. 8. Relative abundance (%) of fish counted during high and low water periods at each sampling station

Diversity indices

The Beablo station recorded the highest values (high water: 1.85; low water: 1.3) of the Shannon index whatever the water level (Table 2). However, station Pk15 had the lowest value (high water: 1.47) of the Shannon index during the high-water period and station Pk28 recorded the lowest value (low water: 0.68) of this parameter during the low-water period (Table 2). On the other hand, the highest values of the equitability index were obtained during low-water periods at almost all the stations, with a maximum value of 0.93 recorded at the Beablo station. The Pk15 station obtained the lowest equitability index value during low-water periods, with a value of 0.62. The Mann-Whitney test showed no significant difference in these indices between the hydrological seasons at each station ($p > 0.05$).

Discussion

The cameras installed at the sampling stations enabled 18 species of fish to be observed in the littoral zone of Lake Buyo. This result is probably linked to the sampling method, which has the advantage of attracting fish present in the environment into the cameras' field of view. Indeed, Willis *et al.* (2000) and Zarco-Perello and Susana (2019) reported that the use of baited cameras in aquatic environments increases the number of species and individuals near the cameras. This specific richness is in agreement with that obtained by N'Dri (2020), who identified 17 species of fish in this same environment using extractive methods, combining day fishing and night fishing. However, certain species such as *Brycinus macrolepidotus* and *Enteromius sublineatus* observed with video surveillance do not appear on the list of species obtained by N'Dri (2020). This could be explained by the fact that some fish species that avoid extractive fishing gear are observed using video surveillance (Cappo *et al.*, 2006). This is the case, for example, of the studies carried out by Stoner *et al.* (2007) in two bays located in Alaska recorded various flatfish from video surveillance but these were absent in captures made with extractive fishing gear.

Qualitative analysis of the fish population revealed that the fish population in the littoral zone of Lake Buyo is dominated by the Cichlidae (5 species), Cyprinidae (4 species) and Alestidae (3 species) families. This dominance is probably linked to the ability of representatives of these families to withstand a wide range of environmental conditions (Lévêque and Paugy, 2006). In fact, these families have a very varied diet and develop a great capacity for behavioural adaptation in certain types of habitat where food is present (Lévêque and Agnèse, 2006). The composition of the ichthyofauna in the littoral zone of Lake Buyo is similar to that observed in African lakes of the same type, such as Ihéma (Rwanda), Tiga (Nigeria), Georges (Uganda) and Toho-todougba (Benin), where these families are important components of the ichthyofauna (Gwahaba, 1975; Plisnier *et al.*, 1988; Adite and Winemiller, 1997; Balogun, 2005). Fish species richness and abundance do not vary between stations. This shows that the littoral zone of Lake Buyo is relatively stable and is capable of providing sufficient food, shelter and breeding sites for riparian fish species. However, significant variations in fish species richness and abundance were observed at all stations, depending on the hydrological season. This could be explained by the variation in hydrological conditions in Lake Buyo following the construction of a second dam (the Soubré dam) on the Sassandra River (Anderson *et al.*, 2021). Among the rivers of Côte d'Ivoire, the Sassandra River has undergone two developments, leading to the creation of the Buyo and Soubré dam lakes. The species richness and abundance of the fish fauna are greater during periods of high water than during low water. This result could be explained by the hydrological variability of this environment, which has major consequences for the biology of species and the dynamics of fish populations (Lévêque and Paugy, 2006). Indeed, rising water supplies the ecosystem with food resources, stimulates spawning behaviour and generates refuges for fish during key phases of the biological cycle (Reid and Sydenham, 1979). On the other hand, abrupt water withdrawal leads to a loss of habitat and food. Similar results were noted in Lake Hlan in Benin by Montchowui *et al.* (2008) and in Lake Buyo by N'Dri (2020). These authors used extractive fishing gear to collect data.

The present study indicates that *Enteromius macrops* (33.46 %) is the most abundant species, followed by *Coptodon zillii* (22.56 %), *Brycinus macrolepidotus* (13.95 %), *Brycinus longipinnis* (13.51 %) and *Oreochromis niloticus* (7.63%). This trend could be explained by the fact that the *Enteromius macrops* species, being small in size, could easily escape extractive fishing gear. The population structure obtained in the present study is quite different from that observed by N'Dri (2020) in the same Buyo lake, who obtained a proportion of 26.87 % for *Coptodon zillii*, compared with 13 % for *Enteromius macrops*. The organisation of the fish population in the littoral zone of Lake Buyo was analysed using the Shannon and equitability indices. The values of the Shannon index (H') indicate that the environment is more diversified during the high-water seasons and well balanced during the low-water seasons.

Conclusion

A study of the fish population using the video surveillance method identified 18 species of fish divided into 13 genera, 9 families and 7 orders at all the stations identified. The Cichlidae (5 species), Cyprinidae (4 species) and Alestidae (3 species) are the most diverse families. Five species (*Enteromius macrops*, *Coptodon zillii*, *Brycinus longipinnis*, *Brycinus macrolepidotus* and *Brycinus* sp.) are constant in the coastal habitats of Lake Buyo. The quantitative study shows that the Cyprinidae, Cichlidae and Alestidae families are the most abundant. In terms of species, *Enteromius macrops* and *Coptodon zillii* dominate. The drop in water level had a major impact on the diversity and abundance of fish at all the sampling stations. The fish population is more diverse and stable during high-water seasons than during low-water seasons. Video surveillance is therefore a non-destructive method that has made it possible to carry out a qualitative and quantitative inventory of fish communities while preserving them in their environment. This method makes it possible to obtain a representative sample of fish populations in coastal areas. In addition, the videos obtained are permanent recordings, enabling future comparative analyses and can be used for public awareness campaigns.

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