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Diversity, Length-weight structure and Condition Factor of fish species and physicochemical changes in four reservoirs in Volta basin, Burkina Faso

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ABSTRACT

The human activities combined to global warming negatively impact aquatic ecosystems mainly in the areas with high human density. This study was undertaken to determine fish diversity and environmental parameters in four reservoirs in Volta basin of Burkina Faso. To do so, from May to June 2020 were collected and identified as species, and the physicochemical variables measured. Thirty (30) fish species were identified in these reservoirs during the research and 601 individuals of three Cichlids species (*Sarotherodon galilaeus, Oreochromis niloticus* and *Coptodon zillii*) were measured for total length and weight. Samendéni reservoir shows the betted physico-chemical conditions: a high value of Transparency (>165 cm) and a low value of Nitrate (0 mg.L-1). By contrast, the other sites like Koubri_AB seem to be influenced mostly by anthropogenic pressures; therefore they show a low value of Transparency (< 15 cm) and a high concentration for Nitrate (8.7 mg.L^{-1}), characterizing the presence of human activities. The allometric results of growth, except for the *Coptodon zillii*, globally show that b values reach up around to 3. A total of 30 fish species were encountered in this basin during this study with specific richness of 18±1 per site.

Keywords: Ichthyofauna, condition factor, reservoir, Volta River, Burkina Faso.

INTRODUCTION

Developing countries such as Burkina Faso are experiencing difficulties in satisfying demand requirements for animal proteins because of poverty and population increase. However, fish turned out a cheaper source of protein contributing to about 18 - 22% source of animal protein (Imtiaz, 2016). A use of fish resources could therefore help to alleviate malnutrition linked to the lack of animal protein. This fact requires a better knowledge of the resource i.e. the existing stocks and the problems facing this resource.

Fish diversity, Length-Weight (L-W) and condition factor (K) analysis are recognized to be important in fish biology (Ikongbeh et al., 2013; Dan-Kishiya, 2017), in evaluation of the commercial potentialities of

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the fish stocks (Okey et al., 2017), in conservation strategies and as useful tools for fish managers (Anene, 2005). Worldwide, there are many researches already conducted on Length-Weight structure and concerning many fish species. At local level, little attention has been devoted to carry out on fish L-W structure specially on cichlids (Da et al., 2018; Minoungou et al., 2020). This relationship is dependent on ecological conditions which could influence positively or negatively on the size and the weight of fish. Human activities such as overfishing and pollution are recognized to affect fish communities negatively by reducing their diversity, quantity and ecological structure (Adaka et al., 2015; Silga et al., 2021).

How do physico-chemical variables influence the development of fish and particularly, cichlids? There are hardly any relevant studies on a national scale on this topic. However; 10 species of the Cichlidae family have been identified in Burkina Faso, these include *Oreochromis niloticus, Sarotherodon galilaeus, Coptodon zillii, Coptodon dageti, Oreochromis aureus, Chromidotilapia güntheri, Hemichromis bimaculatus, Hemichromis fasciatus, Hemichromis letourneuxi* and *Paragobiocichla irvinei*. The first three are the most abundant and the most used in aquaculture (Meulenbroek et al., 2019). This study analyzed the influence of physico-chemical parameters on the fish community of the Volta basin reservoirs in Burkina Faso, to fill the information gap on the effect of environmental variables on fish morphology. Specifically, it aimed at (i) determining the fish species composition in four reservoirs in the Volta Basin, (ii) analyzing the Length-weight relationship of three common species and (iii) determining the main environmental variables that could explain Cichlidae morphometric structure.

MATERIALS AND METHODS

Study sites

Samplings were carried out in four reservoirs (Koubri_AB, Bazèga, Loumbila and Samendéni) belonging to two basins (Mouhoun and Nakanbe) of Volta basin (Figure 1). Koubri_AB, Bazèga and Loumbila, Samendéni are characterized mainly by important human activities as overfishing and pollution, the last one for its wide extension and the recently development of its fisheries (Melcher et al., 2012; Silga et al., 2021).

Data collection

Fish were collected by local fishermen using artisanal gears such as castnets, gillnets and traps. The taxonomic identity of each species and taxonomic list was corroborated by specialized taxonomic keys (Paugy et al., 2003; Van der Laan et al., 2021). The specific composition of catches was determined per site. All Cichlid fish species were counted and each of them were weighed to the gram (g) using an electronic weighing balance. Electronic caliper (0.01 mm) were used for morphological measurements (total length, TL) in with specific fish measuring ruler. These Cichlids species were chosen for morphometric measure because of their availability in the most reservoirs, food importance and local trade in the region. The relation between fish Length and its weight was determined using the allometric formula by Richer (1973) below:

$W = a.L^b$, where W is total body weight (g), L (cm) represents the Total Length. The variables “a” and “b” represent the coefficients of functional regression between weight and length. Fish condition factor (K) was also determined by formula: $K = 100\frac{W}{L^3}$.

In addition, for each site, physico-chemical variables were also measured. Indeed, physico-chemical variables such as temperature, transparency, total dissolved solid are likely to influence the metabolisms of organisms or affect their diet. Parameters such as temperature, pH, transparency, Electrical Conductivity (EC) and Total Dissolved Solid (Tds) were measured *in situ* with a multi-parameter type HANNA. Alkalinity, nitrate, ammonium and total iron were determined for every sampling at the laboratory by chemical method using spectrophotometer Aquamate 8000.

Data analysis

After sampling, data were grouped per sites. Statistical analyses were carried out using R software version 4.0.2 (R Core Team. 2021; R Studio Team. 2021). Principal Component Analysis (PCA) and Venn diagram boxplots are realized. The PCA was used to determine the main variables contributing to characterize sampling sites. To do that, the data were previously centered reduced because of the difference in the units of measurement of the different variables studied as well as the difference in their order of magnitude. The Venn diagram was made to show the relationship of diversity between sites, such as the number of species common to the different reservoirs and the differences. To show the weight structure of Cichlids, boxplots were also made with statistical test of comparison using pairwise comparison test of Wilcoxon test with p adjust method of Bonferroni to $p = 10^{-4}$.

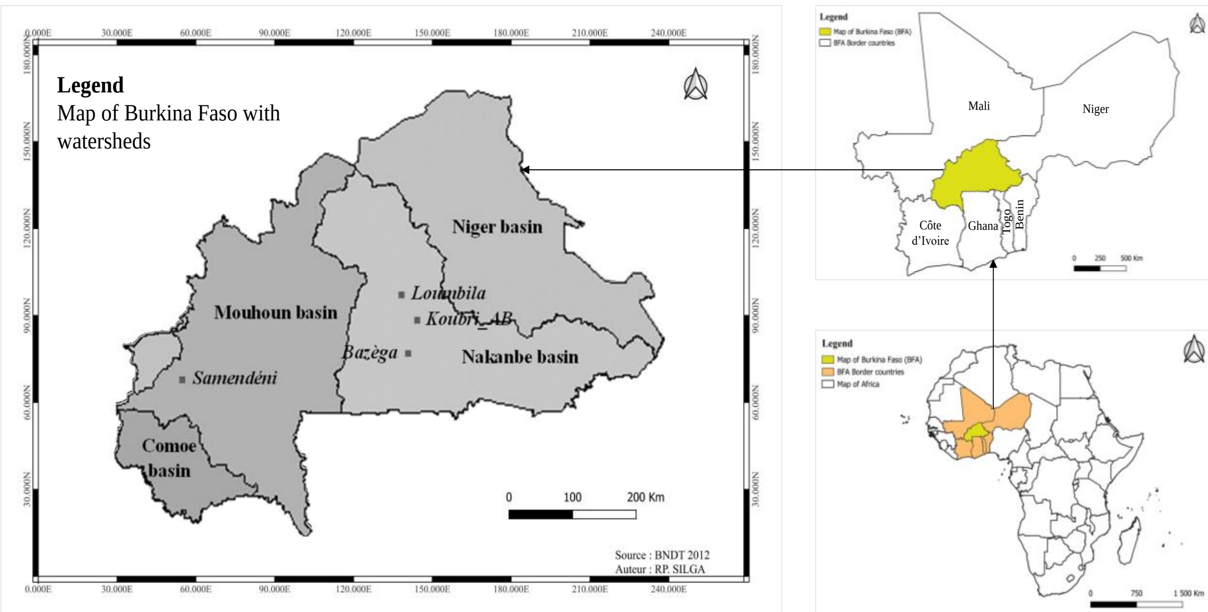

Figure 1: Sampling stations (gray squares) in Mouhoun and Nakanbe basins, Burkina Faso.

RESULTS

Environmental variables characteristics per site

The main characteristics of environmental variables are summarized in the Table 1. Spatial variations of pH and Transparency showed the highest value in the sampling site of Samendéni. This site also recorded the lowest value of Total iron and Nitrate (0 $mg.L^{-1}$ each one). At the same time, Koubri_AB site recorded the highest value of Alkalinity (22.26 $mg.L^{-1}$), TDS (67 $mg.L^{-1}$), electrical conductivity (135 $\mu S.cm^{-1}$) and Nitrate (8.7 $mg.L^{-1}$). Bazega and Loumbila present globally medium value for these parameters.

Samendéni and Koubri_AB reservoirs have the highest value of total dissolved solids (Tds) and alkalinity (alc) which are opposed to sites of Loumbila and Bazega. The PCA focused on environmental variables indicated that the two axes explain 88.4% of information. This is good enough to have a precision in the interpretation. The variables taken into account were electrical conductivity, Transparency, temperature, Total dissolved solids, nitrates and total iron. The results of this analysis are shown in Figure 2. Dimension 1 is characterized by Transparency and nitrates while dimension 2 is mainly characterized by temperature, alkalinity and electrical conductivity. On the one hand, we note that temperature is opposed to Total dissolved solids and electrical conductivity, and on the other hand, Transparency is opposed to iron and nitrate.

Fish diversity

During this study, 30 fish species were identified belonging to 27 genera and 14 families. Maximum number (19) of species was counted in Bazega and Loumbila and minimum of 17 species for Koubri_AB and Samendéni (Table 2). Among them, six species composed by *Brycinus nurse, Clarias anguillaris*, *Coptodon zillii*, *Oreochromis niloticus*, *Mormyrus rume* and *Sarotherodon galilaeus* were present in all sites (Figure 3).

Cichlids weight structure

Three cichlids species were selected because of their relative abundance for the analysis. The number of specimens for each species, the weight structure and p-value of the pairwise comparison of species weight in function of site were presented in the Figure 4. A total of 601 specimens of fish were recorded for L-W analysis. The most abundant species is *Oreochromis niloticus* with 314 specimens. *Coptodon zillii* and *Sarotherodon galilaeus* with respectively one hundred and thirty-two (132) and one hundred and fifty-five (155). Highest weight of 274g, 327g and 597g were recorded respectively for *Coptodon zillii* and *Sarotherodon galilaeus* in Samendéni, *Oreochromis niloticus* in Bazèga. For the other common species, Samendéni recorded the highest average weight value followed by Loumbila.

Cichlids Length-weight parameters (LWP) and condition factor (K)

The LWP of cichlids species in the study sites are presented in Table 3. The value of R^2 coefficient were higher than 0.9 except those of *Oreochromis niloticus* in the Samandeni reservoir which registered R^2=0.86. The condition factor K varied between 1.56 and 2.09 respectively for *Coptodon zillii* in Loumbila and *Sarotherodon galilaeus* in Koubri_AB. In Koubri_AB, all fish species present negative allometric growth with ($b < 3$). However, in Loumbila it is positive ($b > 3$). In Bazèga and Samendéni, except *Coptodon zillii*, the two other species also present a positive allometric growth.

Table 1: Summary of the water quality data at different sites.

Parameters	Koubri_AB	Bazega	Loumbila	Samendéni
Alkalinity (mg.L^{-1})	22.26±1.8	10.31±1.2	21.19±0.9	18.54±1.1
pH	7.71±0.37	8.04±0.42	7.75±0.27	8.26±0.13
Temperature (°C)	30.33±0.21	32.51±0.15	30.02±0.18	30.48±0.12
TDS (mg.L^{-1})	67±3.12	34.5±2.18	47±1.9	58±1.3
Transparency (cm)	15±1.4	26.5±1.3	17±1.1	165±2.5
EC (µS.cm^{-1})	135±3.7	68±2.1	93.5±2.5	120±3.5
Total iron (mg.L^{-1})	0.51±0.1	1.82±0.12	2.18±0.07	0±0
Nitrate (mg.L^{-1})	8.70±0.7	3.60±0.3	3.9±0.41	0±0

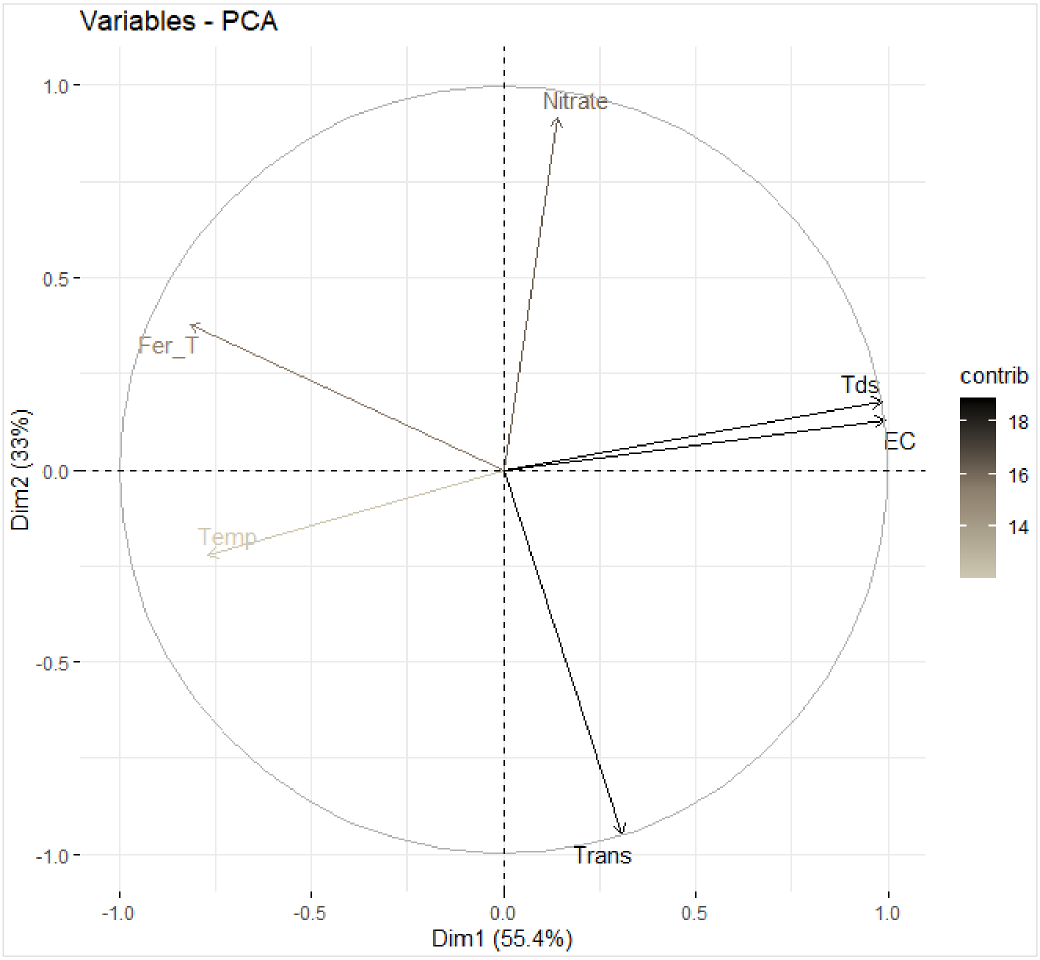

Figure 2: Correlation circle of physicochemical variables derived from PCA.
Legend: EC. Electrical conductivity; Temp. Temperature; Tds. Total dissolved solids; Trans. Transparency; Fer_T. Total Iron; Contrib: represents the contributions (%) of the variables to the principal components.

Table 2 : Systematic list of ichthyofauna and frequency of occurrence at sampling sites.

Order/ Families	Species	Koubri_AB	Bazega	Loumbila	Samandeni
Characiformes Alestidae	*Brycinus nurse* (Rüppel 1832)	*	*	*	*
	Micralestes occidentalis (Günther 1899)		*	*	
Osteoglossiformes Arapaimidae	*Heterotis niloticus* (Cuvier 1829)			*	*
Siluriformes Bagridae	*Bagrus bajad* (Forsskal 1775)		*		*
Cichliformes Cichlidae	*Chromidotilapia güntheri* (Sauvage 1882)				*
	Coptodon zillii (Gervais 1848)	*	*	*	*
	Hemichromis bimaculatus Gill 1862	*	*	*	
	Hemichromis fasciatus Peters 1857		*		*
	Oreochromis niloticus (Linnaeus 1758)	*	*	*	*
	Sarotherodon galilaeus (Linnaeus 1758)	*	*	*	*
	Paragobiocichla irvinei (Trewavas 1943)	*			
Siluriformes Clariidae	*Clarias anguillaris* (Linnaeus 1758)	*	*	*	*
Siluriformes Claroteidae	*Auchenoglanis occidentalis* (Valenciennes 1840)			*	*
	Chrysichthys auratus (Geoffroy St. Hilaire 1809)				*
	Chrysichthys nigrodigitatus (Lacepède1803)	*			*
Cypriniformes Cyprinidae	*Chelaethiops bibie* (Joannis 1835)	*		*	*
	Enteromius leonensis (Boulenger 1915)			*	
	Enteromius macrops (Boulenger 1911)	*	*	*	
	Leptocypris niloticus (Joannis 1835)	*			
Carangiformes Latidae	*Lates niloticus* (Linnaeus 1758)			*	*
Siluriformes Malapteruridae	*Malapterurus electricus* (Gmelin 1789)		*		
Siluriformes Mochokidae	*Synodontis schall* (Bloch & Schneider 1801)	*	*	*	
Osteoglossiformes Mormyridae	*Brevimyrus niger* (Günther 1866)	*	*	*	
	Hyperopisus bebe (Lacepède 1803)		*		*
	Mormyrus rume Valenciennes 1847	*	*	*	*
	Marcusenius senegalensis (Steindachner, 1870)	*	*	*	
	Pollimyrus isidori (Valenciennes 1847)	*	*	*	
Polypteriformes Polypteridae	*Polypterus senegalus* Cuvier 1829	*	*		
Siluriformes Schilbeidae	*Schilbe intermedius* Rüppell 1832		*	*	
Tetraodontiformes Tetraodontidae	*Tetraodon lineatus* Linnaeus 1758				*

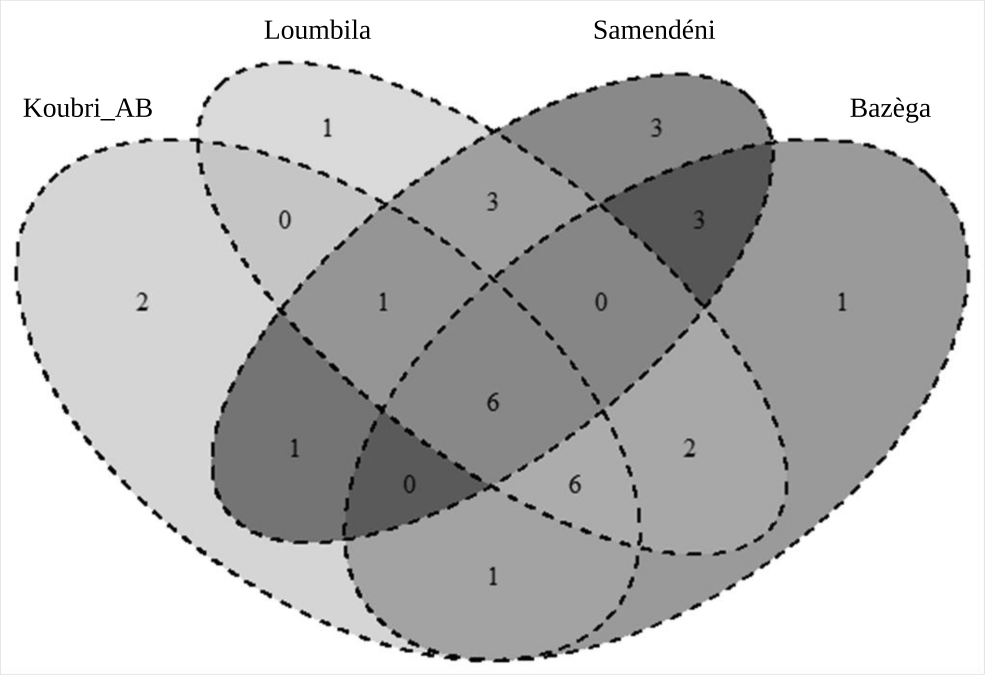

Figure 3: Venn diagram showing fish diversity per reservoirs.
Legend: Koubri_AB. Koubri Arzoum Baongo.

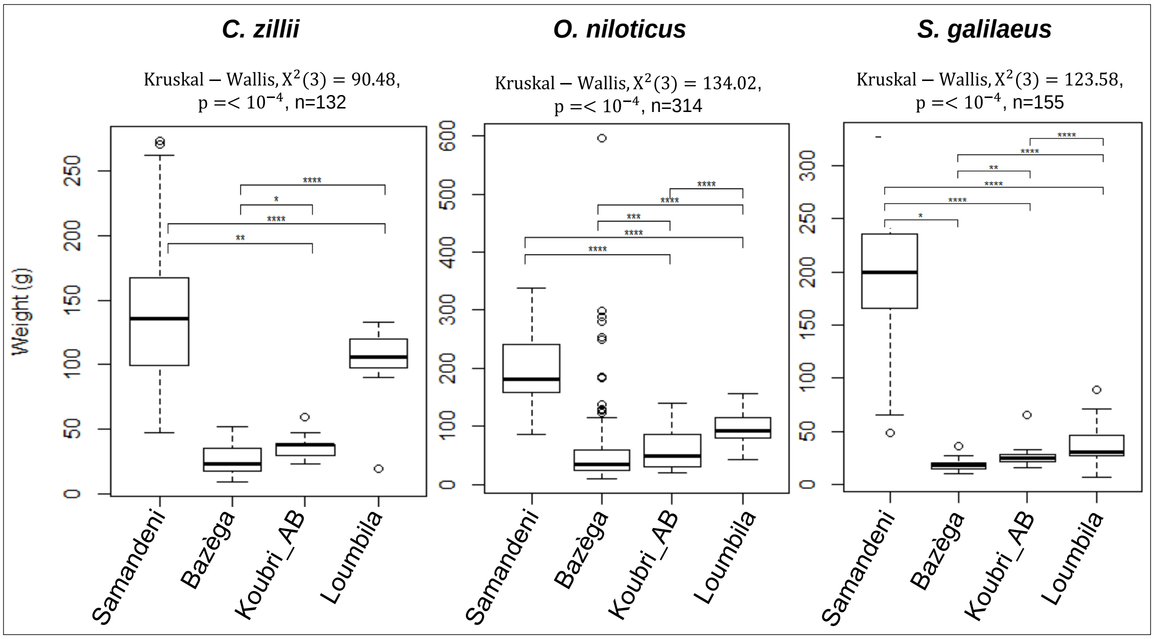

Figure 4: Boxplots showing fish weight variations per site.
Legend: Koubri_AB. Koubri Arzoum Baongo.

Table 3: Summary of fish Growth parameters.

Species / Sites	***Coptodon zillii***			***Oreochromis niloticus***			***Sarotherodon galilaeus***		
	K	b	R^2	K	b	R^2	K	b	R^2
Koubri_AB	1.92±0.15	2.47	0.91	2.04±0.17	2.89	0.98	2.09±0.09	2.85	0.98
Bazega	1.84±0.17	2.72	0.96	1.98±0.22	**3.08**	0.97	1.88±0.14	**3.02**	0.92
Loumbila	1.56±0.08	**3.18**	0.99	1.71±0.1	**3.2**	0.95	1.64±0.22	**3.16**	0.94
Samandeni	1.68±0.18	2.85	0.94	1.81±0.19	**3.03**	0.86	1.86±0.17	**3.15**	0.93
Mean value	1.75±0.58	2.81	0.95	1.89±0.68	**3.05**	0.94	1.87±0.62	**3.05**	0.94

DISCUSSION

The waters of the reservoirs are characterized by low amplitudes of physico-chemical variables, warm temperatures, basic pH, low conductivity and transparency (Bancé et al., 2021b). Sites with high anthropic (agricultural) pressure are characterized by high levels of nutrients such as nitrates, alkalinity and conductivity (Koubri_AB and Loumbila). Overall, these parameters are justified by anthropogenic pressures (Meulenbroek et al., 2019) and climatic conditions (Meybeck & Helmer, 1989) that degrade aquatic ecosystems (Ahmad et al., 2020). For parameters such as alkalinity; geology, soil type may be more determining (Meybeck & Helmer, 1989). The major source of nitrate in the reservoirs can be attributed to the anthropogenic activities as agriculture or the oxidative reactions of ammoniacal nitrogen and nitrites (Zinsou et al., 2016).

Previous studies have already shown the presence of some activities like agriculture, irrigation, gold panning and water pumping nearby the reservoirs (Manful & Opoku-ankomah, 2021; Silga et al., 2021). The consequence of this rate of nitrate could be the increase in algal blooms characterized by eutrophication of the reservoirs (Silga et al., 2022). Transparency is the condition depending on the presence or absence of suspended solids in the water, including wastes, sewage and planktons (Bancé et al., 2021b). The low transparency values in the reservoirs (excepted Samendéni) could be attributed to sediments and sewage loads from nearby areas (Roy et al., 2021). The mean value of temperature is 31±1 °C. These values are all higher than 25°C and similar to those obtained by Pramanik et al. (2020) and should be better for fish growth as indicated by Abou et al. (2010). The mean value of nitrate obtained in this study is similar to those of Dèdjiho et al. (2013) in Lake Aheme (Benin).

The knowledge of these parameters is essential to understand the structure and dynamic of fish. Imam et al. (2010) demonstrated the influence of these variables in fish migration and their distribution. Some environmental parameters by governing the physiology, biology and ecology of fishes determine the catch composition (Cochrane et al., 2009; Imam et al., 2010).

In the Burkina Faso context, low dissolved salt levels are characteristic of organic pollution (Meulenbroek et al., 2019). However, some variables such as total suspended solids, total phosphorus, can induce both direct and indirect sublethal stresses on fish (Kjelland et al., 2015). Other authors have also shown that high suspended solids concentration can have adverse effects on fish in the short or long term such as reduced survival (Kim et al., 2020). Transparency greatly influences the predatory ability of sight-hunting predatory species (Ecoutin & Albaret, 2003). Thus better transparency will increase the probability of capture of predators such as *Hydrocynus forskahlii*, *Coptodon zillii*, *Lates niloticus* and *Clarias anguillaris*.

During this study, 30 species were encountered in the Volta River basin. The species recorded account for around 30% of the total species richness in Burkina Faso. In the same watershed, Mano et al. (2019) recorded 79 species. In comparison to this study two additional and rare species were encountered; *Tetraodon lineatus* and *Paragobiocichla irvinei*. This shows that the identification of catches from fishermen can also be an important technique for taking stock of fish biodiversity.

The most diverse families were Cichlidae (7 species), Mormyridae (5 species), Cyprinidae (4 species) and Claroteidae (3 species). Alestidae was represented by two species (*Brycinus nurse* and *Micralestes occidentalis*). The remaining families were monospecific. In comparison, for Mano et al. (2019) the most diverse families were Alestidae (14), Cyprinidae (12), Mormyridae (12), Mochokidae (9) and Cichlidae (6). The difference of results could be explained by the number of sites sampling, the period and duration of sampling.

In terms of abundance, the ichthyofauna of the water bodies is strongly dominated by species of the Cichlidae family, of which the species *Sarotherodon galilaeus* constitutes 32% of the captures. This dominance can be explained in the context of Burkina Faso by the construction of dams. Indeed, the transformation of the lotic environment into a lentic environment is considered favorable to the Cichlidae and unfavorable to some species such as the Mormyridae. A predominance of Cichlidae and Mormyridae has been noted in neighboring countries such as Benin and Côte d'Ivoire (Achoh et al., 2018; Yao et al., 2019b). Similarly, the abundance of *Oreochromis niloticus* can be explained by its ability to adapt even when ecological conditions become unfavorable (Amoussou et al., 2016). These results are similar to those obtained by Ouedraogo et al. (2015) in Boalin reservoir and Adou et al. (2017) in Lac Ayame 2 (Ivory Coast).

The average weight of the sampled fish varied significantly between sites. The weight varied between 8 g and 597 g. Many of the specimens encountered have an average weight of about 80 to 100 g. These relatively low morphological variables observed are an indication of overexploitation of the fish studied and of the degradation of ecological conditions (Ecoutin & Albaret, 2003). These low catch weight also indicate non-compliance with the regulations concerning the size of the mesh of the nets. At these sizes several species have not yet reached their first maturity size (Gnoumou et al., 2018). Indeed, with overfishing, fishes do not reach their maturity stage and are caught which hinders recruitment and threatens the survival of fisheries.

The high values of the coefficient of determination R^2 of the length-weight relationships of the three Cichlidae (*O. niloticus, S. galilaeus* and *C. zillii*) indicate good quality of the measurements and a strong relationship between the two parameters. Strong relationships have also been reported on fishes from Benin (Lederoun et al., 2016) and on other sites and species in Burkina Faso (Sirima et al., 2009; Da et al., 2018; Minoungou et al., 2020).

The allometric values “b” of Cichlids varied between 2.81 for *C. zillii* to 3.05 for *O. niloticus* and *S. galilaeus*. This range of b-value in our study is similar to the values (2.17-3.47) recorded by Tah et al. (2012) and Ouedraogo et al. (2015) but in terms of growth trend of species, it is opposite. They revealed a negative allometric for *O. niloticus* and *S. galilaeus* and positive allometric for *C. zillii* which is opposed to our results, we obtained negative allometric for *C. zillii* and isometric for the two others. The state of isometric growth for *O. niloticus* and *S. galilaeus* means that species grow equally in terms of length and weight (Fazli & Moghim, 2014). But considering per site, all three species of Loumbila present a positive allometric growth (b>3). However, this range of b-value is in accordance with the range of values of this biometric variable usually recorded in fish between 2.5 and 3.5 as shown by Froese (2006).

Otherwise, the b-value of *S. galilaeus* in this study is more greater than those (b=2.27) of Famoofo & Abdul (2020). What's more, considering species by species, b-value of *C. zillii* is lowest than those of *O. niloticus* and *S. galilaeus*. In fact, all *C. zillii* specimen have b-value inferior to 3 except those of Loumbila. This means that these specimen do not grow but are tapered (Yao et al., 2019a). This fact could also be explained by the lowest number of *C. zillii* comparatively to the others species in all sites. In fact, it is demonstrated that b-value lowest than 2.5 could be generated by low sample size (Zhu et al., 2014). The variability of b-value from site to other and from species to another one could be explained by sample size and range (Ecoutin & Albaret, 2003), water quality or state of fish infection by parasite (Ngueguim et al., 2020).

Overall, the minority allometry is predominantly observed in Cichlidae almost everywhere. This indicates a faster growth in length than in mass of the studied specimens. This may be evidence of overexploitation of the resource and scarcity or inaccessibility of nutrient resources (Ouedraogo et al., 2019) as well as habitat degradation (Tchouante et al., 2019). Nevertheless, the type of allometry varies by site and species. Bazèga, Loumbila, and Samendéni, which have the most major allometry, may therefore have better conditions for the species concerned. The better conditions of Samendéni are related to the youth of its fishery (Minoungou et al., 2020; Bancé et al., 2021).

The K-value of all species is greater than "1" and similar to those obtained on Cyprinids by other authors (Pervin & Golam, 2008). However, these values are lower than those obtained by Fousseni et al. (2017) with other species of the same family. The mean values of the condition coefficient K suggest a better condition of *S. galilaeus* and *O. niloticus* compared to that of *C. zillii*. This confirms that these two species are resilient to the pressures at the various sites. In all cases, approximately equal values of K are noted for *O. niloticus* and *S. galilaeus*. This resemblance would be due to a similarity of pressures and ecological conditions. From the analysis of this factor, all species taken together, it appears that the specimens of Arzoum Baongo have a better body weight. This observation coincides with the fact that the Arzoum Baongo reservoir presents the best physico-chemical conditions. Indeed, it has the best conductivity and dissolved salt levels, with low levels of nitrogen in toxic form (nitrite and ammonium), but the presence of assimilable forms of nitrogen (nitrates).

Conclusion

Fish diversity of our study sites contribute to 30% of fish species in Burkina Faso. Their assemblages have no statistical difference between the study areas. However, it still remains a significant difference among some physicochemical variables. It would be interesting to continue sampling over a long period in order to demonstrate the correlation between the diversity of fish and the physicochemical variables of the reservoirs' waters.

COMPETING INTERESTS

The authors declare that they have no competing interests.

AUTHORS' CONTRIBUTIONS

RPS: collected the data, conceived, designed the analysis and wrote the paper; AO:

conceived and performed the analysis; KM: collected the data; VB: collected the data; GBK: Chief of Laboratoire de Biologie et Ecologie Animales (LBEA) when data were collected.

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