

Fish Diversity, Length-Weight Relationship and Condition Factor in the Boussouma and Nabadogo Reservoirs in Burkina Faso

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Abstract

This study was conducted in the Boussouma and Nabadogo reservoirs, located in the Kadiogo and Nando regions of Burkina Faso, respectively, to determine the diversity and ecology of the fish in these two areas. Fish were collected only during the dry season, between November and December 2023, using cast nets (5, 10, and 15 mm mesh), gillnets (5, 10, 15, and 20 mm mesh size), and No. 13 longlines. Species were identified, and each fish was weighed and measured. Species richness, three diversity indices such as Shannon-Weaver, Pielou's Equitability, and the Simpson index, the length-weight relationship, and the condition factor were assessed. A total of 29 fish species belonging to 12 families were identified in the two reservoirs studied, with 24 species in Boussouma reservoir and 15 in Nabadogo reservoir. The fish fauna of the two reservoirs was not very diverse ($H' = 1.7$ and 1.5). Most species showed isometric growth ($b = 3$). *Sarotherodon galilaeus* showed the best body condition at both Boussouma (3.15 ± 2.38) and Nabadogo (7.60 ± 1.80) reservoirs. The results of this study will serve as indicators for the management of these two reservoirs.

Keywords

Fish, Diversity, Growth, Reservoirs, Burkina Faso

1. Introduction

African aquatic systems are a resource of great ecological, scientific, and economic value [1] [2]. However, they are affected by the development of anthropogenic

activities such as the construction of dams, deforestation, irrigation, overfishing, water withdrawal, sand exploitation, and various forms of pollution [3] [4]. Thus, there is an urgent need to take conservation and rational exploitation measures. However, a good knowledge of species and the relationships that link them to their environment is essential for effective management and conservation measures for aquatic ecosystems [1].

In aquatic ecosystems, fish are the best-known organisms because of their size, abundance, and biodiversity. In addition, they are an important source of animal protein in the diet because they are rich in essential micronutrients (iron, iodine, zinc, calcium, vitamin A, vitamin B) and polyunsaturated fatty acids, which are necessary for optimal brain development and proper body function [5]. The state of fish populations is one of the quality elements for assessing the ecological status of watercourses. In addition to the physico-chemical quality of the water, fish are sensitive to the hydrological regime and the physical state of watercourses [6]. So, the list of species and their respective abundance in a given environment are excellent indicators of how degraded it is [7].

In Burkina Faso, several studies have been conducted on the diversity of fish fauna such as that of the Comoé basin [8], the Sahelian lake of Higa [3], the Boalin reservoir [9] and the Samandeni reservoir [10] [11]. However, no study has been conducted on the Nabadogo reservoir. As far as the Boussouma reservoir is concerned, the last one dates back more than a decade and was carried out by [12] and [13]. It therefore seems necessary to take stock of the fish fauna in these two reservoirs in order to establish a reference situation and update the data in the Nabadogo reservoir and in the Boussouma reservoir. The aims of this study are to increase our understanding of the diversity, biology, and ecology of the fish fauna in the Boussouma and Nabadogo reservoirs.

2. Material and Method

2.1. Study Sites

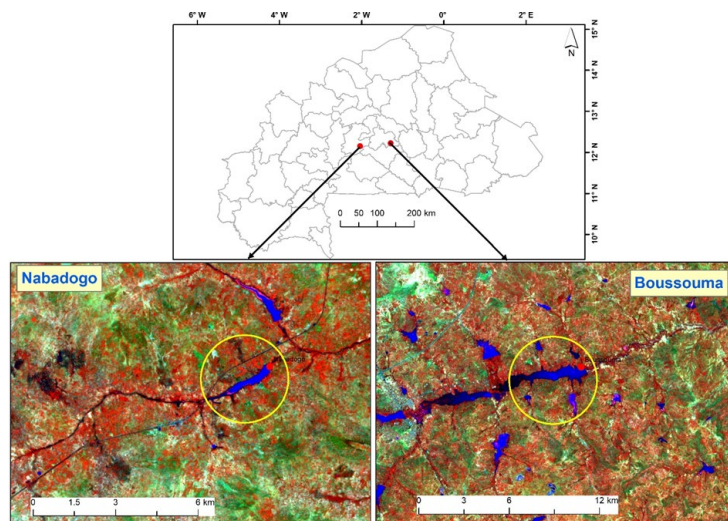


Figure 1. Location of study areas.

This study was carried out in the Boussouma and Nabadogo reservoirs (**Figure 1**). Nabadogo is located in the Nando region, at 11°58'0" north latitude and 1°28'0" west longitude, about 70 km from the capital, Ouagadougou. It was created in 1986 with a capacity of 562,602 m³ [14]. As for Boussouma (12°54'35" N and 1°4'58" W), it is located in the rural commune of Koubri in the Kadiogo region. It was created in 1987 with a capacity of 4,426,780 m³ [14]. Both reservoirs benefit from a Sudano-Sahelian climate, determined by a tropical climate with two main seasons: i) a rainy season from May to October marked by humid monsoon winds and ii) a longer dry season from November to April dominated by harmattan winds. The average annual temperatures are between 17°C and 36°C, *i.e.*, a temperature range of 19°C. Water levels are rarely higher than 700 mm per year ([15]: pp. 164, 188).

2.2. Fish Sampling

Data collection was performed during the dry season. The fish were sampled from November 22 to 28 in Boussouma and from December 4 to 10, 2023, in Nabadogo, *i.e.*, 7 days of sampling per reservoir. The fish were sampled during experimental fishing using cast nets with mesh sizes of 5, 10, and 15 mm and gill nets with mesh sizes of 5, 10, 15, and 20 mm. We also used longlines for fish sampling. On average, 230 cast net throws were made per day in each reservoir during the sampling period. The gillnets, measuring 100 m in length and 1.5 m in depth, used in this study are multi-filament nets. In the water, the fishermen were moving from downstream to upstream generally by canoe and occasionally on foot (**Figure 2**). The gillnets were set between 4 pm and 5 pm and surveyed the next day between 8 am and 9 am. More than ten nets were used per sampling day and per reservoir. Additionally, we sampled in small water pools upstream and downstream of each reservoir.

All fish caught were sorted and then identified in the field using the West African Freshwater and Brackish Fish Identification Keys of ([16]: pp. 457, 815). Total length and body weight were measured using a millimeter-sized ichthyometer and an electronic scale with a range of 3 kg ± 0.1 kg, respectively.

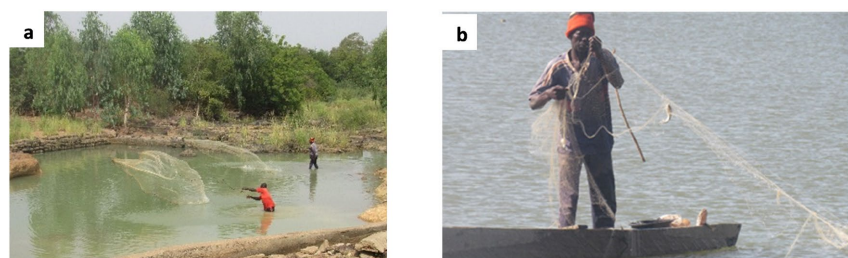


Figure 2. Fishing techniques used to sample fish: throwing cast net (a), gillnet survey (b).

2.3. Data Analysis

The fish population sampled was characterized by various parameters:

- 1) Species richness (Taxa_S) is the number of species recorded in the catches;
- 2) The Shannon-Weaver Diversity Index (H') [17]: it allows diversity to be expressed by taking into account the number of species and the abundance of individuals within each of these species. Thus, a community dominated by a single species will have a lower coefficient than a community in which all species are codominant. The values of this index vary between 0.5 (very low diversity) and 4.5 (in the case of large samples of complex communities) [18]. It is calculated according to the following formula:

$$H' = -\sum_{i=1}^s p_i \ln p_i$$

where i varies from 1 to s (total number of species in the community), p_i is the proportion of individuals of each species, $p_i = n_i/N$, n_i is the number of individuals representing species i , and N is the total number of individuals.

- 3) We calculated the index of evenness of Pielou: $\text{Equitability}_J = H'/\log_2(S)$, where H' is the value of the Shannon index and S is the taxonomic richness (Taxa_S). This index denotes a balance relationship between species and the individual richness of a sample. It ranges between 0 and 1, which expresses the absolute distribution of relative abundance of species [19].

- 4) The value for Simpson's Diversity, sometimes called a Dominance Index, is calculated as $1 - D$, with $D = \sum n_i(n_i - 1) / (N(N - 1))$, where n_i is the total number of individuals of species i and N is the total number of all individuals in the community. The higher the value for this index, the higher the diversity of species.

- 5) We also plotted the rarefaction curve using the method from [20].

- 6) The length-weight relationship is a parameter that allows us to check the growth of the fish population. It is established using formula [21]:

$$P = a * L^b$$

with L = total length in cm; P = body weight in g; A = constant; and b = allometry coefficient.

The parameters a and b are estimated after the logarithmic transformation of the previous power function into a linear function with the formula $\ln P = \ln a + b \ln L$.

The value of b indicates the type of growth of the species under consideration [22].

- If $b = 3$, then there is isometric growth (the growth in weight is equal to that in height);
- If $b > 3$, then the allometry is major or positive. The fish grows faster than it grows;
- If $b < 3$, then the allometry is minor or negative. The fish grows slower than it grows.

- 7) The condition factor makes it possible to assess the state of the fish's overweight. It is useful for understanding the impacts of variations in environmental conditions on species. The condition factor is calculated from the following formula [23]:

$$K = 100 * P / Lt^b$$

where P is the total weight in grams, Lt is the total length in centimeters, and b is the allometry coefficient deduced from the weight-height relationship. The constant b is deduced from the height-weight relationship (the allometry constant).

The statistical analyses (Student's t-test at the 95% threshold) were done in R and PAST software.

3. Results

3.1. Fish Species Relative Frequency per Site

A total of 29 species of fish belonging to 12 families were recorded in all the experimental catches. Specifically, 24 species belonging to 11 families have been recorded in the Boussouma reservoir, while in Nabadogo there are 15 species belonging to 9 families (**Table 1**). The analysis of the fish populations of these reserves has highlighted the existence of 8 families and 10 species common to the two sites. On the other hand, 14 species and 3 families (Anabantidae, Danionidae and Polypteridae) were found only in the Boussouma reservoir, and vice versa for the Nabadogo reservoir, with 5 species and 1 family (Protopteridae). Two species of fish (*Sarotherodon galilaeus*, 51.59% and *Oreochromis niloticus*, 20.31%), all belonging to the Cichlidae family, dominate in Boussouma's catches. As far as the Nabadogo reservoir is concerned, the most represented species are three: *Coptodon zillii* (45.21%) and *Oreochromis niloticus* (17.99%) from the family Cichlidae and *Enteromius macrops* (22.92%) from the family Cyprinidae (**Figure 3**).

Table 1. Assemblage of fish species by study site.

Family (12)	Species (29)	Boussouma		Nabadogo	
		N	FR (%)	N	FR (%)
Alestidae	<i>Brachyalestes nurse</i>	73	4.55	56	1.60
Anabantidae	<i>Ctenopoma kingsleyae</i>	6	0.37	-	-
Cichlidae	<i>Coptodon zillii</i>	96	5.98	1578	45.21
	<i>Oreochromis niloticus</i>	326	20.31	628	17.99
	<i>Sarotherodon galilaeus</i>	828	51.59	13	0.37
	<i>Rubricatochromis bimaculatus</i>	14	0.87	-	-
	<i>Paragobiocichla irvinei</i>	3	0.19	-	-
Clariidae	<i>Clarias anguillaris</i>	28	1.74	63	1.81
Auchenoglanididae	<i>Auchenoglanis occidentalis</i>	-	-	8	0.23
Claroteidae	<i>Chrysichthys nigrodigitatus</i>	8	0.50	-	-
Cyprinidae	<i>Enteromius ablakes</i>	1	0.06	-	-
	<i>Enteromius macrops</i>	14	0.87	800	22.92
	<i>Labeo coubie</i>	-	-	10	0.29

Continued

Danionidae	<i>Chelaethiops bibie</i>	16	1.00	-	-
	<i>Leptocypris niloticus</i>	1	0.06	-	-
Mochokidae	<i>Synodontis membranaceus</i>	2	0.12	-	-
	<i>Synodontis nigrita</i>	3	0.19	-	-
	<i>Synodontis punctifer</i>	5	0.31	-	-
	<i>Synodontis schall</i>	12	0.75	6	0.17
Mormyridae	<i>Hyperopisus bebe</i>	8	0.50	-	-
	<i>Marcusenius senegalensis</i>	21	1.31	4	0.11
	<i>Mormyrus rume</i>	32	1.99	1	0.03
	<i>Pollimyrus isidori</i>	34	2.12	-	-
	<i>Brevimyrus niger</i>	-	-	23	0.66
Polypteridae	<i>Polypterus senegalus</i>	4	0.25	-	-
Protopteridae	<i>Protopterus annectens</i>	-	-	1	0.03
Schilbeidae	<i>Schilbe intermedius</i>	67	4.17	239	6.85
	<i>Schilbe mystus</i>	3	0.19	-	-
	<i>Siluranodon auritus</i>	-	-	60	1.72
Total species		24		15	

Note: N: number of individuals; FR: relative frequency.

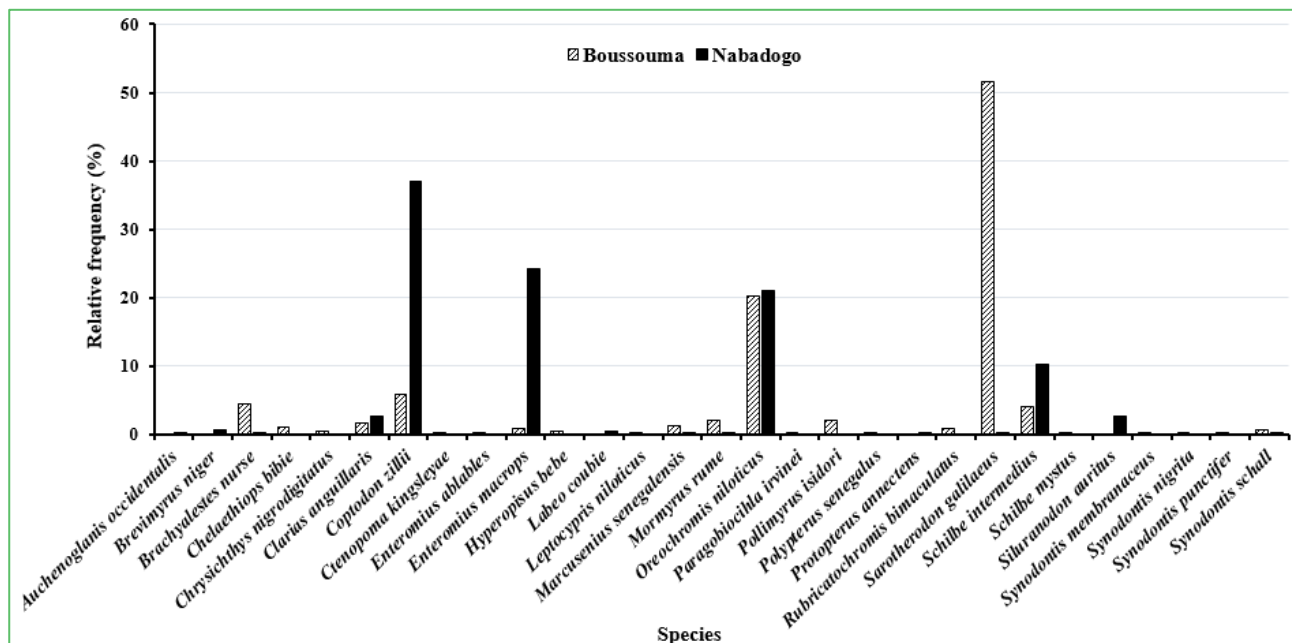


Figure 3. Relative frequency of fish species by reservoir.

3.2. Species Richness and Diversity Index

Diversity indices such as the Shannon-Weaver index, Pielou's evenness, and Simp-

son's dominance, along with their confidence intervals, are summed up in **Table 2**, and the rarefaction curve is illustrated by **Figure 4**. The diversity index such as Shannon-W The Shannon-Weaver diversity index was higher in the Boussouma reservoir ($H' = 1.7$) and lower in the Nabadogo reservoir ($H' = 1.5$). These values indicate that the different reservoirs are not very diverse.

Table 2. Estimate of diversity index by study site.

Sites	Boussouma	Nabadogo
Taxa_S	24	15
Simpson_1-D (95% CI)	0.68 (0.66 - 0.71)	0.75 (0.74 - 0.76)
Shannon_H (95%CI)	1.72 (1.65 - 1.79)	1.57 (1.55 - 1.62)
Equitability_J (95% CI)	0.54 (0.52 - 0.56)	0.59 (0.57 - 0.60)

Note: CI: confidence intervals.

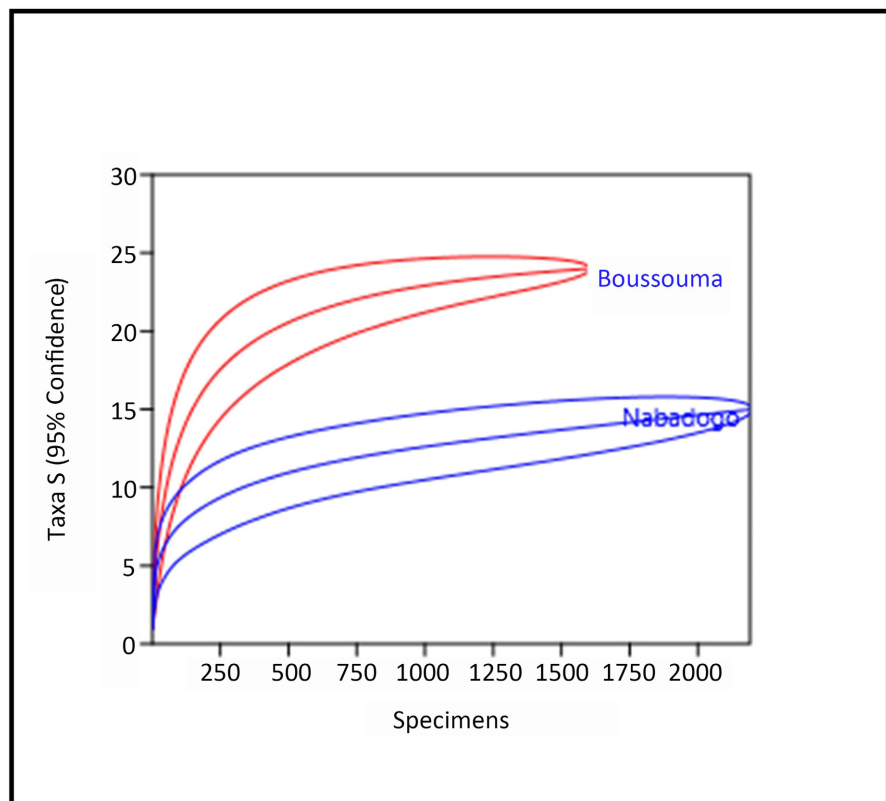


Figure 4. Rarefaction curve of fish species by reservoir.

3.3. Length-Weight Relationship

Descriptive statistics of the seven (7) species common to both reservoirs are presented in **Table 3**. Indeed, three (3) species out of the ten (10) species common to the two reservoirs were excluded from the analyses because of very low numbers (<10 specimens).

Table 3. Descriptive statistics for 7 common fish species of the Boussouma and Nabadogo reservoirs.

Study Site	Species	N	Length (cm)		Weight (g)	
			Min-Max	Mean	Min-Max	Mean
Boussouma	<i>Brachyalestes nurse</i>	73	5.9 - 20.3	13.8	1.6 - 83.7	39.3
	<i>Clarias anguillaris</i>	28	16.1 - 32.3	20.6	23.0 - 183.0	60.1
	<i>Coptodon zillii</i>	96	3.9.0 - 12.7	9.2	1.2 - 37.2	14.8
	<i>Enteromius macrops</i>	14	3.5 - 9.0	6.7	2.2 - 6.1	3.6
	<i>Oreochromis niloticus</i>	326	3.6 - 14.4	8.3	1.0 - 60.0	11.9
	<i>Sarotherodon galilaeus</i>	828	2.4 - 25.0	8.6	0.6 - 76.0	13.7
	<i>Schilbe intermedius</i>	67	5.4 - 15.2	9.1	1.6 - 29.0	5.3
Nabadogo	<i>Brachyalestes nurse</i>	56	6.4 - 14.6	7.7	2.7 - 31.7	5.2
	<i>Clarias anguillaris</i>	63	16.3 - 68.4	24.5	22.5 - 1950.0	132.4
	<i>Coptodon zillii</i>	1578	1.2 - 18.4	8.1	1.2 - 117.8	12.8
	<i>Enteromius macrops</i>	800	4.4 - 8.9	7	0.6 - 27.0	3.5
	<i>Oreochromis niloticus</i>	628	4.1 - 16.9	7.2	0.7 - 88.6	8.9
	<i>Sarotherodon galilaeus</i>	13	5.5 - 17.0	10.3	2.6 - 36.9	17.2
	<i>Schilbe intermedius</i>	239	7.5 - 25.2	15.5	2.8 - 125.8	34.8

Note: Min: minimum; Max: maximum; N: number of specimens.

Statistical analyses (**Table 4**) showed that the allometry coefficient varied between 2.61 (*Enteromius macrops*) and 3.25 (*Brachyalestes nurse*) at Boussouma, compared to 2.30 (*Sarotherodon galilaeus*) and 3.14 (*Schilbe intermedius*) at Nabadogo. In the Boussouma reservoir, one species (*Brachyalestes nurse*) out of the 9 common species showed positive allometric growth ($b > 3$; $p < 0.05$), *i.e.*, they grow faster in weight than they grow in size. As far as the Nabadogo reservoir is concerned, one species, namely *Schilbe intermedius*, showed positive allometric growth ($b > 3$; $p < 0.05$). Negative allometric growth ($b < 3$; $p < 0.05$) was observed in two species in the Boussouma reservoir, while in Nabadogo only one species (*Enteromius macrops*) also showed negative allometry. All other species showed isometric growth ($b \approx 3$; $p > 0.05$).

Table 4. Estimated length-weight relationship parameters for 9 common fish species of the Boussouma and Nabadogo reservoirs.

Study Site	Species	a (CI 95%)	b (CI 95%)	R ²	Student's t	p Value	Growth Type
Boussouma	<i>B. nurse</i>	0.007 (0.004 - 0.009)	3.25 (3.09 - 3.42)	0.956	30.19	3.02E-42	A+
	<i>C. anguillaris</i>	0.007 (0.003 - 0.013)	2.99 (2.74 - 3.23)	0.961	-0.085	0.932	I
	<i>C. zillii</i>	0.018 (0.015 - 0.021)	2.98 (2.91 - 3.06)	0.985	-0.531	0.597	I
	<i>E. macrops</i>	0.020 (0.005 - 0.080)	2.61 (1.90 - 3.33)	0.869	-1.215	0.264	I
	<i>O. niloticus</i>	0.025 (0.022 - 0.029)	2.86 (2.80 - 2.93)	0.958	-4.192	3.50E-05	A-
	<i>S. galilaeus</i>	0.030 (0.027 - 0.034)	2.76 (2.70 - 2.81)	0.918	-8.392	2.07E-16	A-
	<i>S. intermedius</i>	0.012 (0.007 - 0.022)	2.70 (2.42 - 2.97)	0.855	-2.174	0.033	I

Continued

	<i>B. nurse</i>	0.011 (0.008 - 0.016)	2.98 (2.81 - 3.16)	0.956	-0.230	0.82	I
	<i>C. anguillaris</i>	0.009 (0.004 - 0.023)	2.87 (2.59 - 3.14)	0.875	-0.935	0.353	I
	<i>C. zillii</i>	0.019 (0.017 - 0.020)	2.96 (2.92 - 3.00)	0.939	-2.120	0.034	I
Nabadogo	<i>E. macrops</i>	0.016 (0.013 - 0.021)	2.75 (2.61 - 2.89)	0.664	-3.608	0.00033	A-
	<i>O. niloticus</i>	0.018 (0.016 - 0.019)	3.03 (2.99 - 3.08)	0.967	1.35	0.179	I
	<i>S. galilaeus</i>	0.073 (0.014 - 0.380)	2.30 (1.59 - 3.01)	0.823	-2.181	0.052	I
	<i>S. intermedius</i>	0.005 (0.004 - 0.006)	3.14 (3.08 - 3.21)	0.972	4.035	7.38E-05	A+

Note: CI: confidence intervals; A+: positive allometry; A-: negative allometry; I: isometry.

3.4. Condition Factor

The average values of the condition factor are shown in **Table 5**. Analysis of the table shows that 4 fish species were the most overweight in the two reservoirs: Cichlidae (*Sarotherodon galilaeus*, *Oreochromis niloticus*, and *Coptodon zillii*) and *Enteromius macrops*. The best condition factors were noted in *Sarotherodon galilaeus* in both reservoirs (3.15 ± 2.38 at Boussouma and 7.60 ± 1.80 at Nabadogo).

Table 5. Condition factor coefficient obtained for 9 fish species common to both reservoirs.

Study Site	Species	Condition Factor K	
		Mean	SD
Boussouma	<i>Brachyalestes nurse</i>	0.58	0.07
	<i>Clarias anguillaris</i>	0.64	0.07
	<i>Coptodon zillii</i>	1.78	0.15
	<i>Enteromius macrops</i>	1.97	0.19
	<i>Oreochromis niloticus</i>	2.54	0.25
	<i>Sarotherodon galilaeus</i>	3.15	2.38
	<i>Schilbe intermedius</i>	1.22	0.28
Nabadogo	<i>Brachyalestes nurse</i>	1.1	0.1
	<i>Clarias anguillaris</i>	0.98	0.49
	<i>Coptodon zillii</i>	2.96	0.34
	<i>Enteromius macrops</i>	1.67	0.54
	<i>Oreochromis niloticus</i>	1.77	0.21
	<i>Sarotherodon galilaeus</i>	7.6	1.8
	<i>Schilbe intermedius</i>	0.49	0.21

4. Discussion

Twenty-nine (29) fish species belonging to 12 families have been recorded in the two reservoirs, including 24 species from 11 families in the Boussouma reservoir and 15 species from 9 families in Nabadogo. Cichlidae family (*Sarotherodon galilaeus*, *Oreochromis niloticus*, or *Coptodon zillii*) was the most abundant in catches from both reservoirs. This result is consistent with observations made in other parts of the country such as the hippopotamus pond [24], the Higa lake [3] and the Boalin reservoir [9]. The 24 fish species that we recorded contribute less than 60% of the total diversity of the Boussouma sub-catchment compiled by [13]. Although this compilation has to be improved, this suggests that the Boussouma reservoir probably hosts many more species of fish. Actually, the present study took place during the dry season only, but many more species could have been found if the fish were sampled during the rainy season. The variation in the size of the fish obtained is the result of using a mix of different fishing gear and nets with different mesh sizes during the various catches. These results show that juvenile and adult individuals were considered in the sampling. The body mass of the fish caught in both reservoirs is low. Indeed, very few large fish were caught, and the largest specimen observed weighed only 1950.0 g (*Clarias anguillaris*). These findings suggest that the two reservoirs are exploited [22] and severely affected by human activities [12]. Overall, the fish in both reservoirs elongate faster than they grow (lesser allometry). According to [4], values of “b” can be influenced by sex, growth phase, stomach contents, level of gonad development, and environmental conditions. However, these parameters were not specifically considered in this study. The condition factor K varied between 0.58 (*Brachyalestes nurse*) and 3.15 (*Sarotherodon galilaeus*) in the Boussouma reservoir and 0.49 (*Schilbe intermedius*) and 7.60 (*Sarotherodon galilaeus*) in the Nabadogo reservoir. Two species out of seven in each of the two reservoirs have a K value below 1: *Brachyalestes nurse* (0.58) and *Clarias anguillaris* (0.64) in Boussouma, and *Schilbe intermedius* (0.49) and *Clarias anguillaris* (0.98) in Nabadogo. According to [25], a condition factor K less than 1 suggests that fish are in poor condition, and a K greater than 1 implies the opposite. As a result, it can be concluded that at the time of the study, 4 species of fish, namely *Coptodon zillii*, *Enteromius macrops*, *Oreochromis niloticus* and *Sarotherodon galilaeus*, were in good condition in the Boussouma and Nabadogo reservoirs. The mean values of the condition factor for *Sarotherodon galilaeus* (K = 3.15 and 7.60) recorded in this study are higher than the values reported by [26] in the Samandeni reservoir (K = 1.29 in the dry season and 0.98 in the rainy season). On the other hand, the K values reported by these authors for *Oreochromis niloticus* (K = 11.57 and 12.07) are higher than ours (K = 2.54 and 1.77). The condition factor that describes the overall health and well-being of a fish based on its environment can be influenced by several factors, including season, stage of development, level of gonad development, and food availability [25] [27].

5. Conclusion

The present study identified 29 species belonging to 12 families. The species richness per reservoir was 24 species in Boussouma and 15 in Nabadogo. Catches were dominated by Cichlidae in Boussouma (*Sarotherodon galilaeus* and *Oreochromis niloticus*) and Nabadogo (*Coptodon zillii* and *Oreochromis niloticus*), followed by Cyprinidae (*Enteromius macrops*) in Nabadogo. Ichthyological diversity remains low in both reservoirs compared to the values of the Shannon diversity index. Five of the seven common species in both reservoirs showed good adaptation to their environment, with condition factor values greater than 1. The results of this study provide an important database for researchers and environmental managers in the development of management and conservation measures for these populations. However, further studies with monthly sampling are needed to understand the fluctuations of these fish populations over time, their growth, mortalities, exploitation rate, yield, and relative recruit biomass to aid in decision-making.

Author Contributions

Conceptualization: A.E.S. and N.D.; Methodology: N.D. and A.E.S.; Validation: R.O., N.D., and A.E.S.; Formal Analysis: N.D. and Y.M.F.S.; Investigation: Y.M.F.S.; Writing—Original Draft Preparation: N.D. and A.E.S.; Writing—Review and Editing: V.B. and R.O.; Visualization: X.X.; Supervision: R.O. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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