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Trophic Structure of the Fish Community in the Samandeni Reservoir—Burkina Faso

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Abstract

From November 2020 to August 2022, the diet of 12 fish species from the Samandeni reservoir was examined in order to describe the diet and the trophic level of each of them. The analysis of this vital function allows a better knowledge of the concerned ecosystem and gives opportunity for its better management. The fish were sampled with gill nets and cast net. A total of 213 stomach contents of individuals belonging to 12 species grouped in 7 families and 10 genera were analysed. Results showed low to medium vacuity coefficients. The preys were mainly composed of fish, insects, detritus, zooplankton and phytoplankton. Variability in the use of resources by individuals was evident. Thus, the 12 species were classified as fish-eating predators, granivorous, zooplanktivorous, insectivorous and filter-feeding microphages. Then, the fish trophic structure of the Samandeni reservoir was elaborated.

Keywords

Diet, Vacuity Coefficient, Trophic Organisation, Samandeni, Burkina Faso

1. Introduction

The nature of prey and foraging strategies are adaptations that enable fish to cope, as effectively as possible, with environmental changes such as those occurring in a new reservoir [1]. This is the case of the Samandeni reservoir, located in the upper part of the Mouhoun catchment, which was recently impounded in 2017 and is one of the most socio-economically important reservoirs fishery of the country. This type of ecosystem is one of the main supports for fish production in Burkina Faso [2]. According to [3], the reservoirs would increase fish production by an average of 750 tons per year.

Current data and those from the literature have made it possible to list 115 fish species from the Mouhoun sub-catchment [4]-[10] and [2]. These species are grouped into 57 genera and 26 families.

According to [1], foraging is one of the activities to which fish devote most of their time. The analysis of this vital function allows a better knowledge of the concerned ecosystem and gives opportunity for its better management. To this end, several authors have contributed to the knowledge of the diet of some fish species around the world. In Burkina Faso, these are mainly the works of [11]-[14]. But there is no data about fish diet in an ecosystem in transition after impoundment. The Samandeni reservoir gives opportunity to investigate this issue. In addition to this, studying fish diet in Samandeni reservoir will give in-depth knowledge on its ecology and provide data to elaborate policies for the conservation of endemic species, the control of invasive species, the development of fish farming and the sustainable management of the reservoir.

Thus, the general objective of this study is to describe the fish trophic structure of the Samandeni reservoir through the study of the diet of 12 species of fish of the said reservoir, of which the number of individuals collected by species within the framework of this study, allows specifically, to describe the food bolus and to determine the trophic level of each of the studied species.

2. Methodology

2.1. Study Site

This study was conducted in the Samandeni reservoir located between longitudes 11˚23'55.90''N and 11˚19'59.83''N and latitudes 004˚34'41.40''W and 004˚46'00.14''W. The sampling was carried out at 8 stations along the reservoir upstream of the dam (**Figure 1**).

2.2. Sampling of Fish Fauna

Fish sampling took place between January 2020 and April 2022. Seven sampling campaigns covering the dry and the rainy seasons. Fish specimens are from commercial fishing and experimental fishing. For the experiment was carried out with cast net and gillnets of 10, 20, 30, 45, 60 and 65 mm of stretched mesh size. Fish camming from commercial fishing was catch with using trap, longlines and gillnets. After the 7 sampling campaigns, 12 species were selected for stomach content analysis. The other species were discarded due to the low number of collected specimens.

2.3. Analysis of Stomach Contents

In the field, fish standard length and weight were measured then guts were removed and preserved in 70˚ alcohol. Further in the laboratory, after dewatering,

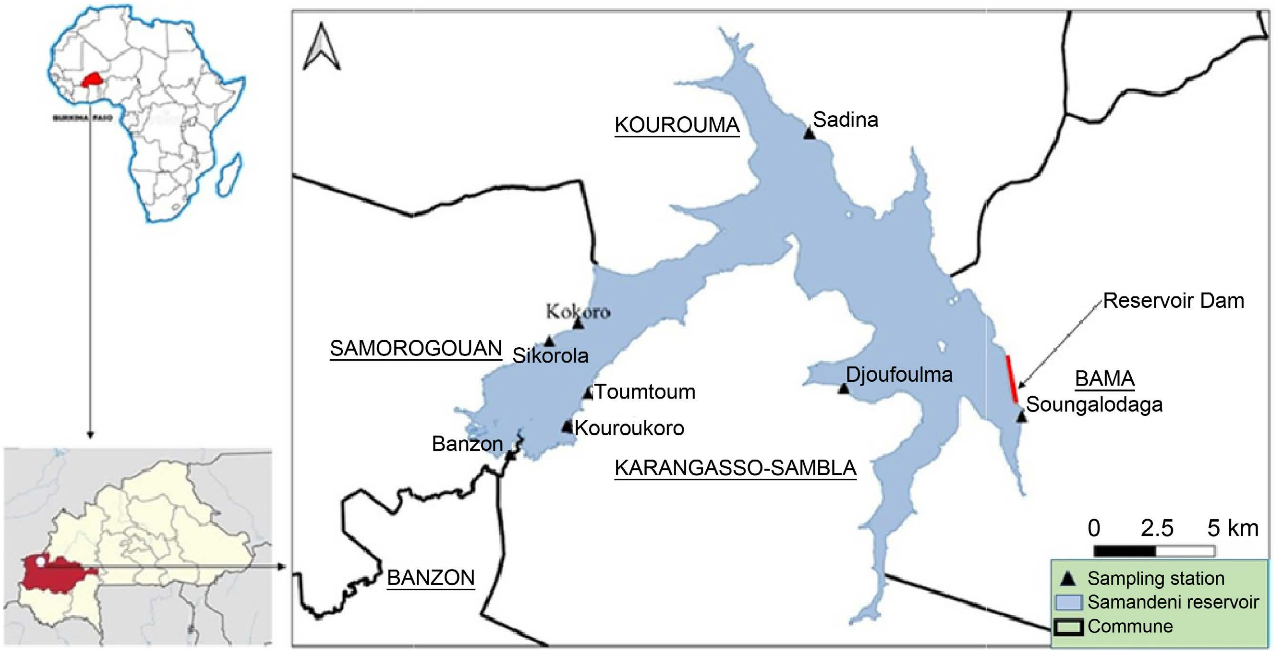

Figure 1. Map of the study area showing locations of the sampling stations.

each item of the stomach contents was isolated and weighed. The prey items were identified to the lowest taxonomic level as possible, and then, counted and weighted (species, genera and family). Large prey items were identified with the naked eye, under a stereomicroscope or under a microscope accordingly to their size. The biovolumes and the length-weight relation were used to determine the weight of microscopic preys such as phytoplankton and zooplankton (cf. [15]).

After the stomach contents counting, the weight (W_i), abundance (n_i) and frequency (N_i) of each prey item were recorded. To discuss each food item importance and the fish feeding strategies, the Main Food Item of [16] and the Costello graphs were used (cf. [17] [18] and [19]) Trophic levels were estimated using the method of [20].

3. Results

3.1. Diet Composition and Trophic Levels

A total of 213 stomachs were examined. Among them, 51 was empty. **Table 1** lists the studied species, with the minimum and maximum standard lengths of the specimens (SL), the number of examined stomachs (NE) and the percentage of empty stomachs or vacuity coefficients (VC). VC varied from 0 (*Clarias anguillaris* and *Ctenopoma kingsleyae*) to 41.66 (*Schilbe intermedius*) with a median of 22.72.

Following the examination of stomach contents, 12 prey categories were defined. In addition to these 12 prey categories, other artefacts such as pieces of net, plastic or polyester, which may have been accidentally absorbed by the fish, were excluded from the analyses in order to limit bias. These categories are: Fish, Detritus, Mollusc, Chaoboridae, Seed, Fish Scales, Chironomidae, Zooplankton,

Table 1. Lists of the studied species.

Species	SL	NE	VC %	TL (SE)
Ctenopoma kingsleyae Günther, 1896	11.6 - 13.3	6	00.00	2.48 (0.26)
Clarias anguillaris (Linnaeus, 1758)	17.3 - 57.6	15	00.00	3.23 (0.55)
Chrysichthys auratus (Geoffroy Saint-Hilaire, 1809)	09.1 - 21.1	39	28.20	2.34 (0.24)
Chrysichthys nigrodigitatus (Lacépède, 1803)	10.8 - 16.3	19	21.05	3.07 (0.50)
Coptodon zillii (Gervais, 1848)	09.8 - 15.8	22	22.72	2.09 (0.18)
Hemichromis fasciatus Peters, 1852	08.6 - 15.2	22	22.72	4.13 (0.73)
Oreochromis niloticus Linnaeus, 1758	10.4 - 21.3	20	35.00	2.00 (0.00)
Sarotherodon galilaeus (Linnaeus, 1758)	09.9 - 21.3	20	35.00	2.00 (0.00)
Synodontis nigrita Valenciennes, 1840	08.1 - 13.3	18	16.66	2.36 (0.42)
Synodontis schall (Bloch and Schneider, 1801)	09.6 - 24.1	8	37.50	2.54 (0.36)
Marcusenius senegalensis (Steindachner, 1870)	15.4 - 20.0	12	08.33	2.63 (0.34)
Schilbe intermedius Rüppell, 1832	10.6 - 24.5	12	41.66	4.03 (0.71)

Minimum and maximum standard length (SL), number of examined specimens (NE) the percentage of empty stomachs (VC) and trophic level (TL) with standard error (SE) for each fish species.

Phytoplankton, Plant fragments (leaf, stem and bark), Crustacea and Other Insects. Following these prey categories, trophic level with its standard error (Table 1) and prey importance index (Table 2) were calculated.

Trophic levels varied from 2 (*Oreochromis niloticus*, *Sarotherodon galilaeus* and *Coptodon zillii* to 4.13 (*Hemichromis fasciatus*) with a global mean trophic level of 2.74. Analyse show that *Oreochromis niloticus*, *Sarotherodon galilaeus* and *Coptodon zillii* are primary consumers. *Chrysichthys auratus*, *Synodontis nigrita*, *Ctenopoma kingsleyae*, *Synodontis schall* and *Marcusenius senegalensis* are also primary consumer with diets integrating sometime prey as insect and zooplankton. *Chrysichthys nigrodigitatus* and *Clarias anguillaris* are the secondary comsumers preying mainly on insect and fish but also integrating some plant and detritus. *Schilbe intermedius* and *Hemichromis fasciatus* are the top-level predators. Their prey on fish and insect.

Details of the diet composition are show in Table 2. Prey are ranked according to the Main Food Item (MFI %) calculated from singles prey importance index (occurrence index (F), abundance index (N), weight index (P), specific abundance index (A)). These data *Oreochromis niloticus* and *Sarotherodon galilaeus* forage mainly on detritus. In addition to detritus *Coptodon zillii* integrate plant as secondary prey. Detritus is also the main food item of *Marcusenius senegalensis*, *Synodontis nigrita* and *Synodontis schall*. But those species add plant, mollusk and insect to their diet. *Chrysichthys auratus*, *Chrysichthys nigrodigitatus* and *Ctenopoma kingsleyae* forage mainly on insect but specifically on Chironomidae for both species of the genus *Chrysichthys*. In addition to

Table 2. Diet composition for the 12 species.

Prey	F	N	P	A	MFI %	Ranking
1) *Chrysichthys auratus*						
Chironomidae	41.0	85.8	17.5	24.7	31.0	Preferential
Detritus	41.0	0.3	41.4	60.9	27.2	Preferential
Plants	30.8	0.3	21.7	34.7	17.1	Secondary
Seed	17.9	2.7	9.5	28.5	9.2	Accidental
Insect	12.8	0.7	4.3	12.5	5.0	Accidental
Chaoboridae	12.8	9.7	2.0	7.3	4.4	Accidental
Fish	12.8	0.2	1.9	86.4	3.3	Accidental
Scale	5.1	0.1	1.3	8.5	1.7	Accidental
Crustacean	2.6	0.0	0.3	17.0	0.6	Accidental
Mollusc	2.6	0.0	0.1	8.9	0.4	Accidental
Zooplankton	10.3	0.1	0.0	0.0	0.1	Accidental
2) *Chrysichthys nigrodigitatus*						
Chaoboridae	31.6	95.5	18.1	21.9	33.7	Preferential
Detritus	47.4	1.0	45.9	77.6	33.1	Preferential
Fish	47.4	2.2	32.2	59.8	28.1	Secondary
Mollusc	5.3	1.0	3.2	66.7	3.2	Accidental
Seed	10.5	0.2	0.4	4.1	1.5	Accidental
Plants	5.3	0.1	0.1	1.4	0.4	Accidental
3) *Clarias anguillaris*						
Fish	66.7	20.7	38.8	42.6	33.3	Preferential
Insect	60.0	25.1	21.2	25.2	24.3	Preferential
Plants	46.7	3.4	19.0	30.7	17.7	Secondary
Mollusc	33.3	8.9	8.3	14.6	10.7	Accidental
Detritus	26.7	2.0	12.0	75.0	10.6	Accidental
Seed	6.7	39.4	0.7	15.7	3.3	Accidental
Scale	6.7	0.5	0.0	0.3	0.1	Accidental
4) *Coptodon zillii*						
Detritus	54.5	5.2	63.6	92.4	51.3	Preferential
Plants	50.0	4.8	33.1	59.0	35.4	Secondary
Insect	4.5	30.6	2.9	63.5	8.4	Accidental
Seed	9.1	53.3	0.4	2.0	3.9	Accidental
Phytoplankton	59.1	5.7	0.0	0.0	0.8	Accidental
Chironomidae	4.5	0.4	0.0	2.4	0.1	Accidental
5) *Ctenopoma kingsleyae*						
Insect	83.3	80.9	39.6	68.9	48.9	Preferential

Continued

Plants	66.7	7.4	43.6	50.4	34.4	Secondary
Detritus	33.3	2.9	16.3	80.1	14.8	Accidental
Mollusc	16.7	2.9	0.5	44.4	1.7	Accidental
Phytoplankton	66.7	5.9	0.0	0.0	0.2	Accidental
6) ***Hemichromis fasciatus***						
Fish	54.5	60.5	83.3	84.2	70.2	Preferential
Plants	45.5	12.3	11.6	17.8	18.6	Secondary
Insect	13.6	8.6	4.3	10.0	7.0	Accidental
Tortoise	18.2	14.8	0.3	38.3	2.1	Accidental
Detritus	13.6	3.7	0.5	2.8	2.1	Accidental
7) ***Marcusenius senegalensis***						
Detritus	58.3	92.8	38.3	51.4	43.9	Preferential
Insect	66.7	0.9	45.8	56.3	32.0	Preferential
Chironomidae	50.0	2.6	6.4	12.5	10.6	Secondary
Plants	16.7	0.0	6.1	26.7	5.8	Accidental
Chaoboridae	33.3	3.6	2.5	4.8	5.5	Accidental
Seed	8.3	0.0	0.7	4.9	1.4	Accidental
Scale	8.3	0.0	0.2	2.5	0.7	Accidental
8) ***Oreochromis niloticus***						
Detritus	65.0	43.3	89.7	89.7	83.3	Preferential
Plants	20.0	13.3	10.2	52.5	15.6	Secondary
Phytoplankton	65.0	43.3	0.0	0.0	1.1	Accidental
9) ***Sarotherodon galilaeus***						
Detritus	65.0	50.0	99.8	99.8	96.1	Preferential
Phytoplankton	65.0	50.0	0.2	0.2	3.9	Secondary
10) ***Schilbe intermedius***						
Fish	33.3	28.9	74.0	77.7	49.5	Preferential
Insect	50.0	51.1	14.0	14.9	27.5	Secondary
Detritus	33.3	8.9	8.2	13.4	13.5	Accidental
Plants	25.0	6.7	2.8	4.8	6.9	Accidental
Crustacean	8.3	4.4	1.1	3.7	2.7	Accidental
11) ***Synodontis nigrita***						
Detritus	16.7	17.6	89.3	94.5	60.7	Preferential
Plants	50.0	58.8	8.8	26.8	34.0	Secondary
Insect	5.6	5.9	1.9	100.0	5.1	Accidental
Phytoplankton	16.7	17.6	0.0	0.0	0.2	Accidental

Continued

12) ***Synodontis schall***						
Detritus	62.5	35.7	42.4	42.4	47.0	Preferential
Plants	50.0	28.6	17.9	19.0	27.3	Preferential
Mollusc	12.5	14.3	39.4	74.9	23.7	Secondary
Chaoboridae	12.5	14.3	0.3	4.5	2.0	Accidental
Phytoplankton	12.5	7.1	0.0	0.0	0.0	Accidental

F: Occurrence index; N: Abundance index; W: weight index; A: Specific abundance index; MFI%: percentage of the Main Food Item.

Chironomidae *C. auratus* and *C. nigrodigitatus* integrate Detritus. But *Ctenopoma kingsleyae* add plant. *Clarias anguillaris*, *Hemichromis fasciatus* and *Schilbe intermedius* forage mainly on fish. Insect is also the main food item of *Clarias anguillaris* and plant in addition. However, for the other two piscivores species, while *Schilbe intermedius* adds insect to its diet, *Hemichromis fasciatus* adds plant instead.

3.2. Feeding Strategies

Figure 2 shows the Costello diagrams, based on [19], of the feeding strategies of the 12 species. These diagrams reveal that some species, such as *S. galilaeus*, *O. niloticus* and to a lesser extent *C. zillii*, are mainly herbivorous or detritivorous, while *S. intermedius* and *H. fasciatus* are mainly piscivorous. The diagrams also show that a very few *C. auratus* individuals have fish in their diet. When they do, the proportion is quite high. In contrast, in *C. nigrodigitatus*, most individuals consumed fish in moderately large proportions. In *C. anguillaris*, there is a small proportion of individuals which food bolus is mainly composed of detritus. The Costello diagram for this species also indicates that most individuals have a food bolus containing a significant number of plants, insects and fish. *C. kingsleyae* and *M. senegalensis* have many insects in their food bowls.

4. Discussion

This study is the first one that provides reliable information on the diet of 12 species of fish of Samandeni reservoir, in the Mouhoun river catchment. The values of the vacuity coefficients could suggest that within the Samandeni reservoir, some fish species such as *Clarias anguillaris* and *Ctenopoma kingsleyae* have easy access to their food resources and in sufficient quantity. However, others, such as *Schilbe intermedius*, *Synodontis schall* and *Hemichromis fasciatus*, have relatively poor access to their food resources. The competition for food between certain species in the reservoir could partly explain this situation. This is the case between *Synodontis schall* and *Synodontis nigrita*, two sympatric species, phylogenetically close [21] and with very similar feeding habits. This also applies to *Chrysichthys auratus* and *Chrysichthys nigrodigitatus*. Some phenomena

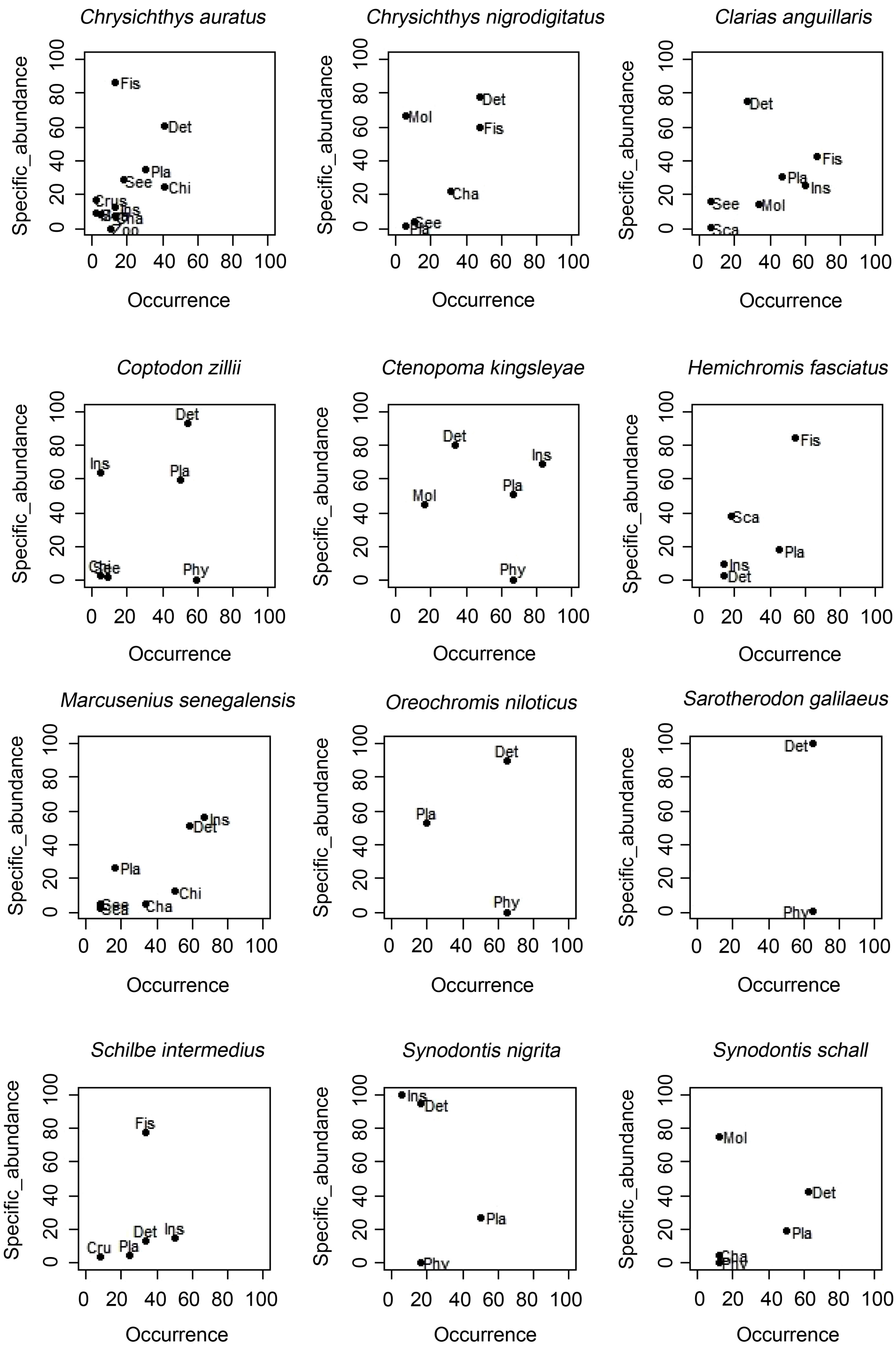

Figure 2. Feeding strategies of the 12 species studied. Fis = Fish, Ins = Insect, Det = Detritus, Mol = Mollusc, Cha = Chaoboridae, Gra = Seed, Eca = Scale, Chi = Chironomidae, Zoo = Zooplankton, Phy = Phytoplankton, Veg = plant fragments: leaf, stem and bark, Raw = Crustacean.

other than the presence or absence of prey could also explain the low proportion of prey in the stomach of some species. This is the case with *O. niloticus* and *S. galilaeus*, two species characteristics of the Sudano-Sahelian zone and that are oral incubators. During incubation, the parents carrying the eggs (and later the larvae) have a slower feeding rate [1].

Some authors such as [22] argue that the vacuity coefficient is relatively high in small and large individuals and low in intermediate size classes. Indeed, the reproductive period of most fish species is characterized by an increase in the volume of the ovaries and a compression of the digestive tract, thus reducing their trophic activities.

As for the juvenile fishes, beyond the competition, they are potential prey for piscivorous species. This could also be a limiting factor in the access to food for small individuals. Furthermore, the stress created during the capture of fish and the pressure exerted on their abdomen during their extraction from the mesh of the nets could also influence the vacuity coefficient because of the possible regurgitation of the prey [23].

The results on the feeding strategy show that there is a variability in the use of food resources. *Hemichromis fasciatus* and *Schilbe intermedius* show a specialist strategy in fish consumption. As pointed out by [1] zooplanktonivorous species have behaviors that differ from one species to another because they do not consume the same prey. In our case, *Synodontis* forage in the benthic bottom in search of animal carcasses and plant debris, while the two species of the genus *Chrysichthys* prefer insect larvae. Insectivorous such as *Ctenopoma kingsleyae* and *Marcusenius senegalensis* are visual predators. *Coptodon zillii*, *Oreochromis niloticus* and *Sarotherodon galilaeus* are microphagous, specializing in the consumption of detritus and phytoplankton.

Three groups of fish can be identified from the results of the estimation of the trophic level of the species. The empirical methods of [1] and [24] enabled the 12 species to be classified into three trophic levels, namely levels 2, 3 and 4. Firstly, the primary consumers (trophic level 2) which feed mainly on algae and plant debris. Then there are the secondary consumers (trophic level 3) that mainly consume benthos invertebrates, zooplankton and phytoplankton. Finally, the terminal consumers of trophic level 4 and above. These fish are mainly piscivorous and feed on both primary and secondary consumers. However, some omnivorous fish have such complex trophic relationships that it has proved impossible to assign them a precise place in the food chain. This is the case for *Clarias anguillaris*, which is classified at level 4 but could also be classified among the other consumers. Our results are in line with those of [25], who found that *C. anguillaris* is an omnivorous predatory fish with a food spectrum in which fish and insects are the most abundant prey. The trophic levels of the species were determined on the basis of individual prey weight abundance indices and their average trophic levels. This method provided real values of trophic levels. Thus, primary consumers, secondary consumers and terminal consumers would have trophic levels ranging from 2 to 2.63, 3.07 to 3.23 and 4.03 to 4.13 respectively. Our results are consistent with those obtained by [1].

A large diversity of algae with a predominance of the genus Microcystis was observed in the diet of the studied species. In total, 60 species were identified. However, apart from a few copepods, a small proportion of zooplankton was observed. This could be explained by the recent impoundment of the reservoir. Indeed, authors such as [26] [27] [28] have documented the profound changes caused by the construction of reservoir such Samandeni one on the Mouhoun River in terms of chemical variables and the velocity of the water flow in the original environment, on which aquatic organisms, particularly plankton, are highly dependent. It emerges from these different studies that the first moments of the arrival of water are characterized by high turbidity, low light penetration in the water columns and a low level of nutrients, as revealed by [10] work on the said reservoir. This would limit the development of zooplankton [15].

5. Conclusion

The results of this study are of great use in the domestication of endemic species and of economic interest in Burkina Faso, as it has enabled the diet of 12 species of fish in the Samandeni reservoir to be partially understood. These data will enable to elaborate the fish trophic organization of the Samandeni reservoir. However, the extension of such a study to all the fish species in the reservoir will allow this trophic organization to be further refined. Furthermore, the transition from a more or less fast-flowing lotic system to a lake system, which is calmer due to the construction of the reservoir, will inevitably bring about ecological changes which it is essential to monitor in order to ensure the sustainability of the increasingly threatened fish species.

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Conflicts of Interest

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

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