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Original Article

Effect of Dam on the Trophic Guilds Structure of Fish Assemblages in the Bia River-Lake Systems (South-Eastern Of Côte d'Ivoire)

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ABSTRACT

This study compares fish trophic structure in the river-lake system Bia to Agnéby river, a river with similar characteristics but have not impacted by the dam. Sampling sites were retained in upstream, the lake part and downstream areas of Bia river-lake system, and in upstream, middle stream and downstream of river Agneby. Samples were collected monthly during 23 surveys on each sampling zone with gillnets.

A total of 78 and 45 fish species were recorded respectively in Bia and Agneby. Fish species were classified in nine trophic guilds using available information: Herbivore-microphage, Herbivore-phytoplanctonivore, Omnivore-benthophage, Omnivore-generalist, Omnivore-zooplanctonivore, Predator_1-insectivore, Predator_1-microphage, Predator_2-generalist and Predator_2-piscivore. Predator_1-insectivore was most abundantly found in the rivers Bia and Agneby with respective percentage of 41.51 and 37.11. It is followed by Omnivore-generalist and Predator_2-generalist. Trophic guilds which are the most poorly represented are Herbivore-microphage (4.34%) and Predator_2-piscivore (3.97%) in Bia and Herbivore-microphage (0.62%) and Herbivore-phytoplanctonivore (2.89%) in Agneby.

The analysis highlighted clearly two groups with no overlap in Bia river-lake system: samples from the lake and the upstream composed first group, and samples from the downstream are associated to second group. Two dominant guilds separating these two groups: Predator_2-generalist and Omnivore-generalist. The lake part and upstream are characterized by Omnivore-generalist, while Predator_2-generalist is mainly occurred in downstream. By contrast, samples from Agneby River couldn't reveal any difference between downstream, middle part and upstream. The presence of dam on Bia main channel impact trophic guild structure of fish fauna by inhibiting communication between upstream and downstream.

Keywords: *Fish, Trophic guilds, hydrosystem, dam, west Africa*

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INTRODUCTION

In rivers, numerous factors potentially affect biological communities: water quality, food, hydraulics, zoogeographic history, biotic factors, fishing activities, dams [1], [2], [3]. Dams affect the longitudinal gradient by changes in basin geomorphology and hydrology, consequently, physicochemical and biological variables [4]) As for biological variables, the presence of dam limits for example the migrations of some organisms such as shrimps and fishes. Along such gradient, fish assemblages may vary widely in composition [5, 6].

Many studies showed the important role plays by catchment area cover in the distribution and movement of fish across different aquatic ecosystems [7,8,9,10,11,12]. These conditions affect fish assemblage distributions by altering fish habitats in terms of light intensity, organic matter, nutrients or sediment load, and directly by the interactions with other anthropogenic drivers (climate change, invasive species, dams…) [8, 9]. In fish ecology, the structure of fish assemblages depends on many interacting factors and can be quantified by summarizing species richness, composition and feeding guilds [13, 14]. Besides, the presence of dam creates two different habitats,

a lacustrine area up stream and a lotic zone downstream. Habitat type is an important factor influencing the feeding strategy of a species by determining foraging opportunities [15]. Trophic ecology is a useful tool to understand the functional role of fishes within their environment [16, 17]. Commonly used in fish population studies, the trophic guild offers the opportunity of dividing the community into functional groups [18, 19, 20]. Ecosystems are structured in both spatial and temporal, so one of the most questions when studying an ecosystem and its component organisms is the strategy of its occupation with respect to space and time [21]. The study of ecological communities leads to obtaining a huge matrix, which is often difficult structure apparent [22].
Although hydroelectric reservoirs have been widely studied in Côte d'Ivoire (*e.g.* [23, 24, 6, 25, 26, 27, 28, 29, 30], few studies on fish trophic organization have been conducted (*e.g.* [31, 26]). Analysis of feeding habits and guild structure could enhance the knowledge of fish ecology within those hydrosystems.
In this study, we compare fishes trophic organization in the river-lake system Bia to Agnébi river, a river with similar characteristics on which none dam has been constructed.

MATERIALS AND METHODS

Study area and sampling sites

Located in the South and South-East of Côte d'Ivoire respectively, Agneby River and Bia River-lake system (Figure 1) belong to the Western Guinean ichthyoregion, sector Eburneo-Ghanaian [32].
Bia system encompasses an area of 9300 km^2. With 300 km length, this hydrosystem (05°30' - 05°50' N and 03° - 03°15' W) has a mean annual flow of 83 $m^3.s^{-1}$ ([23], [24]). Two hydroelectric dams were built on this river (Ayamé I in 1959 and Ayamé II in 1963). There is no particular scheme for the transit of fish in these two dams. Sampling sites were retained in the upstream (Bianouan), the lake (Kétésso, Ebikro, Bakro, Ayamé) and the downstream (Aboisso, Krindjabo) areas of this stream (Figure 1).
Agneby river is 200 km length with a catchment area of about 8700 km^2 [23, 24]. An average flow rate at the mouth is 50 $m^3.s^{-1}$. Three sampling sites were chosen on this river: Gbessé upstream, "Pont Autoroute" in the middle course and Armebé downstream (Figure 1). This river has no dam on its main course.

Fish sampling

Samples were collected monthly during 23 surveys. The sampling sites covered a river section of approximately 1.5 km in length (i.e. reach scale). This section length was selected to cover a fair degree of habitat heterogeneity. Fish populations were collected with two sets of 9 gillnets (mesh sizes 10, 12, 15, 20, 25, 30, 40, 45 and 50 mm), allowing the capture of almost all the fish longer than 90 mm total length. These gillnets were 25 m long and 2 m high. At each sampling occasion, fishing was done overnight (17.00 to 7.00) and during the day (7.00 to 13.00). All specimens were identified according to the keys of [33] and [34] revised by [35].

Feeding guilds classification

Fish species were classified in trophic guilds using available information. First, we established a list of species sampled in the Bia and Agnebi basins. Then, data base was made up starting from the bibliographical references relating to the diets of the species listed in Bia and Agnébi [31, 36-52].
In order to determine whether the observed differences between sampling zones were significantly different, data were subjected to the non-parametric comparison tests (Kruskal-Wallis test and Mann-Whitney test). Differences between sampling zone based on trophic guilds were compared with 0.05. A factor analysis using a principal component analysis (PCA) program was run on the correlation matrix from untransformed data. All statistical analyses were carried out by the software Paleotological Statistic (PAST) version 2.17*c* [53].

RESULTS

In this study, a total of 78 and 45 fish species were recorded respectively in the Bia river-lake system and in the Agneby river. Those species were classified in one of the nine following trophic guilds: Herbivore-microphage (H_micr), Herbivore-phytoplanctonivore (H_phyt), Omnivore-benthophage (O_bent), Omnivore-generalist (O_gene), Omnivore-zooplanctonivore (O_zoop), Predator_1-insectivore (P1_inse), Predator_1-microphage (P1_micr), Predator_2-generalist (P2_gene) and Predator_2-piscivore (P2_pisc).

The trophic guild P1_inse that was most abundantly found in the rivers Bia and Agneby cover respectively a percentage of 41.51 and 37.11 (Figure 2A). This trophic guild is followed by O_gene and P2_gene with respectively 14.30% and 11.53% in Bia system and 18.97% and 14.85% in river Agneby. Trophic guilds which are the most poorly represented are H_micr (4.34%) and P2_pisc (3.97%) in Bia and H_micr (0.62%) and H_phyt (2.89%) in Agneby.

Considering the different areas investigated in each hydrosystems, P1_inse represents 40.51%, 39.80% and 47.01% respectively in upstream, lake and downstream of Bia (Figure 2B). It followed by O_gene (13.50%) and P1_micr (9.70%) in upstream, by O_gene (16.48%) and P2_gene (8.81%) in the lake and by P2_gene (22.65%) and O_gene (9.40%) in downstream. The least encountered were P2_pisc with 3.80% and 3.75% respectively in upstream and lake part and O_zoop with 1.28% in downstream of Bia river-lake system.

In the river Agnéby the trophic guild P1_inse also appeared as the most important with 36.22% for the upstream, 35.26% for the middle zone and 39.11% for the downstream (Figure 2C). This trophic guild is followed by O_gene and P2_gene which cover respectively 18.90 and 15.75% in upstream, 20.51 and 14.85% in the middle part, 17.82 and 14.10% in downstream. The H_micr and H_phyt are less represented with respectively 0 to 0.79% in upstream, 1.28 and 3.21% in the middle part, 0.50 and 3.96% in downstream of river Agnéby.

A principal component analysis (PCA) using the correlation matrix highlighted clearly the presence of two groups with no overlap in Bia river-lake system following the component 2 (Figure 3A). One group, located above (encircle in black and blue), is composed of samples from the lake and the upstream. The second group, located below (encircle in red), is associated with samples from the downstream of this hydrosystem. Factors loading showed that the second component of the PCA is dominated by various feeding guilds, but the two dominant which separating these two groups are: Predator_2-generalist (P2_gene) and Omnivore-generalist (O_gene) (Figure 3B).

The figure 4 shows that on Bia river-lake system, the lake part and upstream are characterized by a significant presence of Omnivore-generalist (O_gene) (Mann-Whitney U-tests, $p < 0.001$). By contrast, Predator-generalist (P_2-gene) is mainly occurred in downstream (Mann-Whitney U-tests, $p < 0.001$).

A PCA for samples from the Agneby River basin could not reveal any difference between downstream, middle part and upstream (Figure 5).

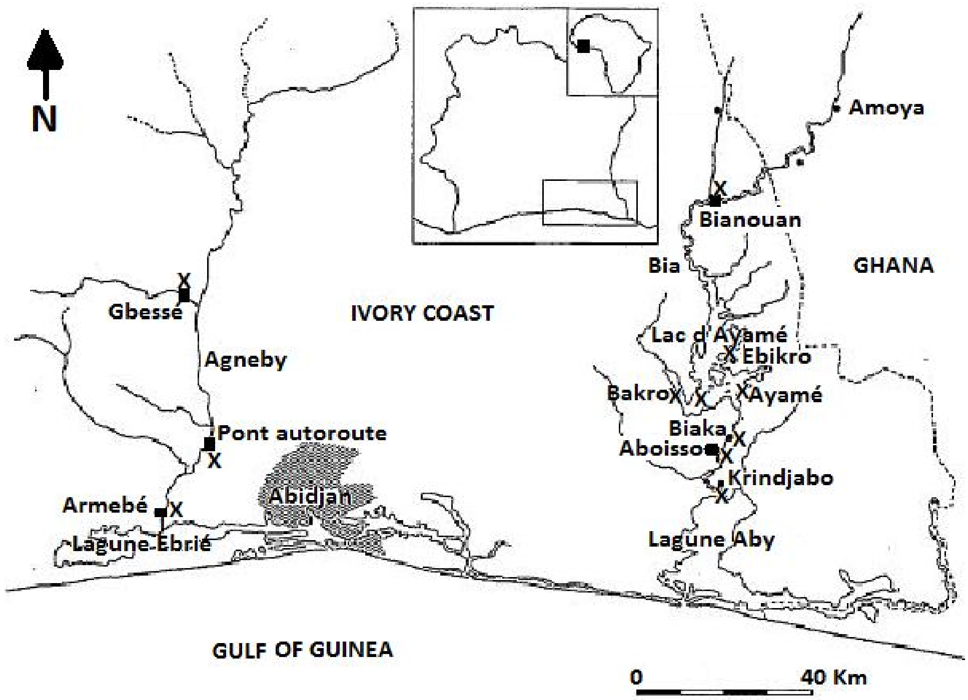

Fig. 1. Location of the sampling stations (marked with a cross) on rivers Bia and Agnébi in southern and south-eastern of Côte d'Ivoire ([23]).

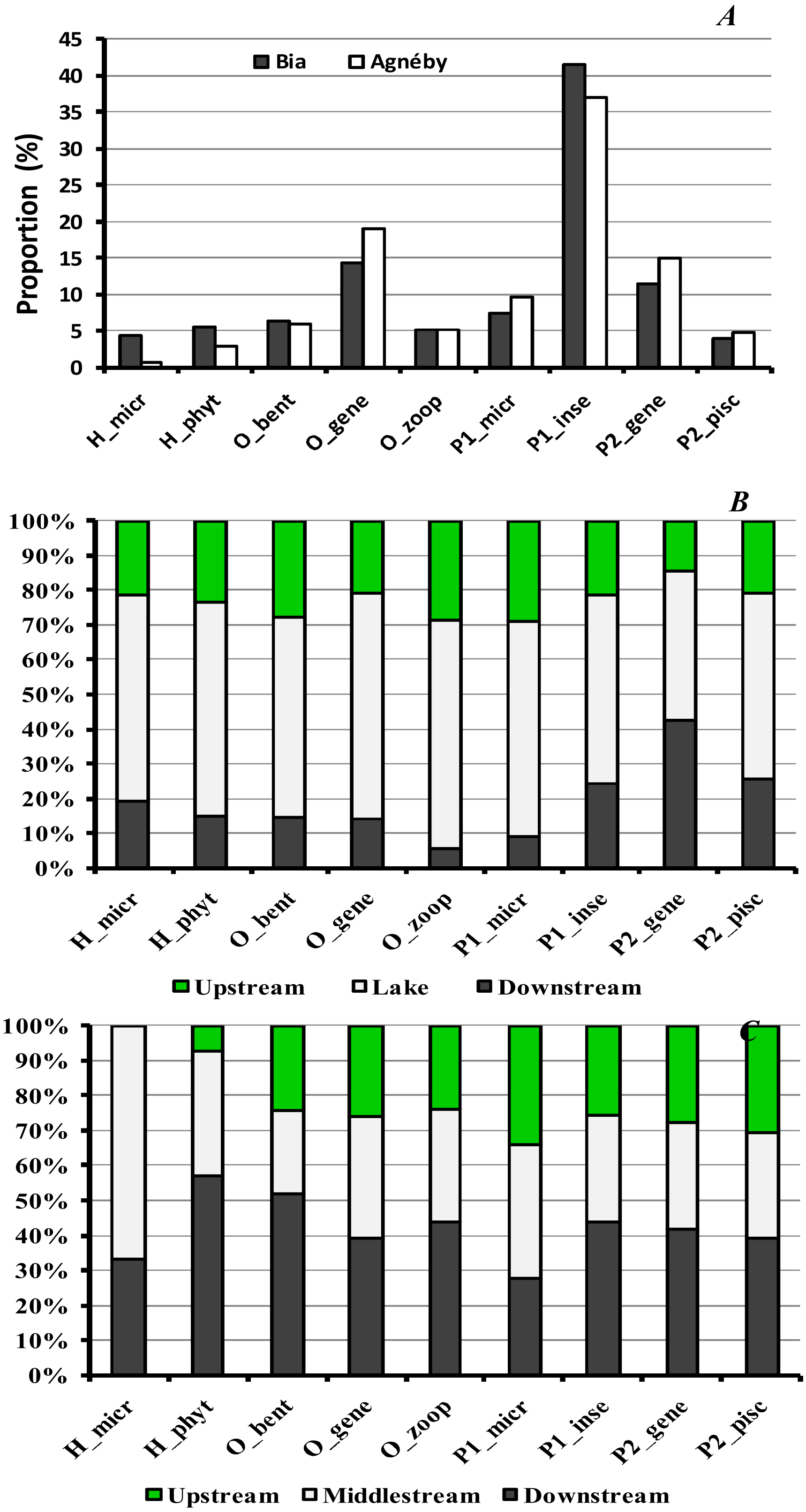

Fig. 2. Spatial variations of the abundances of different trophic guilds observed in A) Bia and Agneby, B) river-lake system Bia and C) the river Agnéby.

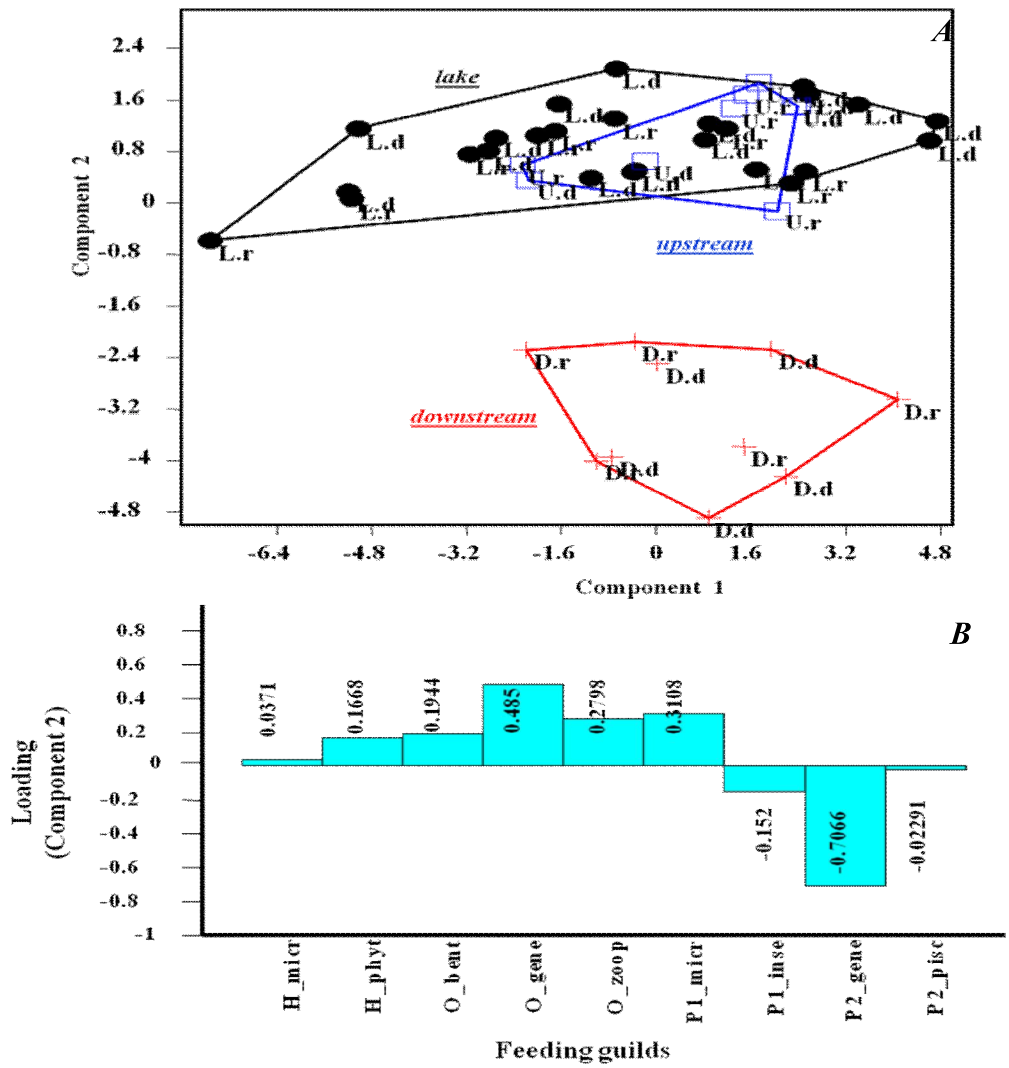

Fig. 3. A) Plot of scores on the first and second axis of a PCA on feeding guilds of fish from Bia river-lake system. Samples from downstream are represented by red cross; those from lake are represented by black dots; those from upstream are represented by blue square. B) Correlation coefficients of feeding guilds in relation with the PCA axis 2.

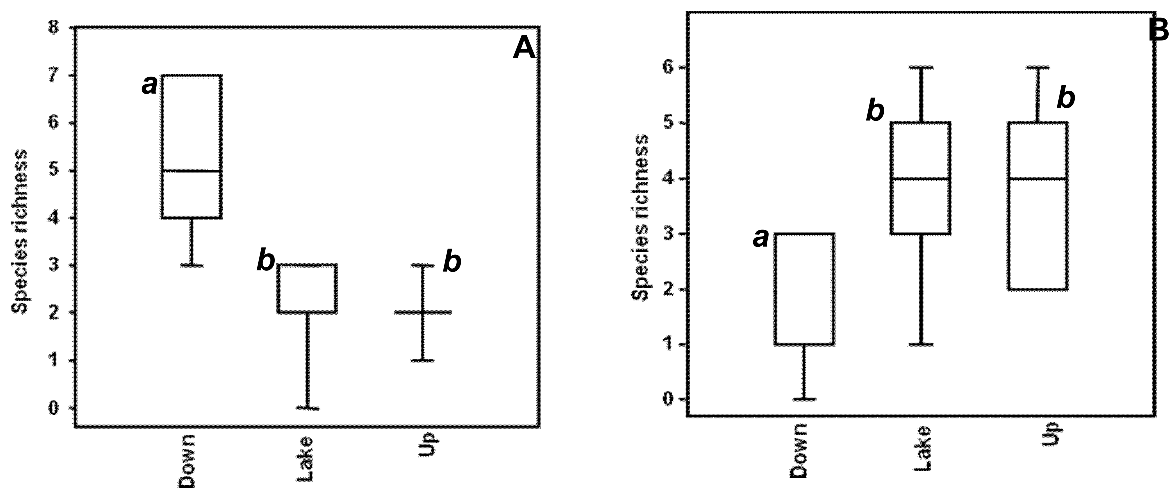

Fig. 4. Plot of A) P2_gene (Predator_2-generalist) and B) O_gene (Omnivore-generalist) from Bia river-lake system. Alphabetical letters on the box-plots indicate a significant difference ($p < 0.05$; Mann-

Whitney two samples comparison) between zone; there is no significant difference between the box having the same alphabetical letter (p > 0.05).

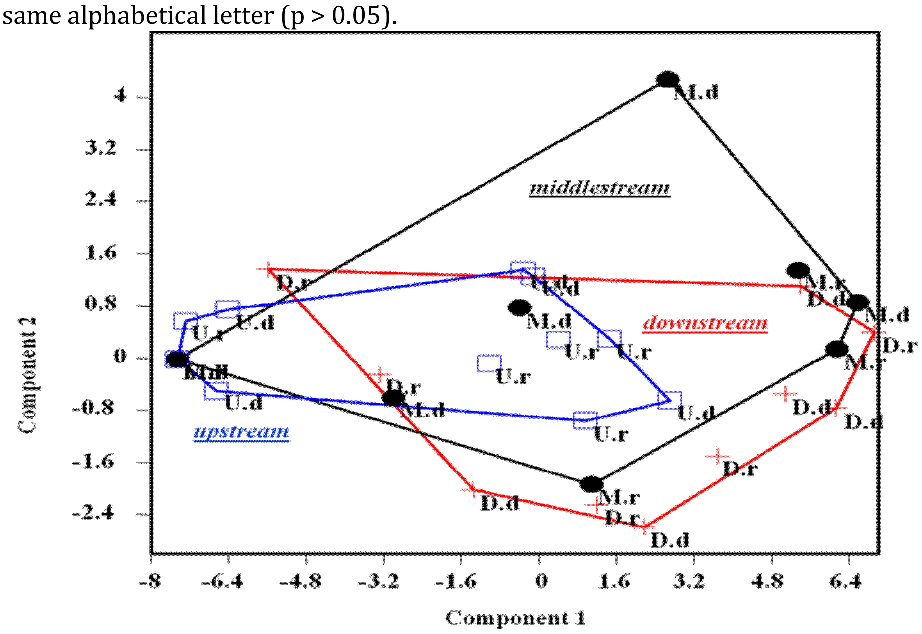

Fig. 5. Plot of scores on the first and second axis of a PCA on feeding guilds of fish from Agnebi river. Samples from downstream are represented by red cross; those from lake are represented by black dots; those from upstream are represented by blue square.

DISCUSSION

A total of 78 and 45 fish species were recorded respectively in the Bia river-lake system and in the Agneby river. Diversity of fish community in Bia river display a very high spatial variation [23], [24], [30]). On the basis of their diet, these fishes were classified into nine trophic guilds: Herbivore-microphage, Herbivore-phytoplanctonivore, Omnivore-benthophage, Omnivore-generalist, Omnivore-zooplanctonivore, Predator_1-microphage, Predator_1-insectivore, Predator_2-generalist and Predator_2-piscivore. Variation of trophic guilds between the fish fauna of both hydrosystems suggests that fishes have somewhat different nutritional requirements and feeding strategies. These groups were also observed by [31] in their study on the trophic structure of fish populations from small dams in the north of Côte d'Ivoire.

Overall, the trophic guild Predator_1-insectivore, followed by Omnivore-generalist, Predator_1-microphage and Predator_2-generalist, is the most widely observed (more than 35%) in all zones of both hydrosystems explored. Most fishes inhabiting these ecosystems have a high food intake and were potential specialists, with only few of them considered as generalists. Reference [31] have noted that in lentic environments, omnivores dominate the populations. This type of dominance in food webs is generally linked to greater control of the lower levels by predation, as opposed to a control of lower trophic levels by a limitation of resource [54, 31, 27]. According to these authors, in "long" food webs, predation is an important regulating factor of the abundances which increase with the reduction of environmental stress. Reference [55] recommended that because of high capture rates when preys are abundant, the feeding niche breadth of a predator will be narrowest when food in a particular environment is rich. So predation is an important regulatory factor in stable environments than in unstable environments. This control by predation suggests that the lake part of Bia is in fact stable environments.

The trophic guilds which are the most weakly represented are Predator_2-piscivore and Omnivore-zooplanctonivore in Bia river-lake system and Herbivore-microphage and Herbivore-phytoplanctonivore in Agnéby river. This reflects that trophic niches of Predator_2-piscivorous and Omnivore-zooplanctonivore on the one hand and those of Herbivore-microphage one the other hand remain vacant respectively in Bia river-lake system and in river Agnéby. For this last river, this could result from improper use of energy "stored" in the sediment. Our results corroborate observations of [56], [57] and [31]. These authors indicated that all trophic levels available in tropical environment are not operated by native species.

The PCA performed highlighted clearly two groups with no overlap in Bia river-lake system, contrary to the river Agnéby which appears a single and indivisible group. The first group of Bia is composed of samples from the lake and the upstream. Their trophic structures appear similar. These zones are marked by a relative homogeneous trophic spectrum, but with a significant presence of Omnivore-generalist. Although the habitat is impacted by the presence of dam in the main course of the Bia River, most fishes inhabiting this ecosystem have a high food intake. According to [58], deeper environments may have a greater complexity of habitats, supporting a larger number of fish species. Indeed, in the lake zone, the diet of several organisms is diversified and thus these organisms can adapt to environmental changes [27]. Most of them were potential specialists, with only few considered as generalists. Reference [59] showed that lakes have more habitats and abundant feed. In addition, [60] revealed that habitat complexity influences both the structure and trophic organization of fish assemblages. The second group included samples from the downstream and characterized by Predator-generalist. The presence of species guilds in a particular environment has been widely discussed as a potential strategy for avoiding trophic competition [61], [60] or for optimizing available resources [15].

However, the difference in the dietary composition of these trophic guilds does not mean that species categorized in different guilds feeds on a totally different suite of food organisms, because there was some overlap in food selection [15]. Indeed, according to [60], neither species richness nor abundance are primarily important in determining the more complex trophic organization in terms of more functional groups and a more complex guild structure.

Moreover, the highest trophic guild heterogeneity within lake and downstream suggests that both zones present partially distinct ichtyofauna. The upper course and the lake were restricted to the downstream part after the construction of the two dams Ayamé I and II. These barriers impede fish migration between downstream and lake areas. However, in absence of major obstacles numerous species from the brackish and/or marine water species can go upstream in the rivers [62, 63, 6, 11, 30]. Indeed, in the lower course of Bia system, estuarine/marine species recorded by [30] represented more than 33% of the species of this river. Thus, there is a mixing of fish populations with a possible communication between upstream and downstream as observed in the river Agnéby where there is no dam on the main channel.

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