Fish diversity and assemblages according to distance from source along a coastal river gradient (Ehania River; south-east of Ivory Coast)

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Abstract

Fish assemblage was investigated during the study of longitudinal profile of the Ehania River Basin in south-eastern Côte d'Ivoire. This area is subjected to intense human activities with many plantations (palm tree, banana, pineapple, coffee, rubber and cocoa). Samples were collected, with gillnets of different mesh sizes, through 6 sampling surveys during dry and rainy seasons from February 2010 to December 2010 at 6 sampling sites. A total of 70 fish species belonging to 48 genera, 28 families and 10 orders were recorded. The temporal variation of diversity index is less marked than spatial variation. The upstream, with 35 species, was less rich in species than the medium area and downstream areas (respectively 46 and 68). The upstream and downstream areas gathered 35 species. Thirty three species were common to the upper and middle areas and 46 species appeared both in the lower courses and the middle area. The 21 species restricted to the lower part of the river are mainly estuarine/marine origin. The beta diversity value revealed low similarity between the lower and upper course of Ehania River. The lowest values of Shannon's diversity index and equitability index were observed in the middle part of the River which characterized by high population density and intense agricultural activity with many plantations.

Keywords: Fish assemblages, Diversity, Spatial gradients, Artisanal dams, Anthropogenic impact, Coastal river, West Africa

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Introduction

Study of factors structuring biological communities has a rich and long history. Reyjol *et al.* (2005) noted that, as ecosystems are structured both spatially and temporally, one of the major questions when studying an ecosystem and its component organisms is the strategy of its occupation with respect to space and time. Increasingly, bio-assessment measures have become a widely shared tool to estimate the ecological condition and identify impacts to aquatic organisms in the river systems (Tejerina-Garro *et al.*, 2005; Flinders *et al.*, 2008). This technique has advantages with regard to more traditional methods of evaluating water quality and pollution loading because of its ability to detect low level and non-point source pollutants (Barbour *et al.*, 1999), physical habitat alteration (Kutka and Richards, 1996; Nerbonne and Vondracek, 2001), and long-term ecosystem effects of disturbance events (Barbour *et al.*, 1999). Moreover, the growing environmental awareness has led to an increase in demand by water resource managers for ecological information on which to base management plans and decisions (Simon, 2000). Indeed, unless living resources in general and in particularly those of hydrosystems are used and managed rationally, natural production faces the risk of collapsing (Yapi-Gnaoré *et al.*, 2000). Because the fish assemblages are strongly influenced by physical habitat, they have long been used to quantify the effects of disturbance on the environment (Karr, 1981). Disturbance to physical habitat (Marchetti and Moyle, 2001; Quist *et al.*, 2003) and water quality (Rabeni and Smale, 1995; Bonner and Wilde, 2002; Ebrahimi and Taherianfard, 2011) have resulted in fish assemblage shifts, decreased native species diversity, community homogenization, range reduction and extinction. Fish assemblage structures such as guilds (feeding, reproduction, behavior, etc.) can be used to determine habitat degradation associated with nonpoint source pollution (Moyle, 1994). Moreover, understanding spatial patterns in fish assemblage structure is critical for the conservation and management of native fish (Jackson *et al.*, 2001; Wright and Li, 2002).

In West Africa, many streams that drain the coastal regions are an important resource for human populations, especially in rural areas. Indeed, these rivers are used for domestic activities (drinking, cooking, bathing...), agriculture (irrigation, cattle drinking); and fish constitute an important food resource for local population (Konan *et al.*, 2006; Konan *et al.*, 2013). However, in this region freshwater resources are under pressure from a multitude of stressors. The watershed of the Ehania River, subject of this study, is particularly under multiple forms of human pressure. Indeed, its catchment area shelters large plantations of palm tree, banana, rubber, cocoa, and coffee. It is also the place of discharge of domestic and some industrial waste. These anthropogenic pressures could profoundly affect the integrity of both water resources and its biodiversity. To expand the scope for assessing the potential impacts human stresses impose on freshwater ecosystems, it is imperative to collect relevant information, both on water resource and its contains living. Ibanez *et al.* (2007) pointed out that to ensure a sound management and sustainable exploitation of freshwater biodiversity, it is vital to develop a deeper understanding of the factors and processes that determine aquatic diversity at different spatial scales.

The purpose of this study was to characterize the spatial and seasonal patterns in fish assemblage structure in Ehania River and to discuss conservation implications.

Materials and methods

Study area and sampling sites

The Ehania River, located (05°17'–05°43' N and 02°46'–03°03' W) in the South-East of the Côte d'Ivoire (Fig. 1), belongs to the Western Guinean ichtyoregion, sector Eburnéo-Ghanaian (Daget and Iltis, 1965; Hugueny and Lévêque, 1994; Paugy *et al.*, 1994). This small coastal river is located in lowland rainforest. The Ehania River, a tributary of the Tano River, has a catchment area of 1050 km^2, a main-channel total length of 140 km and a slope of 2.36 $m.km^{-1}$. Its mean annual flow corresponds to 15.7 $m^3.s^{-1}$ (dry season: 14.3 $m^3.s^{-1}$; rainy season: 19.8 $m^3.s^{-1}$). Five sampling sites were retained in the main-channel from upstream to downstream areas of the stream (Fig. 1). The sixth station is located on the Tano River, approximately 1.5 km downstream of the river mouth Ehania. Table 1 gives some characteristics of sampling sites. Canopy closure was relatively high in upstream and downstream sites (60-80%), medium in middle sites (40-60%) and human activities occurred mostly in middle courses of Ehania basin (Konan *et al.,* 2006; Konan, 2008).

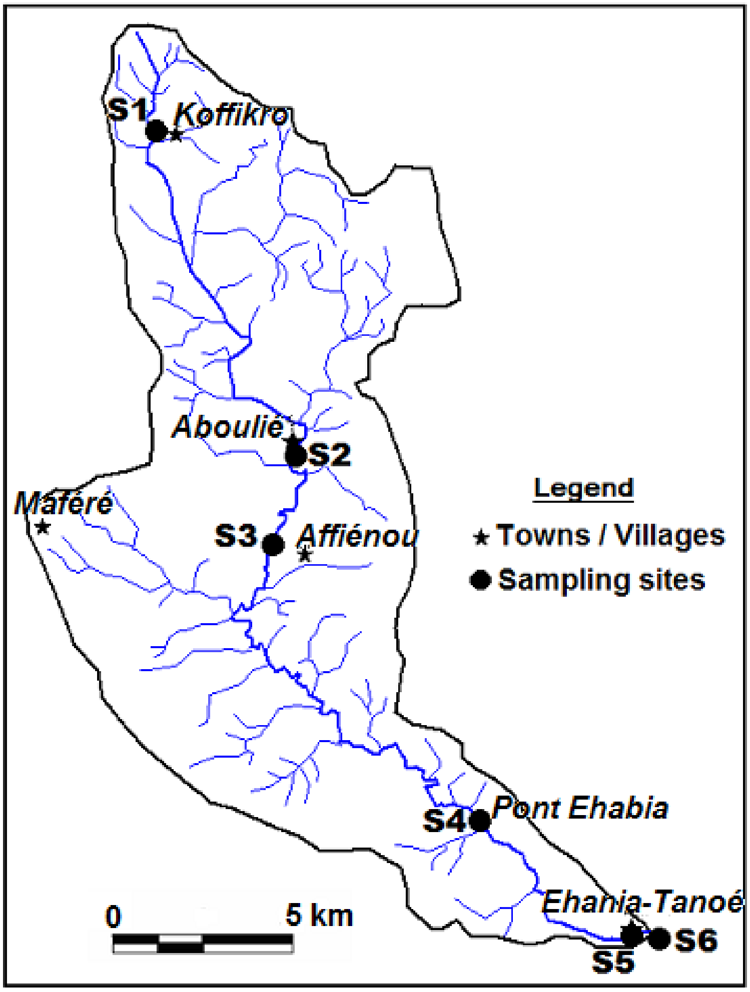

Figure 1: Location of Ehania River and the sampling sites (S1 to S6).

Table 1: Some characteristics of sampling stations identified on the river Ehania.

Sites	Position of site on river	Distance of source (km)	*Canopy (%)	*Influence of human activities (%)
S1	upstream	7.2	70	65
S2	middle stream	41.2	60	85
S3	middle stream	53.5	40	95
S4	downstream	107.9	60	2
S5	downstream	139	80	50
S6	downstream	140.5	60	5

S1 to S6 = sampling sites. *sources: (Konan *et al.*, 2006; Konan, 2008)

Fish sampling

Samples were collected during 6 sampling surveys from February 2010 to December 2010 (i.e. 3 during the rainy season (April, June, October) and 3 during the dry season (February, August, December)). The 6 sampling sites were sampled during each survey. Each site was also characterized spatially by its distance from the source. The sites covered a river section of approximately 1.5 km in length (i.e. reach scale). This river section length was selected to cover a fair degree of habitat heterogeneity.

Fish were collected with two sets of 8 gillnets of varying mesh (12 mm to 45 mm knot to knot, stretched mesh size), allowing the capture of almost all the fish longer than 80 mm total length. These gillnets were 30 m long and 1.5 m high. At each sampling occasion, fishing was done overnight (17.00 to 7.00). All fish specimens were identified according to the identification keys of Paugy *et al.* (2003). Each specimen was measured (standard length) to the nearest mm and weighed to the nearest gram.

Data analysis

Species turnover analysis is important because it shows the degree to which habitats have been partitioned by species; β-diversity values may be used to compare habitat diversity between different systems; with α-diversity, β-diversity measure total diversity, or the biotic heterogeneity of a specific area (Wilson and Shmida, 1984). Beta diversity index (Harrison *et al.,* 1992) was used to examine the pairwise differentiation between sampling zones: $\beta_H = ((S/\alpha) - 1).(N - 1)) * 100$; where S is the number of species in the two sites combined; α is the average richness of the two; N is the number of sites. Harrison *et al.* (1992) ranges β_H from 0 (complete similarity) to 100 (complete dissimilarity).

Using Shannon's diversity index (Shannon and Weaver, 1963) and equitability index (Piélou, 1969), we made a comparative study of the spatial and temporal variations of the diversity of fish population along the river:

- $H' = -\Sigma q_i \, Log_2(q_i)$; where qi is the relative abundance of each species;
- $E = H' / Log_2(Rs)$; where H' is the Shannon's diversity index and Rs is the total number of species.

Between-sampling sites, differences in species richness (number of species, Shannon diversity and equitability) were evaluated using the Kruskal-Wallis test, a non-parametric analysis of variance, followed by Mann-Whitney test to identify specific differences. Shannon's diversity index, equitability index and all statistical analyses were carried out by the software Paleotological Statistic (PAST) version 2.15 (Hammer *et al.*, 2001).

Results

Fish species composition

The composition of fish population (species, genera, families, order) sampled during this study is shown in Table 2. A total of 70 fish species belonging to 48 genera, 28 families and 10 orders were captured in Ehania River. The most abundant order was Perciformes with 39% of all captured families and 40% of all species. It is followed by Siluriformes (18% of families and 19% of species), Osteoglossiformes (11% and 16%), and Characiformes (7% and 10%). Only one family belonging to Cypriniformes, accounted for 9% of species. Among the families collected, Cichlidae (19% of species), Mormyridae (13%), Alestidae (9%), Cyprinidae (9%) and Clariidae

(7%) are largely represented. Twenty eight marine/brackish species (i.e. 40% of the species) were collected, as well as two introduced species (*Oreochromis niloticus* and *Heterotis niloticus*).

Table 2: Fish species collected in the Ehania River during this study.

	Sampling zones					
	Upstream	**Middle zone**		**Downstream**		
	S1	**S2**	**S3**	**S4**	**S5**	**S6**
Perciformes						
Anabantidae						
Ctenopoma petherici	17	0	17	33	67	83
Channidae						
Parachanna obscura	100	83	50	83	50	33
Eleotridae						
Eleotris senegalensis *	0	0	0	50	17	33
Kribia nana *	0	0	0	0	0	67
Gerreidae						
Eucinostomus melanopterus *	0	0	0	0	67	100
Gobiidae						
Awaous lateristriga *	0	0	0	0	67	83
Sicydium crenilabrum *	0	0	0	0	0	67
Monodactylidae						
Monodactylus sebae *	0	0	0	0	67	67
Polynemidae						
Polydactylus quadrifilis *	0	0	0	0	67	83
Haemulidae						
Pomadasys jubelini *	0	0	0	0	83	100
Pomadasys perotaei *	0	0	0	0	67	100
Carangidae						
Caranx hippos *	0	0	0	0	83	83
Hemicaranx bicolor *	0	0	0	0	100	100
Trachinotus teraia *	0	0	0	0	67	67
Cichlidae						
Chromidotilapia guntheri	83	83	83	83	83	83
Hemichromis fasciatus	83	67	83	83	67	100
Sarotherodon galileus *	50	0	0	0	67	100
Sarotherodon melanotheron *	0	0	0	33	17	17
Oreochromis niloticus **	50	50	67	50	50	100
Tilapia busumana	0	17	0	33	67	67
Tilapia guineensis *	0	17	67	50	100	100
Tilapia mariae	17	83	67	83	83	100
Tilapia zillii	17	33	17	33	67	100
Thysochromis ansorgii *	0	0	0	33	50	33
Tylochromis intermédius *	0	0	0	0	83	100
Tylochromis jentinki *	0	0	0	0	50	100

Tabale 2 continued :						
Tylochromis leonensis *	0	0	0	0	17	83
Lutjanidae						
Lutjanus goreensis *	0	0	0	0	0	50
Siluriformes						
Malapterurudae						
Malapterurus electricus	67	50	33	50	17	67
Claroteidae						
Chrysichthys maurus	0	17	33	17	50	67
Chrysichthys nigrodigitatus	0	17	50	33	83	83
Chrysichthys sp.	0	17	0	17	33	33
Mochokidae						
Synodontis bastiani	0	0	0	33	67	67
Schilbeidae						
Parailia pellucida	17	50	83	67	83	100
Schilbe intermedius	50	67	67	83	83	67
Schilbe mandibularis	0	33	33	83	67	100
Claridae						
Clarias anguillaris	0	17	17	67	83	83
Clarias buettikoferi *	0	0	0	17	33	67
Clarias ebriensis	17	0	50	83	67	67
Heterobranchus isopterus	0	50	50	50	50	67
Heterobranchus longifilis	0	0	50	33	50	83
Synbranchiformes						
Mastacembelidae						
Mastacembelus nigromarginatus	67	33	50	50	17	33
Charaiformes						
Hepsetidae						
Hepsetus odoe	17	17	67	33	50	67
Alestidae						
Brycinus imberi	50	33	33	33	33	33
Brycinus longipinnis	100	100	0	100	100	100
Brycinus macrolepidotus	17	83	83	67	83	83
Brycinus nurse	50	33	33	17	17	17
Micralestes elongatus	33	50	50	17	0	0
Micralestes occidentalis	17	17	33	0	83	67
Osteoglossiformes						
Notopteridae						
Papyrocranus afer	50	50	17	50	17	17
Arapaimidae						
Heterotis niloticus **	33	0	33	50	83	100
Mormyridae						
Brienomyrus brachyistius *	0	0	0	33	50	83
Marcusenius furcidens	83	83	83	67	67	67

Tabale 2 continued :						
Marcusenius senegalensis	67	50	17	33	17	50
Marcusenius sp.	100	83	83	67	83	83
Marcusenius ussheri	83	67	83	33	33	33
Mormyrops anguilloides	50	67	33	33	33	33
Mormyrus rume	33	33	17	33	50	100
Petrocephalus bovei	67	50	67	50	33	33
Pollimyrus isidori	17	17	0	0	50	67
Mugiliformes						
Mugilidae						
Liza falcipinnis *	0	17	0	17	50	67
Elopiformes						
Elopidae						
Elops lacerta *	0	0	0	0	100	100
Clupeiformes						
Clueidae						
Pellonula leonensis *	67	67	17	50	83	67
Cypriniformes						
Cyprinidae						
Barbus ablabes	83	50	50	33	0	0
Barbus trispilos	67	67	67	33	0	0
Barbus wurtzi	0	17	17	67	50	67
Labeo coubie	33	67	67	50	50	83
Labeo parvus	0	33	17	17	83	100
Raiamas senegalensis *	33	0	0	17	50	100
Pleuronectifomes						
Paralichthyidae						
Citharichthys stampflii *	0	0	0	0	83	100

S1 to S6 = sampling sites; Values = fish species occurrences percentage at sites during study period ; * = species with estuarine/marine affinities ; ** = introduced species.

Fish population analyzed

Fish diversity varied with spatial gradients in Ehania River (Fig. 2A). The upstream, with 35 species, was less rich than the middle and downstream areas (46 and 68 respectively). Thirty three (33) species were very common and occurred in almost every sampling zone (Table 2). The upstream and downstream areas gathered 35 species. Moreover, 33 species were common to the upper and middle areas of Ehania basin. Finally, 46 species were common to the lower courses and the middle area. The Mann-Whitney test revealed a significant difference ($p<0.05$) between the species richness of the sampling sites (Fig. 2B). Sampling sites S5 and S6, which are located more downstream, have the highest species richness (Fig. 2B). The 21 species restricted to the downstream of the river are mainly estuarine/marine species (Table 2).

Along longitudinal gradient, beta diversity index recorded was 18 between the upstream and the middle area, and 19 between the middle area and the downstream. The highest beta diversity value, which was observed between the lower and upper course (32), revealed low similarity between both those last sampling zones.

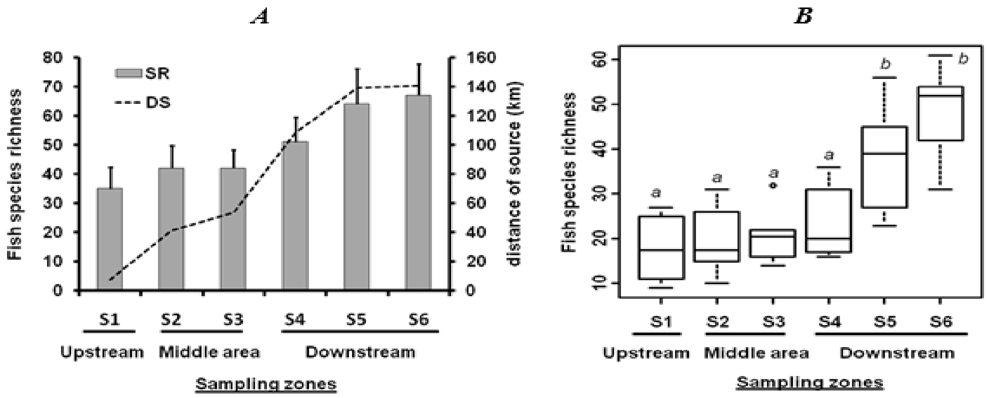

Figure 2: Variations of fish species richness in Ehania River along the longitudinal gradient. S1 to S6 = sampling sites; SR = fish species richness; DS = distance from source; vertical bars (*A*) represent the standard error. The different alphabets (*B*) indicate significant difference in the Mann-Whitney test (p< 0.05).

The Shannon's diversity index and equitability index varied across the river, respectively 1.30 (S3_08) to 5.54 (S6_04) and 0.34 (S3_08) to 0.94 (S6_02) (Figs. 3 and 4). Along the longitudinal gradient, the lowland area had the highest (Mann-Whitney test, p<0.05) diversity index values (Figs. 3 and 4). As for the lowest values (Mann-Whitney test, p<0.05), they were observed at station S3 in the middle part of the River. The temporal variation of diversity index is less marked than spatial variation (Fig. 4). Species richness, Shannon diversity and equitability index do not change significantly from one season to another.

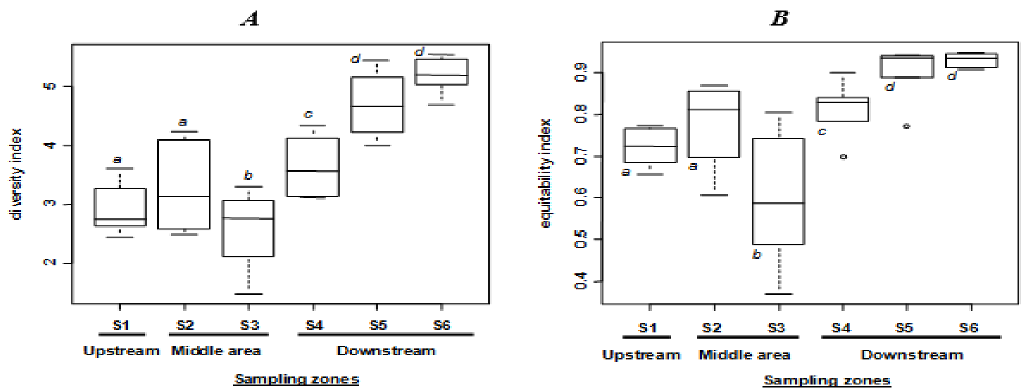

Figure 3: Variations of Shannon-Wiener diversity (*A*) and equitability (*B*) index in Ehania River along the longitudinal gradient. S1 to S6 = sampling sites. The different alphabets indicate significant difference in the Mann-Whitney test (p< 0.05).

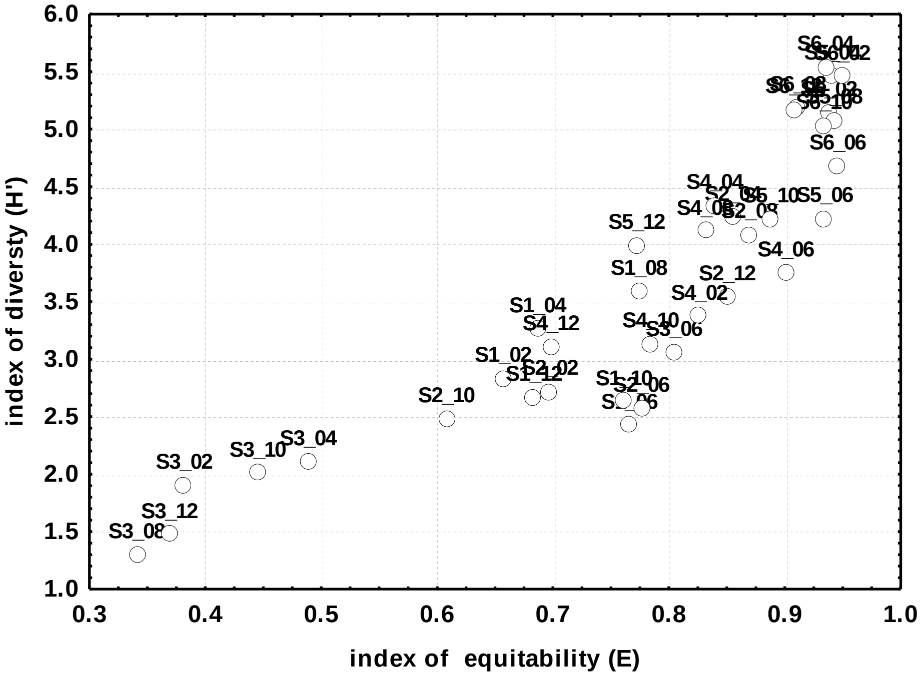

Figure 4: Spatial and temporal variations of fish diversity along the river basis on Shannon's diversity and equitability index. S1 to S6 = sampling sites; Numbers (_02, _04, _06, _08, _10, _12) = sampling months (from February 2010 to December 2010).

Discussion

Examination of the ichtyofauna of the river Ehania shows that Perciformes, Siluriformes, Osteoglossiformes, Characiformes and Cypriniformes are the orders containing the most families and species, as also observed by Teugels *et al.* (1988), Da Costa *et al.* (2000), Konan *et al.* (2006) and Froese and Pauly (2012) in some rivers of the same region. About families, five of them dominate by species number (i.e. Cichlidae, Mormyridae, Alestidae, Cyprinidae, Clariidae), as also mentioned by Da Costa *et al.* (2000) and Konan *et al.* (2006).

The number of species (48), reported by Konan *et al.* (2006) in the Ehania sub-basin, is inferior to those listed in this study (70 species). The differences between these data were mainly related to the sampling procedure, the sampling periods and the types of habitats prospected. Indeed, during this study, we surveyed along the river (from upstream to downstream) through six sites during all four seasons (two dry seasons and two rainy seasons). In addition, sampling sites were chosen so as to explore the maximum habitat. This study increased the richness of the Tano Basin from 79 (Teugels *et al.*, 1988; Konan *et al.*, 2006; Niamien-Ebrottié *et al.*, 2008; Froese and Pauly, 2012) to 104 species.

Fish diversity varied with spatial gradients in Ehania River. Along the longitudinal gradient, total diversity presented a peak in the lowland area, followed distantly by the middle zone. Indeed, the downstream (68 species) was richer in species compared to the middle and headwater areas (respectively 46 and 35), as also observed by Hugueny (1990), Tito de Morais and Lauzanne (1994), Da Costa *et al.* (2000), Koné *et al.* (2003), Konan *et al.* (2006) and Kouamé *et al.* (2008) in other tropical river systems. The reason generally seems to be related to the gradual raise in habitat heterogeneity and diversity (Vannote *et al.*, 1980; Quist and Guy, 2001; Fischer and Paukert, 2008). Petry and Schulz (2006) underlined that fish assemblages reflect structural and physicochemical changes from the upper to the lower reaches.

The beta diversity index calculated between the defined zones indicated significant differences in the species composition pattern among the lower and upper course. We observed biotic zonation with two distinct fish fauna zones: upper river fauna comprised of native fish species and lowland fauna dominated by species with estuarine/marine affinities. Such pattern clearly would denote a longitudinal gradient in fish assemblage distribution in Ehania River basin. The homogeneity in fish composition among up and middle stream stations may result from higher connectivity between stations, since they are contiguous and fish may swim more easily between them than between this upper zone and the lower course. In the river Ehania, dams have been built by fishermen between stations S4 and S5, in downstream, to trap fish. Preventing migration of fish (estuarine/marine species example) above upstream, the dams have the effect of reducing the species diversity of fish fauna in the upper and middle areas of the river. Indeed in this study, we collected 27 estuarine/marine species at station S5 just after dams, against 9 estuarine/marine species collected by Konan *et al.* (2006) at stations S3 and S4 before dams in the same river. In addition, these barriers profoundly alter the spatiotemporal distribution and structure of fish in this river. It was also reported by Diouf *et al.* (1991), Pouyaud (1994), Lévêque and Paugy (1999), Quist and Rahel (2006), Konan *et al.* (2013), that dams impede estuarine/marine fish from migrating upstream during floods, which disturbs their life cycle, especially reproduction in favorable habitats. In the Bia River for example, Da Costa *et al.* (2000) observed that estuarine/marine species, previously observed in the upper course of the Bia River, were restricted to the lowland after the construction of two dams, which have been recognized as a major threat to aquatic fauna (Allan, 1995). The massive presence of estuarine/marine species (38% of species found in Ehania River) can be due to the use of additional food resources, hence optimizing the energy costs of reproduction. This can occur in the lagoon (Albaret and Legendre, 1985), freshwater systems (Bruslé, 1981), and sometimes in the sea (Pillay, 1965).

Among the 22 species reported for the first time in the Ehania River, two introduced species appeared: *H. niloticus* and *O. niloticus*. The presence of this non-native species in Ehania River may be related to the many farm ponds established along this river. Attention should be paid to their spread in this River basin because, according to Rahel (2002), Sax *et al.* (2002), Schulze *et al.* (2006), Leprieur *et al.* (2006), Benejam *et al.* (2007), Trujillo-Jiménez *et al.* (2009) exotic species can have harmful impacts on native species.

Analysis of the diversity indices along Ehania River showed that the lowest values were observed at station S3 in the middle stream. According to Amanieu and Lasserre (1982), Zabi (1993) and Dajoz (2000), the low values of diversity indices characterize undiversified communities with a low degree of organization. The low level of organization of fish communities observed in the middle zone could be related to modes of occupation of the basin. Indeed, the middle part of Ehania River traverses an intense agricultural activity area with many plantations (palm tree, banana, pineapple, coffee, rubber and cocoa). The seasonal drainage flows associated with these agricultural activities constitute sources of pollution to aquatic ecosystems. In addition, many villages along this part of the river discharge their waste (solid and liquid) in the stream. This highly anthropogenic environment could imposea significant stress level on the fish fauna of this part of the river Ehania. Alterations to stream environments can take many forms, including changes in water quality, instream habitat, riparian habitat, and the introduction of new species (Brown, 2000). Leveque and Paugy (1999), Karr and Chu (2000), Bozzetti and Schulz (2004), Rashleigh *et al.* (2009) argue that continental water systems are particularly affected by human activities taking place both in the aquatic environment and on the basin. According to Wootton (1992) and Fischer *et al.* (2010) the resulting living conditions might be unfavorable to some fish species. Moreover, according to Harmelin-Vivien (1992), Leveque (1995), Lemoalle (1999), Brown (2000), Quinn and Kwak (2003), Petry and Schulz (2006), fish populations respond quickly to disturbances of their environment that cause changes in species composition, staffing and trophic structure.

No seasonal significant differences were seen in fish community structure in any sampling site. Species richness, Shannon diversity and equitability index were not changed significantly from one season to another in some rivers in the same sub-region, as also observed by Da Costa *et al.* (2000), and Konan *et al.* (2006). In other tropical regions, Ostrand and Wilde (2002), Bozzetti and Schulz (2004), Flinders *et al.* (2009) suggested that the assemblage structure is determined more by average or persistent differences in environmental conditions among sites, than by seasonal variation in environmental conditions.

As a result of this study of ichthyofauna diversity patterns along spatial gradients, we suggest the following:

- Adequate fishery activity management, taking into account the non-random spatial structure and fish diversity along the longitudinal gradient;

- Maintenance of a monitoring program allowing the study of the fish diversity pattern dynamics of such small coastal rivers.

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