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Diversity patterns and community characteristics of the fish assemblage of a West African lagoon

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Abstract. Coastal lagoons are important habitats in West Africa, being also irreplaceable for many species of fish. The community structure and the diversity patterns of their fish assemblages have however been poorly studied so far. In order to evaluate the community structure and diversity metrics of fish assemblages of one of these lagoons (Lake Togo, Togo), we surveyed four stations that were different in terms of morphological and ecological characteristics, from July to September 2017. The fishing gears were recorded and catches of small-scale fisheries were analyzed. A total of 40 species in 37 genera, 24 families and 10 orders were recorded, with Cichlidae (six species), followed by Eleotridae (five species) and Gobiidae (three species) being the most diverse families. The most abundant species in the catches were: *Sarotherodon melanotheron*, *Coptodon guineensis*, *Chrysischthys nigrodigitatus* and *Ethmalosa fimbriata*. Strict estuarine species (Es) were the most represented forms in the catches. Calculated indices of diversity showed that Lake Togo has moderate diversity and a poor organization of individuals within species.

Key words: fish fauna, community metrics, ecology, Lake Togo

Introduction

Coastal lagoons, especially in tropical regions, are particularly productive habitats due to their exchanges with both marine and inland waters (Laë 1994, Koranteng et al. 1996, Kennish & Paerl 2010). Most lagoons are biodiversity rich, but are also very important for the local communities of fishermen (Koranteng et al. 2000, Addo et al. 2014) because of the high abundance of fishes (Pauly 1976) flourishing on the zooplankton and phytoplankton resources (Issola et al. 2008). According to Ruiz et al. (2012), these lagoon systems are among the most fragile ecosystems in the world (Laë 1997), with growing pressures derived from anthropogenic activities (industry development, enhanced population in the nearby settlements, increasing pollution of the waters, etc.). Thus, a better knowledge of the functioning of these productive but fragile ecosystems can contribute to an efficient management of their natural habitats, thus minimizing anthropogenic pressures (Issola et al. 2008).

Tropical lagoon systems are irreplaceable habitats for many species of fish, crustaceans, molluscs and migratory birds, particularly in tropical regions (Bousso et al. 1992, Dankwa et al. 1999, Kennish & Paerl 2010). Many tropical fish species inhabit lagoons at the juvenile stage and return at sea when adults in order to reproduce (Blaber & Blaber 1980, Day et al. 1989, Albaret & Diouf 1994, Albaret 1999, Albaret et al. 2004, Brando et al. 2004). Scientific knowledge of fish communities in West African lagoons is scanty (Koranteng et al. 2000, Dankwa et al. 2004, 2016), and for Togo the only available data came from Laë (1994), Paugy & Bénech (1989), Okangny (2012) and Lederoun (2015).

Lake Togo represents the main lagoon system of Togo and one of several large lagoons in West Africa (e.g. the Lagos-Lekki lagoons in Nigeria, Lake Nokoué in Bénin, the Keta lagoon in Ghana, the Ebrié lagoon in Côte d'Ivoire). Until few decades ago, Lake Togo was subject to a seasonal dynamic sedimentation process interrupting water connectivity between lake and ocean during the dry season, whereas communication was regular during the wet season. Since more than a decade, because of coastal erosion, there has been a permanent communication between Lake Togo and the ocean through the opening of the Aného channel. This phenomenon has certainly changed the chemical and ecological characteristics of the lake's waters, including changes in fish fauna (see Albaret & Ecoutin 1991). The objective of this work is to provide scientific data on the species diversity and community characteristics of the ichthyological fauna of this West African lagoon system. More in detail, we ask the following key questions: (1) What are the patterns of diversity and abundance among the different species that compose the fish community of Lake Togo? (2) What is the spatial variability of the characteristic community patterns?

Material and Methods

Study area

Located in the south-eastern part of the country, Lake Togo is a wide lagoon 30 km east of Lomé. It is a relatively narrow body of water with an area of 46 km² during the low water period. It is located between latitudes 6°17′42″ and 6°12′18″ North and longitudes 1°22′43″ and 1°36′36″ East (Fig. 1). It is located in the central depression of a sedimentary basin, in direct contact with the outcrops of "terre de barre" formations of Abobo and Togoville which dominate from 30 m above (Blivi 1993). Lake Togo is fed mainly by two rivers: the Zio and the Haho, which lead respectively to the West and to the North of the lagoon. The channels take the waters to the lagoon of Aného where the system communicates episodically with the sea (Wilson-Bahun 2015). The area has a subequatorial climate, with two rainy seasons and a mean yearly rainfall of 900 mm (Wilson-Bahun 2015).

The field study was conducted in four sampling stations (Fig. 2; station 1: Adénykoe, station 2:

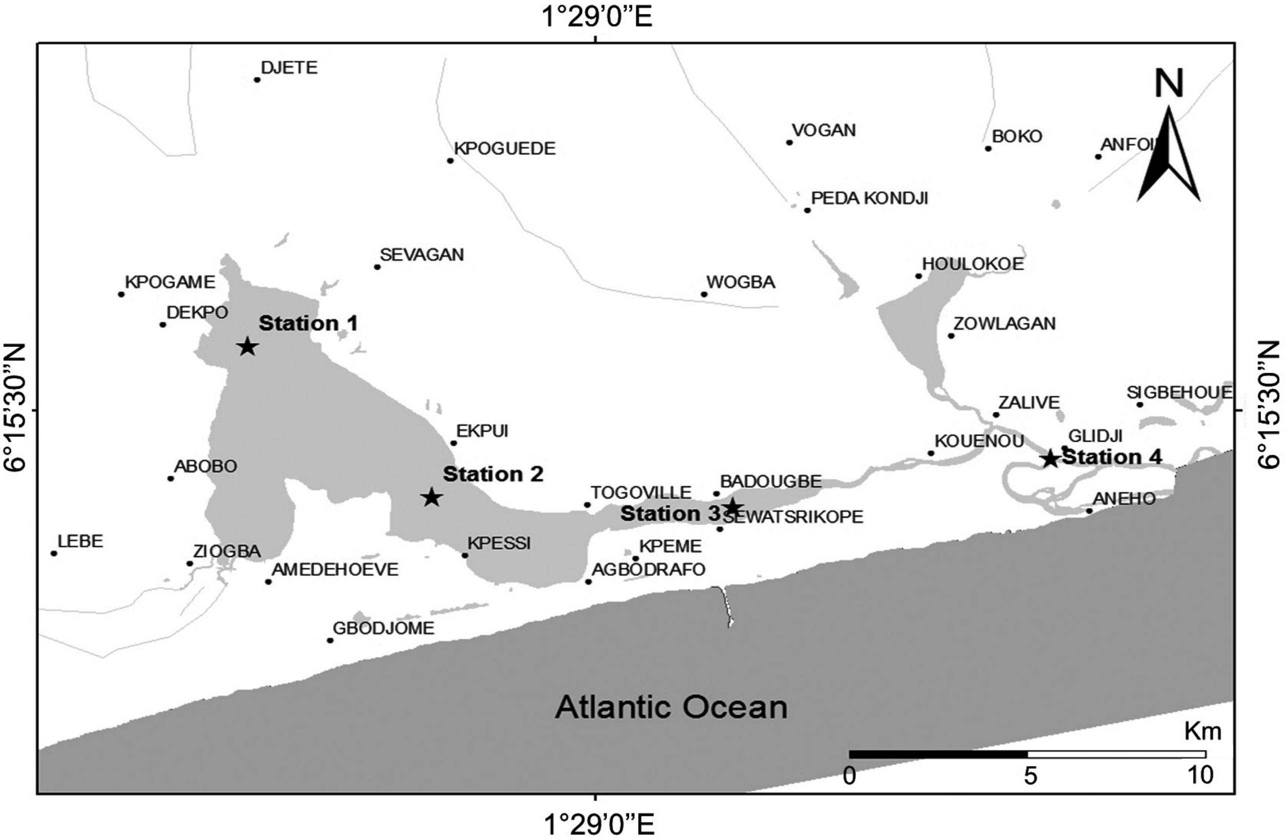

Fig. 1. Map of the study area, with the four sampling stations. Study stations were as follows: station 1 (Adénykoe), station 2 (Amédéhoèvé), station 3 (Sewatrikopé) and station 4 (Pont de Zébé).

Table 1. Physico-chemical parameters (water depth, pH, transparency, conductivity, temperature, oxygen) recorded at the four sampling stations in Lake Togo. Temp = water temperature; Cond = water conductivity; Trans = water transparency.

	Parameter		Adénykoe	Amédéhoèvé	Sewatrikopé	Pont de Zébé
July	Temp (°C)	Surface	26.6	26.4	27.6	-
		Bottom	26.5	26	27.5	-
August	Temp (°C)	Surface	30	27.3	28.7	27.2
		Bottom	30	27.3	28.4	27
September	Temp (°C)	Surface	30.6	29.4	31.3	28.6
		Bottom	30.6	29.3	31.3	28.6
July	pH	Surface	6.81	6.32	6.87	-
		Bottom	6.08	6.29	7.08	-
August	pH	Surface	6.84	6.84	6.85	7.3
		Bottom	6.84	6.84	7.78	6.66
September	pH	Surface	6.68	6.84	6.85	7.69
		Bottom	6.68	6.85	6.85	7.93
July	Cond (µS)	Surface	184	298	325	-
		Bottom	197	310	326	-
August	Cond (µS)	Surface	304	268	3587	332
		Bottom	304	268	3999	300
September	Cond (µS)	Surface	168	162	1442	3999
		Bottom	168	298	1442	3999
July	Trans (cm)		38	60	20	-
August	Trans (cm)		15	60	40	40
September	Trans (cm)		18	70	20	50
July	Water depth (cm)		100	110	200	-
August	Water depth (cm)		70	80	200	260
September	Water depth (cm)		95	100	200	260
July	O_2 (mg/l)	Surface	6.05	6.96	10.55	-
		Bottom	6.78	7.78	9.56	-
August	O_2 (mg/l)	Surface	6.67	4.75	5.96	3.33
		Bottom	6.67	4.75	5.78	4.11
September	O_2 (mg/l)	Surface	6.02	5.98	6.75	6.7
		Bottom	6.02	6.22	6.75	6.28
July	O_2 (%)	Surface	73.6	84.7	132.6	-
		Bottom	95	90	119.6	-
August	O_2 (%)	Surface	86.5	59.1	76.1	41.9
		Bottom	86.5	59.1	74.5	51.5
September	O_2 (%)	Surface	80.4	78	91.7	86.1
		Bottom	80.4	80.3	91.7	79.2

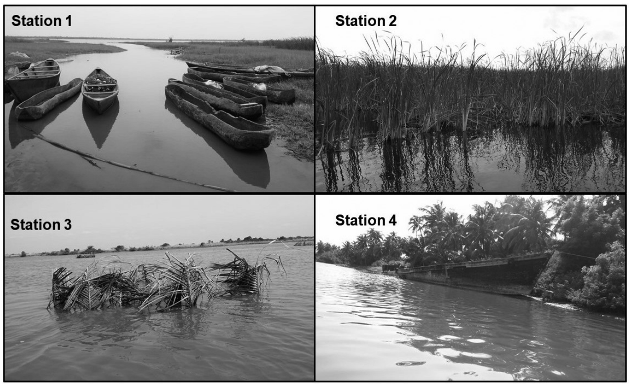

Fig. 2. The four study stations in Lake Togo. Study stations were as follows: station 1 (Adénykoe), station 2 (Amédéhoèvé), station 3 (Sewatrikopé) and station 4 (Pont de Zébé).

Amédéhoèvé, station 3: Sewatrikopé, and station 4: Pont de Zébé). These stations were selected on the basis of their geographical position (they were distant > 7 km), and because they differed remarkably in terms of water parameters (pH, transparency, conductivity and temperature) (Table 1). The bottom of stations 1, 2 and 3 consisted essentially of mud, whereas that of station 4 was sand.

Protocol

Data were collected at the selected stations during the period of July-September 2017. During this period, we visited the various stations early in the morning (between 06:00 and 08:00 a.m.) in order to meet all the fishermen with their catch. Information on fishing gears, mesh of nets used, fishing time and total weight of fish caught were taken (Appendix 1). Hawk net had a mesh size of 1 × 1 cm and gillnets of 2.4 × 2.4 cm. All the captured fishes were counted. In some cases, when the catch was very successful (and high number of fishes were captured), we identified and counted a random sample of the catch, i.e. about ¼ of the total volume. We tagged all samples by date, station and type of gear used and transported in a coolbox to the laboratory. In the laboratory, sampled fish were identified according to the work of Paugy et al. (2003a, b). Fish were sorted by species and their morphometric parameters were taken: total length (Lt), standard length (Ls) and total weight (Pt) were measured. Total and standard lengths were measured to the nearest millimeter using an ichtyometer and the total weight was taken using a KERN 440-49N electronic balance of 0.01g precision.

The species were classified according to the bioecological categories indicated by Albaret (1994) and Albaret et al. (2004): (Co: occasional continental taxa, C: continental taxa with estuarine affinity, Ec: estuarine taxa of continental origin, Es: strict estuarine taxa, Em: estuarine taxa of marine origin, ME: marine-estuarine taxa, Ma: marine accessory taxa, MB: occasional marine taxa). For the taxonomic arrangment, we followed Nelson et al. (2016).

Statistical analyses

For each station, and in each month (July, August and September), we calculated various diversity indices used to analyze the community, such as: species richness, Shannon & Weaver (1948) diversity index, Piélou (1966) evenness index, and Simpson's diversity index (Piélou 1969, Pearson & Rosenberg 1978). Species richness (S): is the number of species represented in the catches. Shannon & Weaver's (1948) diversity index (H'):

$$H' = -\sum_{i=1}^{S} P_i \,(\mathrm{Log}_2 P_i)$$

with $P_i = n_i/N$; N being the total number of individuals obtained for all species, n_i is the number of individuals of species i and P_i the relative abundance of species i in the sample.

Simpson's diversity index $(1-D)$: this index is calculated by subtracting the Simpson index from its maximum value: 1 (Piélou 1969, Pearson & Rosenberg 1978). It therefore varies from 0 to 1. The formula is:

$$D = 1 - \sum_{i=1}^{S} \frac{n_i\,(n_i - 1)}{N\,(N - 1)}$$

with n_i = number of individuals in species i and N = total number of individuals.

Piélou's evenness index (E): It allows to see if the individuals are equitably distributed among the species of the target area, and varies between 0 and 1. It tends towards 0 when almost the totality of the catches is concentrated on one species and towards 1, when all species have the same abundance within the given sample. It is calculated according to the formula:

$$E = H'/\log_2 S$$

with S being the specific richness and H' being the Shannon diversity index.

Bootstrap analysis was applied to generate upper and lower confidence intervals of all indices, with 9999 random samples, each with the same total number of individuals as in each original sample being generated (Harper 1999). A Principal Component Analysis (PCA) was used to arrange the various stations in a multivariate space on the basis of the presence/absence + abundance of the various fish species (Hammer 2012). In this analysis, selection

Table 2. Synopsis of the total number of fish recorded by species and by station at Lake Togo, Togo. Study stations were as follows: station 1 (Adénykoe), station 2 (Amédéhoèvé), station 3 (Sewatrikopé) and station 4 (Pont de Zébé). St = station.

Species	St1	St2	St3	St4
Bostrychus africanus (Steindachner, 1880)	0	1	0	0
Chromidotilapia guntheri (Sauvage, 1882)	0	9	13	0
Chrysichthys (Chrysichthys) maurus (Valenciennes, 1840)	0	1	0	0
Chrysichthys (Melanodactylus) nigrodigitatus (Lacépède, 1803)	5	50	21	15
Citharichthys stampflii (Steindachner, 1895)	0	4	0	0
Clarias ebrensis (Pellegrin, 1920)	0	1	0	0
Clarias (Clarias) gariepinus (Burchell, 1822)	5	5	0	0
Coptodon guineensis (Günther, 1862)	45	43	31	4
Cynoglossus senegalensis (Kaup, 1858)	0	0	1	1
Dalophis cephalopeltis (Bleeker, 1863)	0	0	1	0
Dormitator lebretonis (Steindachner, 1870)	0	49	0	0
Eleotris senegalensis Steindachner, 1870	0	1	0	0
Eleotris vittata Duméril, 1858	0	1	0	0
Elops senegalensis Regan, 1909	0	5	9	1
Ethmalosa fimbriata (Bowdich, 1825)	0	48	134	1
Eucinostomus melanopterus (Bleeker, 1863)	0	2	28	1
Gymnarchus niloticus Cuvier, 1829	0	1	0	0
Gobioides africanus (Giltay, 1935)	0	0	1	0
Gobionellus occidentalis (Boulenger, 1909)	0	0	3	0
Hemichromis bimaculatus Gill, 1862	0	8	0	0
Hemichromis fasciatus Peters, 1857	2	22	1	0
Hepsetus odoe (Bloch, 1794)	1	0	0	0
Heterotis niloticus (Cuvier, 1829)	0	2	0	0
Hyporamphus picarti (Valenciennes, 1847)	0	0	1	0
Kribia kribensis (Boulenger, 1907)	0	3	0	2
Liza falcipinnis (Valenciennes, 1836)	0	0	3	0
Lutjanus agennes (Bleeker, 1863)	0	0	2	9
Lutjanus goreensis (Valenciennes, 1840)	0	13	0	0
Monodactylus sebae (Cuvier, 1829)	0	0	1	0
Mugil cephalus Linnaeus, 1758	0	0	5	18
Oreochromis niloticus (Linnaeus, 1758)	1	3	0	0
Parachanna obscura (Günther, 1861)	0	3	0	0
Pellonula leonensis Boulenger, 1916	0	1	0	0
Periophthalmus barbarus (Linnaeus, 1766)	0	0	0	1
Pomadasys jubelini (Cuvier, 1830)	0	0	4	41
Protopterus annectens annectens (Owen, 1839)	1	0	0	0
Sarotherodon melanotheron Rüppel, 1852	160	253	299	4
Schilbe intermedius Rüppell, 1832	1	2	0	1
Synaptura lusitanica Capello, 1868	0	2	0	0
Synodontis nigrita Valenciennes, 1840	2	1	0	0

of the factors was based on Kaiser's criterion, which retained all factors with eigenvalue ≥ 1. All statistical tests were performed with Past 3.0 software, with alpha being set at 5 %.

Results

General community characteristics

Overall, 1414 fish (1401 individuals from multiply captured species and 13 singletons) were identified in

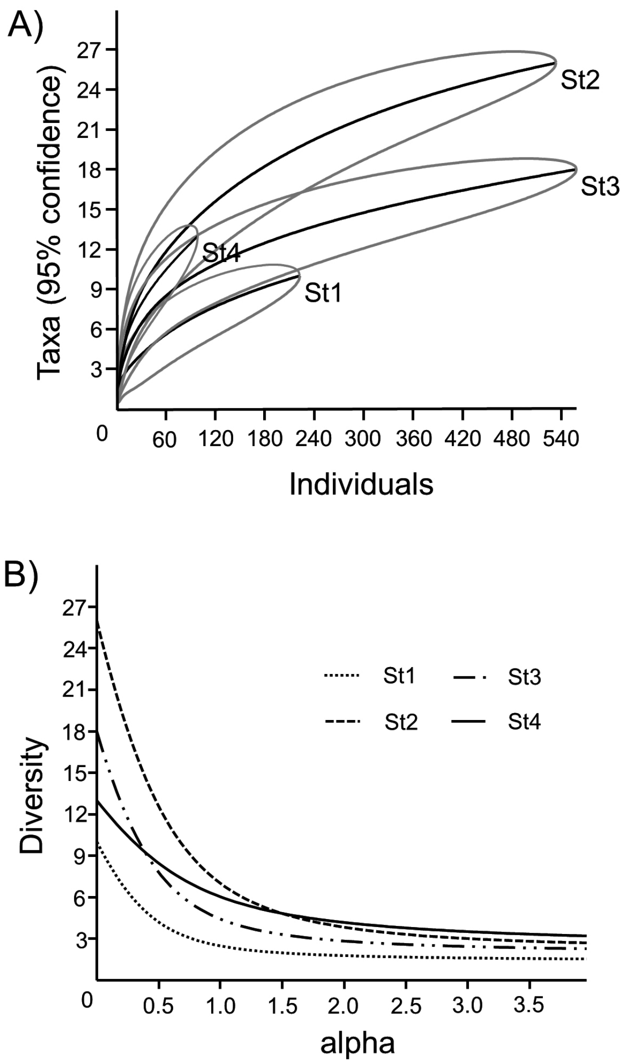

Fig. 3. (A) Saturation curves (with 95 % confidence intervals after 9999 bootstraps) and (B) Diversity profiles (95 % confidence, after 9999 bootstraps), for the community diversity of fish in the four stations at Lake Togo, Togo. Study stations were as follows: station 1 (Adénykoe), station 2 (Amédéhoèvé), station 3 (Sewatrikopé) and station 4 (Pont de Zébé), St = station.

the four study stations (Table 2). Most singletons (35 %) occurred in station 2. Fish individuals were caught using several fishing gears (Appendix 1). A total of 40 species have been recorded throughout Lake Togo.

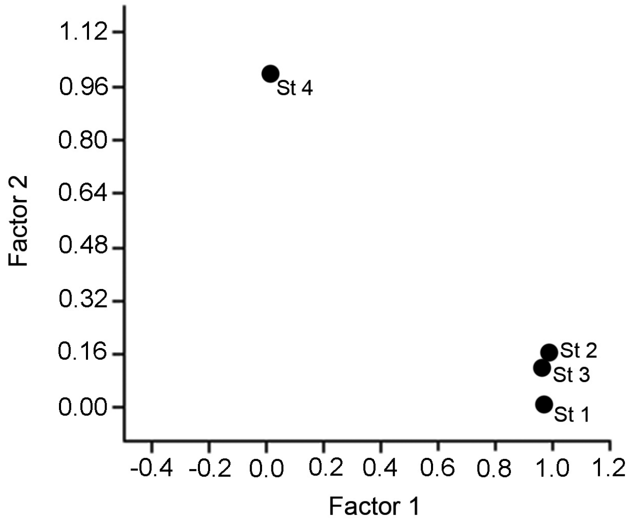

Fig. 4. Scores of the first two factors extracted by a principal component analysis (PCA) performed on the number of fish species by station (St).

They are divided into 37 genera, 24 families and 10 orders. The most diverse families were Cichlidae (six species), Eleotridae (five species) and Gobiidae (three species). All other families were represented by one or two species each. Strict estuarine taxa were the most represented (13 species) while occasional marine taxa were the least represented (a single species) in our samples (Appendix 2).

Sarotherodon melanotheron dominated our samples (> 50 % in terms of individuals and biomass in three out of four stations), followed by *Ethmalosa fimbriata* (13 %), *Coptodon guineensis* (8.8 %) and *Chrysichthys nigrodigitatus* (6 %), all other species each representing less than 5 % of the catches (Table 2). However, in station 4 our catches were dominated by *Pomadasys jubelini* (41.4 %) in terms of individuals, and by *Chrysichthys nigrodigitatus* (32.4 %) and *Mugil cephalus* (31.5 %) in terms of biomass. The synopsis of the number of fish individuals captured by month is given in Table 3, whereas the number of captured individuals per month is reported in Appendix 3.

Table 3. Diversity indices of samples taken in Lake Togo. H' = Shannon and Weaver diversity index, D = Simpson diversity index and E = evenness index. Study stations were as follows: station 1 (Adénykoe), station 2 (Amédéhoèvé), station 3 (Sewatrikopé) and station 4 (Pont de Zébé). St = station.

	H'	D	E
Lake Togo total (all stations pooled)	2.76	0.71	0.52
Station 1	1.32	0.45	0.40
Station 2	2.74	0.73	0.58
Station 3	2.24	0.66	0.53
Station 4	2.59	0.77	0.70

Spatial variation in community diversity metrics
Diversity metrics varied considerably from station to station. Individual rarefaction curves (Fig. 3A) revealed that community diversity was higher in station 2 (27 species that accounted for 67.5 % of all fish fauna in the lake) than in the other three stations, followed by station 3 with 18 species (46.1 %), station 4 with 13 species (33.3 %) and station 1 with 10 species (25.6 %). However, our bootstrapping procedure showed that station 4 was similar to station 2 but apparently less satisfyingly analyzed (its saturation curve did not reach a plateau phase; Fig. 3A), with station 1 characterized by a considerably lesser species diversity than the other three stations (Fig. 3A). Diversity profiles, however, showed a relative similarity across sampling stations in relation to the alpha values (Fig. 3B). In terms of taxonomic diversity and abundance, factor scores of a PCA analysis (determinant of correlation matrix = –1.876) showed that stations 1, 2 and 3 were most similar, whereas station 4 was placed in a entirely different sector of the multivariate space (Fig. 4). In this analysis, Factor 1 (eigenvalue = 2.847) explained 71.2 % of the total variance, whereas Factor 2 (eigenvalue = 1.00) explained 25 % of the total variance.

Indices of diversity showed that station 4 had a much higher E than the other three stations (Table 3). Both the H' and the D values for Lake Togo (i.e. with the four stations pooled) revealed an average diversity (2.5 < H' < 3.9). On the other hand, the average E index of the lake had a value (E = 0.53, Table 3) that is compatible with a poorly even frequency distribution across species. This can be explained by the fact that some species such as *Sarotherodon melanotheron* and *Ethmalosa fimbriata*, for example, dominated the catches while others were singletons in our samples.

Discussion
In Lake Togo, we observed a total of 40 species, with a dominance of continental and estuarine taxa in our catches, probably because our study period coincides with the flooding period on the lagoon (Albaret & Ecoutin 1990, 1991). Fish assemblages inhabiting lagoon environments and estuaries, especially if close to the channels of communication with the ocean, are usually heterogeneous and unstable (Albaret & Ecoutin 1990), and it is likely that the same instability could characterize Lake Togo fish communities as well.

We inventoried a considerably higher species richness than those obtained by Paugy & Bénech (1989; n = 26 species divided into 22 genera and 14 families in the coastal lagoon system of Togo) and Lederoun et al. (2018, 29 species belonging to 23 genera and 18 families in the lower Mono River basin). Among the species mentioned by Paugy & Bénech (1989), only six (*Hepsetus odoe*, *Chrysichthys auratus*, *Clarias gariepinus*, *Parachanna obscura*, *Chromidotilapia guntheri* and *Hemichromis fasciatus*) were found in our samples. This may be due to the fact that Paugy & Bénech (1989) sampled in the streams that feed the lake, while in the case of this study we sampled only the lake. Thus, the species inventoried in this study may be added to those obtained by Paugy & Bénech (1989) to produce an updated checklist of the species of the basin. The most diverse fish families on Lake Togo were Cichlidae (six species), Eleotridae (five species) and Gobiidae (three species). Clariidae, Claroteidae, Clupeidae, Lutjanidae and Mugilidae were each represented by two species. The absence of Mormyridae in the catch might be explained by the high conductivity of the lake water during the study period (1124.79 ± 1123.55 µS/cm) as according to Lévêque & Paugy (2006), there is no Mormyridae in waters with conductivity greater than 500 µS/cm. Nonetheless, it should be remarked that this is not a general rule as, for instance, the conductivity of Lake Tanganyika is over 650 µS/cm (De Wever et al. 2005) and yet there are Mormyridae species recorded from the lake (e.g. Kuwamura 1987).

The richness of Lake Togo fish communities can be explained by the fact that the lagoon connects the Zio and Haho rivers (and their tributaries) and the sea. It can also be due to the existence of riparian wetlands that represent both an important source of food and spawning grounds for several species of fish (Montchowui et al. 2007). The specific richness of Lake Togo is consistent with data from Eyi et al. (2016) and Adou et al. (2017) who recorded 39 and 40 species respectively in the Ono Lagoon and Lake Ayamé 2 in Côte d'Ivoire. Species richness was lower than that of the River Hlan in Bénin (43 species of fish divided into 35 genera and 22 families, see Montchowui et al. 2007), to the Baoulé and Bagoé rivers in the Niger River basin in Mali (over 70 species, Sanogo et al. 2012, 2015) or to southern Nigeria's waterbodies (mean number of species per site was 44.6 ± 19.1; median = 49, range 18-79; Amadi et al. 2017). Lederoun (2015) identified 91 fish species belonging to 67 genera and 42 families in the whole of the Mono River basin (including the river and lagoons) between Togo and Bénin.

The difference between the values of species richness of the present study and of some previous studies (e.g.

Montchowui et al. 2007, Lederoun 2015) could be due to sampling effort (overall study duration, number of study stations, diversity of techniques and gears used in the sampling and the area of the water bodies concerned), as our study was conducted for three months in four stations while the studies cited covered at least six months in a higher number of sampling stations. Also, the fact that our data came just from small-scale fisheries targeting species with economic value for fishermen may justify this low species richness. If otherwise our data were supplemented with data coming from also experimental and electrical fisheries (Lévêque & Paugy 2006), higher number of species would have been likely detected. In addition, the low richness of detected species may also be due to the shallow depth of the lake because the variation in species richness is a function of the depth of the water body (e.g. Hugueny 1990, Amoussou 2016).

Spatial variation in fish community composition

Our data on spatial variation in fish community composition may be affected by the different fishing gear that were deployed to capture fish by local communities. While in two localities out of four, the fishermen only used the hawk net (stations 3 and 4), on station 1 they used only gill net, and in station 2 fishermen used several fishing gears such as longlines, gill nets, traps and hawk nets. Therefore, a direct comparison among localities may be problematic (for instance, the much higher diversity of species detected in station 2 may be partially due to the use of several fishing gears by fishermen). In addition, it cannot be excluded that fisherman-based collection may be at least partially biased towards the species that people like to catch, basically meaning that they may have optimized their device (such as gill net mesh size) and fishing spots (microhabitats) in order to get most of the species that have high economic values and that they prefer for their own consumption. If so, these biases might have positively influenced the abundance of the cichlid species *Sarotherodon melanotheron* and *Coptodon guineensis* in our samples.

Despite the above-mentioned considerations, the differences between Amédéhoèvé (station 2) and the other three sampling stations can be explained by other factors such as the much higher transparency of water (about 70 cm, Appendix 1). According to Amoussou (2016), habitat greatly influences biotic interactions and several vital functions such as reproduction, feeding, shelter (security against predation), etc. In this regard, since Amédéhoèvé has a much more abundant aquatic vegetation than the other stations, its habitat should be much more heterogeneous, which reduces interspecific competition and, as a result, contributes to an higher diversity of species.

At three out of four stations, the catches were dominated by *Sarotherodon melanothron* individuals, whereas in station 4 the most dominant species were *Pomadasys jubelini* in terms of number of captured individuals and *Chrysichthys nigrodigitatus* in terms of biomass. All of these dominant species were herbivores/omnivores, thus confirming that herbivore/omnivore species tend to dominate West African assemblages of fishes (Amadi et al. 2017). The remarkable difference between station 4 and all other stations in terms of fish diversity (as highlighted by our PCA analysis) mirrors differences also in bottom structure, as station 4 has a sandy and not a mud bottom as the other three sites.

All the values of the various diversity indices calculated from the present data are characteristic of moderately diverse communities with a low degree of organization of individuals within species (Eyi et al. 2016). However, it should be noted that these indices varied between the sampling stations, thus showing that the whole of Lake Togo cannot be considered as a homogeneous area in terms of fish communities diversity and functioning. For instance, at Amédéhoèvé (station 2), H' was very high (H = 2.74) but with a weak evenness (E = 0.58). The low value of E is explained by the strong dominance of *Sarotherodon melanothron* in the catches. On the other hand, at Pont de Zébé (station 4), the opposite was true, with H' being low (H' = 2.59) and evenness being high (E = 0.70). Thus, further stations should be studied in order to obtain a more comprehensive view of the variation of fish community in the various areas/habitats of the lagoon.

The permanent opening of the Aného channel, connecting the lagoon with the ocean, over the last ten years has most likely brought consequences for the renewal of the lake's stock. According to Albaret & Ecoutin (1991), it causes profound changes in the nature of fish populations. However, our data are not yet sufficient to draw any firm conclusions on this issue.

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Appendix 1. Fishing effort in the four study stations in Lake Togo.

Date	12/7/2017	18/7/2017	18/7/2017	31/7/2017	31/7/2017	31/7/2017	31/7/2017	10/8/2017
Station	Amédéhoèvé	Amédéhoèvé	Sewatrikopé	Adénykoe	Amédéhoèvé	Amédéhoèvé	Amédéhoèvé	Pont de Zébé
Fishing gear	longline	gillnet	hawk net	gillnet	gillnet	traps	hawk net	hawk net
Fishing time (hours)	4	6	5	7	6	8	3	4
No. of fishermen	1	1	1	2	1	1	2	2
No. fishing gear	2	12	1	6	4	10	2	2
Weight of the fish sample	2338.40	1825.35	1659.75	4528.42	806.96	532.68	771.17	5450.32
Date	10/8/2017	10/8/2017	10/8/2017	29/8/2017	14/9/2017	14/9/2017	14/9/2017	
Station	Amédéhoèvé	Amédéhoèvé	Adénykoe	Sewatrikopé	Amédéhoèvé	Pont de Zébé	Sewatrikopé	
Fishing gear	gillnet	hawk net	gillnet	hawk net	hawk net	hawk net	hawk net	
Fishing time (hours)	6	5	7	6	5	3	2	
No. of fishermen	2	2	1	2	3	1	2	
No. fishing gear	6	2	4	1	3	1	1	
Weight of the fish sample	5011.09	1721.63	3493.88	3637.16	5715.21	2390.00	3057.69	

Appendix 2. List of fish inventoried in Lake Togo. Bioecological categories follow Albaret (1994) and Albaret et al. (2004). Ad = Adénykoe, Am = Amédéhoèvé, Se = Sewatrikopé, Pz = Pont de Zébé, Cat = Bioecological categories, x = Presence of species.

Orders	Families	Species	July				August				September				Cat
			Ad	Am	Se	Pz	Ad	Am	Se	Pz	Ad	Am	Se	Pz	
Perciformes	Cichlidae	*Sarotherodon melanotheron* Rüppel, 1852	x	x	x		x	x	x	x		x	x		Es
Clupeiformes	Clupeidae	*Ethmalosa fimbriata* (Bowdich, 1825)		x	x				x	x		x	x		Em
Perciformes	Cichlidae	*Coptodon guineensis* (Bleeker in Günther, 1862)	x	x	x		x	x	x	x		x	x	x	Es
Siluriformes	Claroteidae	*Chrysichthys (Melanodactylus) nigrodigitatus* (Lacépède, 1803)		x	x		x		x	x		x	x	x	Ec
Perciformes	Eleotridae	*Dormitator lebretonis* (Steindachner, 1870)		x											Es
Perciformes	Haemulidae	*Pomadasys jubelini* (Cuvier, 1830)			x				x	x				x	Em
Perciformes	Gerreidae	*Eucinostomus melanopterus* (Bleeker, 1863)		x	x				x	x		x	x		ME
Perciformes	Cichlidae	*Hemichromis fasciatus* Peters, 1852	x	x			x	x	x			x			Ec

Appendix 2. Continued

Perciformes	Lutjanidae	*Lutjanus goreensis* (Valenciennes, 1840)		x	x				x	x				x	Ma
Perciformes	Mugilidae	*Mugil cephalus* Linnaeus, 1758			x					x				x	ME
Perciformes	Cichlidae	*Chromidotilapia guntheri* (Sauvage, 1882)										x	x		Co
Elopiformes	Elopidae	*Elops senegalensis* Regan, 1909		x	x				x	x			x		Ma
Siluriformes	Clariidae	*Clarias (Clarias) gariepinus* (Burchell, 1822)	x	x			x					x			Co
Perciformes	Cichlidae	*Hemichromis bimaculatus* Gill, 1862		x								x			Co
Perciformes	Eleotridae	*Kribia kribensis* (Boulenger, 1907)		x						x					Es
Pleuronectiformes	Paralichthydae	*Citharichthys stampflii* (Steindachner, 1895)		x								x			Em
Perciformes	Cichlidae	*Oreochromis niloticus* (Linnaeus, 1758)	x					x				x			Co
Siluriformes	Schilbeidae	*Schilbe intermedius* Rüppell, 1832					x	x		x		x			Ce
Perciformes	Gobiidae	*Gobionellus occidentalis* (Boulenger, 1909)			x										Es
Perciformes	Mugilidae	*Liza falcipinnis* (Valenciennes, 1836)			x				x						Em
Perciformes	Channidae	*Parachanna obscura* (Günther, 1861)						x							Ce
Siluriformes	Mochokidae	*Synodontis nigrita* Valenciennes, 1840					x					x			Co
Pleuronectiformes	Cynoglossidae	*Cynoglossus senegalensis* (Kaup, 1858)			x					x					Em
Osteoglossiformes	Osteoglossidae	*Heterotis niloticus* (Cuvier, 1829)										x			Co
Pleuronectiformes	Soleidae	*Synaptura lusitanica* Capello, 1868		x											Ma
Characiformes	Hepsetidae	*Hepsetus odoe* (Bloch, 1794)					x								Co
Beloniformes	Hemiramphidae	*Hyporamphus picarti* (Valenciennes, 1847)							x						Ma
Perciformes	Monodactylidae	*Monodactylus sebae* (Cuvier, 1829)											x		Es
Clupeiformes	Clupeidae	*Pellonula leonensis* Boulenger, 1916		x											Ec
Perciformes	Gobiidae	*Periophthalmus barbarus* (Linnaeus, 1766)								x					Es
Ceratodontiformes	Protopteridae	*Protopterus annectens annectens* (Owen, 1839)	x												Co

Appendix 2. Continued

Perciformes	Gobiidae	*Gobioides africanus* (Giltay, 1935)			x		Es
Perciformes	Lutjanidae	*Lutjanus agennes* Bleeker, 1863			x		Mo
Siluriformes	Claroteidae	*Chrysichthys (Chrysichthys) auratus* (Geoffroy Saint-Hilaire, 1808)		x			Ec
Perciformes	Eleotridae	*Eleotris vittata* Duméril, 1858		x			Es
Perciformes	Eleotridae	*Eleotris senegalensis* Steindachner, 1870		x			Es
Perciformes	Eleotridae	*Bostrychus africanus* (Steindachner, 1880)		x			Es
Anguilliformes	Ophichthyidae	*Dalophis cephalopeltis* (Bleeker, 1863)			x		Es
Siluriformes	Clariidae	*Clarias (Anguilloclarias) ebriensis* Pellegrin, 1920		x			Es
Osteoglossiformes	Gymnarchidae	*Gymnarchus niloticus* Cuvier, 1829	x			x	Co

Appendix 3. Synopsis of the number of fish individuals captured by month.

Species	July	August	September
Bostrychus africanus (Steindachner, 1880)	1	0	0
Chromidotilapia guntheri (Sauvage, 1882)	0	0	22
Chrysichthys (Chrysichthys) maurus (Valenciennes, 1840)	1	0	0
Chrysichthys (Melanodactylus) nigrodigitatus (Lacépède, 1803)	59	23	9
Citharichthys stampflii (Steindachner, 1895)	3	0	1
Clarias ebrensis Pellegrin, 1920	1	0	0
Clarias (Clarias) gariepinus (Burchell, 1822)	7	2	1
Coptodon guineensis (Günther, 1862)	41	55	27
Cynoglossus senegalensis (Kaup, 1858)	1	1	0
Dalophis cephalopeltis (Bleeker, 1863)	1	0	0
Dormitator lebretonis (Steindachner, 1870)	49	0	0
Eleotris senegalensis Steindachner, 1870	1	0	0
Eleotris vittata Duméril, 1858	1	0	0
Elops senegalensis Regan, 1909	12	2	1
Ethmalosa fimbriata (Bowdich, 1825)	58	81	44
Eucinostomus melanopterus (Bleeker, 1863)	16	13	2
Gymnarchus niloticus Cuvier, 1829	1	1	0
Gobioides africanus (Giltay, 1935)	1	0	0
Gobionellus occidentalis (Boulenger, 1909)	3	0	0
Hemichromis bimaculatus Gill, 1862	7	0	1
Hemichromis fasciatus Peters, 1857	4	6	15
Hepsetus odoe (Bloch, 1794)	0	1	0
Heterotis niloticus (Cuvier, 1829)	0	0	2
Hyporamphus picarti (Valenciennes, 1847)	0	1	0
Kribia kribensis (Boulenger, 1907)	3	2	0
Liza falcipinnis (Valenciennes, 1836)	2	1	0
Lutjanus agennes Bleeker, 1863	1	9	1
Lutjanus goreensis (Valenciennes, 1840)	13	0	0
Monodactylus sebae (Cuvier, 1829)	0	0	1
Mugil cephalus Linnaeus, 1758	5	3	15
Oreochromis niloticus (Linnaeus, 1758)	1	2	1
Parachanna obscura (Günther, 1861)	0	3	0
Pellonula leonensis Boulenger, 1916	1	0	0
Periophthalmus barbarus (Linnaeus, 1766)	0	1	0
Pomadasys jubelini (Cuvier, 1830)	3	39	3
Protopterus annectens annectens (Owen, 1839)	1	0	0
Sarotherodon melanotheron Rüppel, 1852	173	330	213
Schilbe intermedius Rüppell, 1832	0	3	1
Synaptura lusitanica Capello, 1868	2	0	0
Synodontis nigrita Valenciennes, 1840	0	2	1
Totals	473	580	361