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Inventorying the ichthyologic fauna of Ahémé Lake and its Channels (South-West Benin, West Africa)

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Abstract

The present study aims at contributing to a better understanding of Lake Ahémé and its surroundings together with its channels through an update of its fish fauna. The study covers twelve months, from May 2016 to April 2017. Fish specimens which were examined were collected from catches by fishermen as well as from monthly experimental fishing at 19 stations. A total of 73 fish species belonging to 59 genera and 38 families were identified. The Gobiidae family is the most represented with 6 species; the Carangidae and Cichlidae families are next, with 5 species each; then comes the Clupeidae with 4 species; and the Eleotridae, Clariidae, and Lutjanidae families with 3 species each. Strictly estuarine species (E) dominate the population and account for 87.7% of the total species richness

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Introduction

Estuaries and lagoons are ecosystems of great ecological importance. They play an interface role between continental and marine environments. However, functional complexity varies widely from one environment to another (Charbonnel *et al.*, 1995). They are diverse, productive habitats that are rich in nutrients. These nutrients support the establishment and growth of many animal populations, such as marine fish species, crustaceans, and other species such as planktonic communities and macro invertebrates (Cardona, 2000; Adandédjan, 2012). These environments play a vital role in the life cycle of many biological species. They are home to important animal and plant biological diversity (Ahouansou, 2011). On the other hand, fish fauna is an important source of protein and income for the populations (Jouffre, *et al.,* 2005).

Lake Ahémé and its channels, located in southwestern Benin, constitute an ecosystem that plays an important role in the economy of the region. The local population exerts all kinds of pressure to secure most of their food for survival. But this previously identified human pressure on aquatic ecosystems is neglected (Gourene *et al.*, 1999; Villanueva, 2004). In fact, in the area covered by Lake Ahémé and its channels, socio-economic development requirements have led to activities with recursive threats to aquatic ecosystems (Oyédé, 1983; Paugy *et al.*, 2003; ADELAC, 2018). The construction of hydroelectric dams in Nangbeto, the discharge of industrial and domestic waste, the leaching of cultivated land and the overexploitation of resources, further weaken these already confined environments characterized by overpollution and low renewal of the water (Adandédjan, 2012).

In order to tackle this situation, the national government of Benin has decided to rehabilitate Ahémé Lake and its channels. Thus, the intercommunal program for the rehabilitation of Ahémé Lake and its channels was conceived. This program aims at rehabilitating Ahémé Lake and its channels through dredging. Integrated Development for Economic Zone of Ahémé Lake and its Channels Agency (ADELAC), is a Government office which charge to execute this Program.

But dredging can potentially lead to disturbances in the aquatic ecosystem. On the other hand, no scientific work has been carried out to date on the fish species of those water bodies. So, the purpose of the present study is to develop an inventory of those fish species before the upcoming dredging and provide the lacking scientific information regarding the fish species of the study area. Specifically, this study will collect, identify, and conserve specimens from all fish species obtained in the study area. This will serve as reference data for all aquatic ecosystems involved in this dredging.

Material and methods

Study area

Benin has an important hydrographic network comprising four systems in which Lake Ahémé and its channels are included: maritime, lagoon, lacustrine and fluvial. Lake Ahémé is a major water body located in southwestern Benin. It is part of a fluvial-lacustrine and lagoon complex with a significant biodiversity and fragile and valuable ecosystem. It covers an average area of 85km² and is located between latitudes 6°20’ and 6°40’ N and longitudes 1°55’ and 2°00’ E (Viaho, 2014). Trapped between the Kpomassè and Comé plateaus, it is fed by waters from the Couffo and Mono rivers and flows into the ocean through the Ahô channel, the coastal lagoons of Grand-Popo., and the mouth of the "Bouche du Roy". The study area covers municipalities bordering Lake Ahémé and its channels, namely: Bopa, Comé, Grand-Popo, Houéyogbé, Kpomassè, and Ouidah (Fig. 1).

According to ADELAC (2018), the study area benefits from a subequatorial Beninian climate characterized by the two rainy seasons and two dry seasons distributed as follows:

- Major rainy season: mid-March to mid-July;
- Small rainy season: mid-September to November;

- Long dry season: December to mid-March;
- Short dry season: mid-July to mid-August.

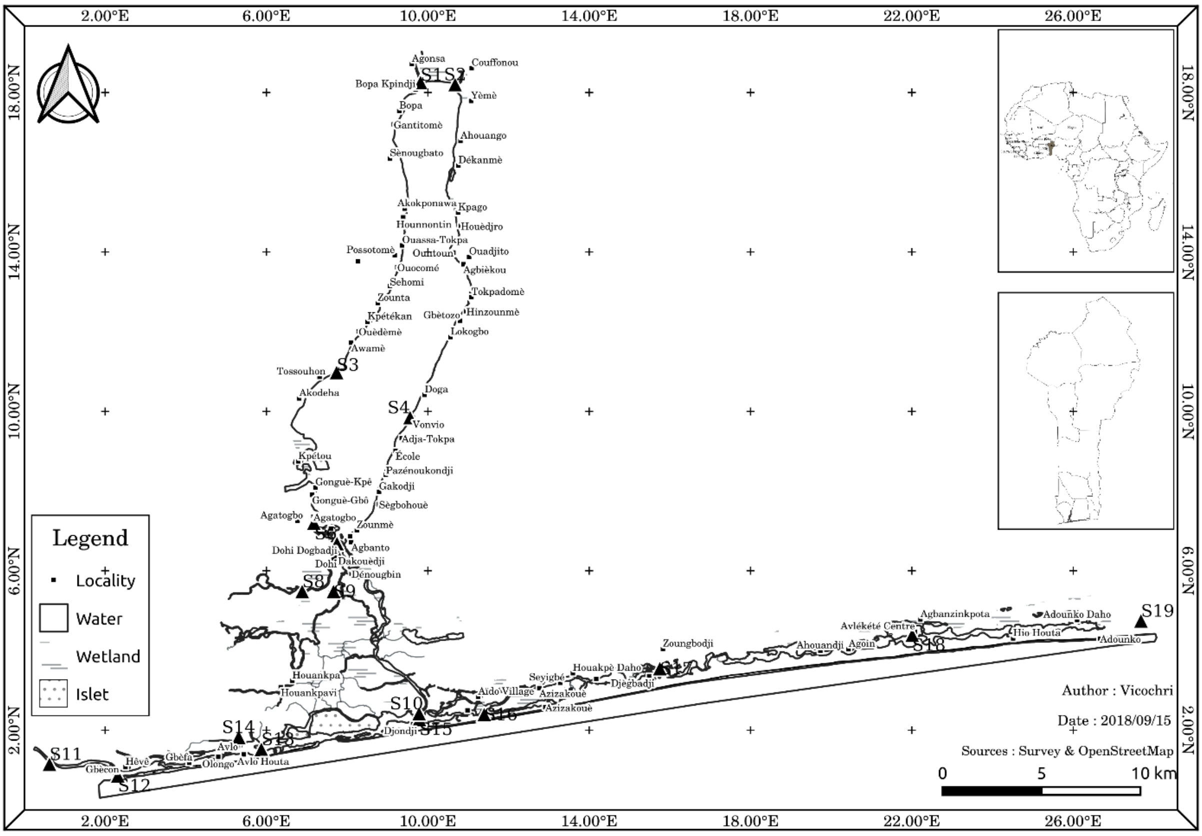

Fig. 1. Geographical location of Ahémé Lake and its channels.

Rainfall amounts are higher on the one hand in May, June and July when they exceed 120mm with a peak in June (196.9mm in the Comè municipality in 2017) and 296.5mm in the Ouidah municipality in 2017) and are higher elsewhere in September and October. In December, January and February (dry months), recorded rainfall amounts are less than 40mm. The first rainy season concentrates 40 to 60% of the rainfall compared to 18 to 30% for the second. The average number of rainy days is higher in June during the major rainy season and is higher in October for the small rainy season. Temperatures in the study environment vary depending on weather conditions, the season (dry or wet), the month of year. Temperatures are relatively high throughout the year with an annual average of 27.4°C and 21.1°C is minimum observable especially in the months of August and December. As for maxima, they are of the order of 36.6°C in the month of February, which is one of the hottest months. The study area is characterized by the presence of several types of natural (mangrove, meadow, sacred forest, etc.) and anthropogenic (mosaic culture, coconut plantation, private plantation, communal planting) vegetation. In there can be found *Acacia auriculiformis, Tectona grandis, Eucalyptus camaldulensis, Terminalia sp. Adansonia digitata, Ceiba pentandra, Milicia excelsa, Triplochyton scleroxylon, Antiaris toxicaria, etc.* It is worthy to note the presence of wetlands along the water bodies where aquatic vegetation consists of *Raphia gigantea, Rhizophora racemosa, Avicennia africana and Acrostichum aureum.* In addition to marshy meadows and mangroves, there are relics of fruit plantations in some places (including mango, orange, etc.). A few rare signs of wet or semi-humid natural forests survive in the form of sacred forest.

Sampling stations

The study area forms a hydrological complex composed of Lake Ahémé which flows into the Ahô channel. Then the Ahô channel feeds into the Tihimey channel and ends in the Ouidah and Grand-Popo lagoons. The Grand-Popo Lagoon is home to the mouth of Mono River delta in the Avlo village, which connects the whole thing to the Atlantic Ocean. As part of this study, each water body was considered as a separate entity, for a better understanding of each environment. Each area has been subdivided into observation stations. These stations were set in the general direction in which the water flows: upstream, middle, downstream, taking into the lake and channels. In sum, the study environment has been subdivided into five areas within which we have nineteen sampling stations presented on a map of the area (Fig. 2).

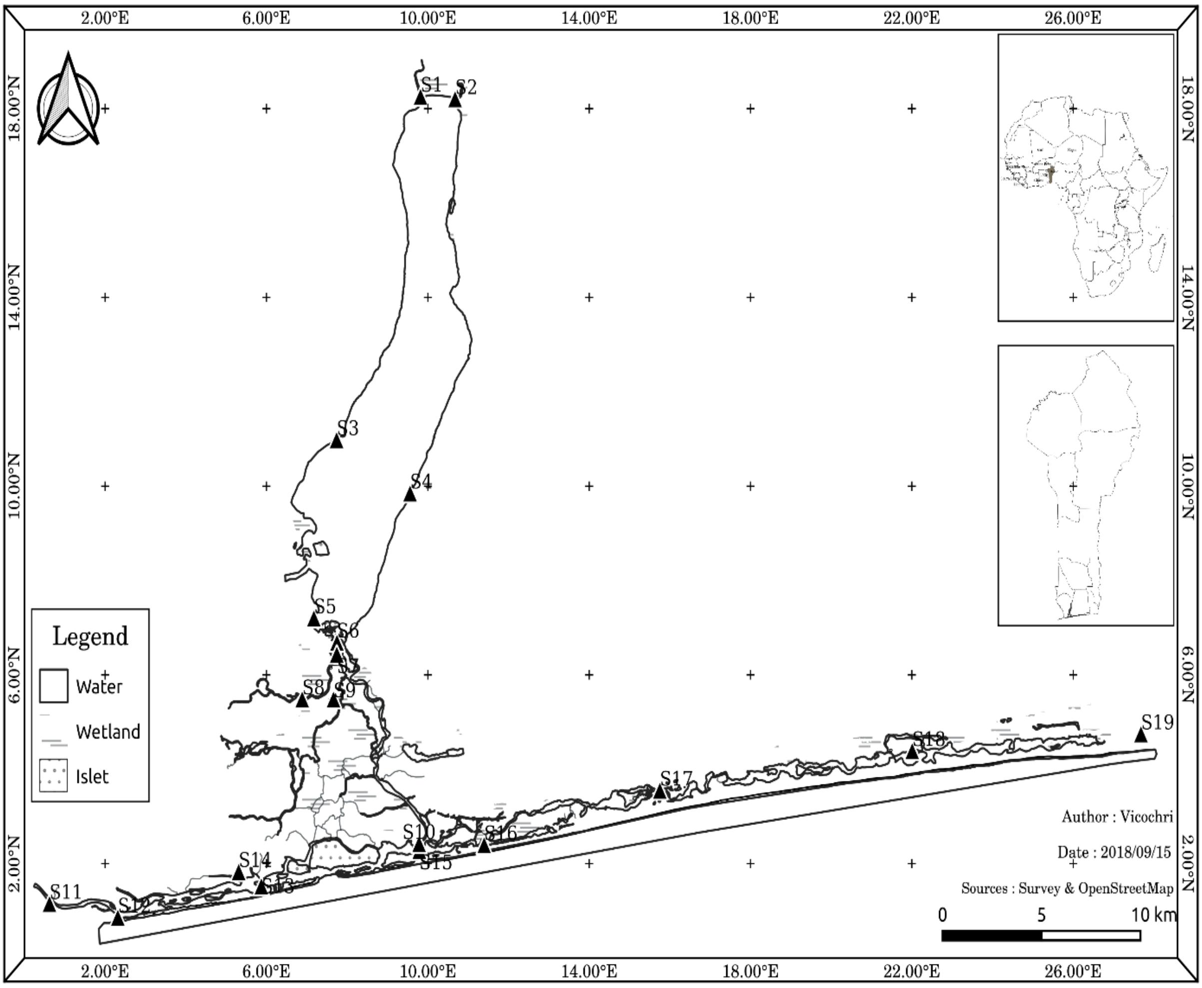

Fig. 2. Sampling stations.

Sampling fish species

The collection of fish species was made each month from fishermen catches, from May 2016 to April 2017. This collection was supplemented by monthly experimental fishing. Thus, gill nets have been made with different mesh sizes, namely: 10mm, 12mm, 15mm, 20mm, 25mm, 30mm, 35mm, 40mm and 45mm. Experimental fishing was conducted for 2 days at each station every month. The nets were set at 5:00 pm and surveyed every 4 hours to observe and collect data on the species caught. The nets were arranged perpendicular to water current, taking into account the tides, and were set in descending order of mesh sizes (45mm, 40mm, 35mm, 30mm ... 10mm).

Identification of fish species

Specimens collected were first stored in a 10% formalin solution for 10 days and then in a 70% alcohol solution after identification in the appropriate jars (suitable for specimen size). Fish identification was made on the basis of morphometric and meristic characteristics using the key according to Paugy *et al.* (2003).

Category of fish species

In this study, the fish species were grouped according to the classification by Albert (1999). They are species in marine (ME + Ma + Mo), estuaries (E + Ec + Em) and continental (C + CO) forms. This classification offered by Albert (1999), was used taking into account the specificity of the environment (lake, lagoon, sea), and the peculiarity of the species that live there. Thus, the fish species collected were classified according to the different ichthyofaunic forms as indicated in Table 1.

Table 1. Classification of the fish fauna population, according to Albert 1999.

Ecological categories		
Continental Species	Continental occasional	Co
	Continental estuarine	Ce
Estuarine Species	Estuarine continental	Ec
	Estuarine strict	Es
	Estuarine marine	Em
Marine Species	Marine Estuarine	ME
	Marine accessory	Ma
	Marine occasional	Mo

Data processing

Model for predicting and estimating fish species

The exact number of species in a community is rarely known. Thus, species richness was estimated from specific cumulative curves obtained by adding new species to the cumulative list of species in a chronological order of the seasons (Colwell and Coddington, 1994; Gotelli and Colwell, 2001). A statistical estimate of this number from species accumulation curves based on non-parametric estimators made it possible to assess the effort and the perfection of the inventory. This curve was performed using the EstimateS version 7 software (Colwell *et al.*, 2004). There is no single model in itself that is the most reliable for predicting true species richness by extrapolating from specific cumulative curves. They generally predict more or less different values (Colwell and Coddington, 1994). For that reason, several models are often used at the same time. The value of species richness is the average of the values of the estimators used for this purpose (Brose, 2002; Petersen and Meier, 2003, Petersen *et al.,* 2003; Colwell, 2005). The totals of singletons and doubletons in the chronological order of the sample collection seasons were also determined using the same software. The latter made it possible to establish the accumulation curves of the randomized species resulting from 100 simulations at a 95% confidence interval. Abundance-based Coverage Estimator (ACE), Chao1, Jack1 and Bootstrap were used for this study.

Frequency of fish species

The frequency of the species was determined with the calculation of their occurrence. The occurrence percentage (C) makes it possible to obtain the constancy of a species in a given medium. This is the ratio expressed as a percentage between the number of samples (p) in which species appears and the total number of samples (P) of the biocenotic unit under consideration (Dajoz, 2000). It is obtained according to the formula:

$$C = \frac{px100}{P}$$

The value of C helps distinguishes four groups of species

- Constant species (C ≥50%);
- Accessory species (25% ≤ C <50%);
- Accidental species (5% ≤ C <25%);
- Rare species (C <5%).

Results

Overall fish species richness per water body

The inventory of the fish fauna conducted from May 2016 to April 2017 at Lake Ahémé and its channels has identified 73 species, 59 genera, and 38 families (Table 2). Specific richness varies according to the ecosystem. Overall, there were 53 species in Lake Ahémé and 46 species in the Tihimey Channel, accounting respectively for 72.60% and 63.01% of the species richness of the study area (Fig. 4). In addition, 36 species were collected from the Ouidah lagoon, compared to 64 species from the Grand-Popo lagoon, representing a respective rate of 49.32% and 87.67% of the total species richness within the environment during the study period. As for the Ahô Channel, 46 species were recorded, representing 63.01% (Fig. 3)

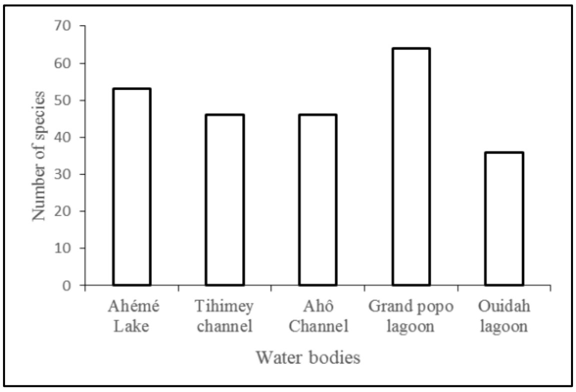

Fig. 3. Fish species richness per water body.

Table 2. List of fish species in Lake Ahémé and its channels.

Fish Families	Genera / Species	Lake Ahémé						*Tihimey Channel*		*Ahô Channel*			*Grand Popo Lagoon*				*Ouidah Lagoon*				*Ecological Category*
		Stations						*Stations*		*Stations*			*Stations*				*Stations*				
		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	ES
Acanthuridae	*Acanthurus monroviae Steindachner, 1876*	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	Ma
Anabantidae	*Ctenopoma» petherici* Günther, 1864	0	0	1	1	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	Ce
Belonidae	*Strongylura senegalensis* (Valenciennes, 1846)	1	1	0	0	0	0	0	0	1	1	1	0	1	1	1	0	0	0	0	ME
	Caranx hippos (Linnaeus, 1766)	1	1	0	0	0	0	1	1	1	1	1	1	1	0	0	1	1	0	0	ME
	Chloroscombrus chrysurus (Linnaeus,1766)	1	1	0	0	0	0	1	1	1	1	1	1	1	0	0	0	0	0	0	ME
	Selene dorsalis (Gill, 1863)	0	0	0	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	0	Ma
Carangidae	*Trachinotus goreensis* Cuvier, 1832	0	1	0	0	0	0	0	0	1	1	1	1	1	0	0	1	1	0	0	Em
	Trachinotus teraia Cuvier, 1832	0	1	0	0	0	0	0	1	1	1	1	1	1	0	0	1	1	0	0	Em
Centropomidae	*Lates niloticus* (Linnaeus, 1762)	0	0	1	1	0	1	0	0	0	0	0	0	1	1	1	0	0	0	0	Co
Channidae	*Parachanna obscura* (Günther, 1861)	0	0	1	1	1	1	0	0	0	0	0	0	0	1	1	0	0	0	0	Co
	Hemichromis bimaculatus Gill, 1862	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	0	0	0	0	Co
	Hemichromis fasciatus Peters, 1852	1	1	1	1	1	1	1	1	0	0	0	0	0	1	1	0	0	0	0	Ec
Cichlidae	*Oreochromis niloticus* (Linnaeus, 1758)	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	Co
	Sarotherodon melanotheron Rüppell, 1852	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	Es
	Coptodon (Tilapia) guineensis (Bleeker in Günther, 1862)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	Es
	*Clarias ebriensis (*Pellegrin, 1920)	0	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	Ec
Clariidae	*Clarias agboyiensis (*Sydenham, 1980*)*	0	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	Ce
	Clarias (Clarias) gariepinus (Burchell, 1822)	0	0	1	1	1	1	0	1	0	0	0	0	0	1	0	0	0	0	0	Ce
Claroteidae	*Chrysichthys nigrodigitatus* (Lacépède, 1803)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	Ec
	Chrysichthys auratus (Geoffroy Saint-Hilaire, 1808)	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	0	0	Ec
	Laeviscutella dekimpei Poll, Whitehead et Hopson, 1965	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	0	0	Ec
	Ethmalosa fimbriata (Bowdich, 1825)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	Em
Clupeidae	*Pellonula leonensis* Boulenger, 1916	1	1	0	0	0	0	0	1	1	1	1	1	1	0	0	1	1	0	0	Ec
	Sierrathrissa leonensis Thys van den Audenaerde, 1969	1	1	0	0	0	0	0	1	1	1	1	1	1	0	0	1	1	0	0	Co
Cynoglossidae	*Cynoglossus senegalensis* (Kaup, 1858)	0	1	1	1	1	0	1	1	1	1	1	1	1	1	0	1	1	0	0	Em
Cyprinidae	*Raiamas senegalensis* (Steindachner, 1870)	1	0	1	1	1	1	0	0	0	1	0	0	0	1	1	0	0	0	0	Co
	Labeo senegalensis Valenciennes, 1842	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Co
Dasyatidae	*Dasyatis margarita* (Günther, 1870)	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	Ma
	Dormitator lebretonis (Steindachner, 1870)	1	1	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	0	Es
	Kribia kribensis (Boulenger, 1907)	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	Es
Eleotridae	*Eleotris senegalensis* Steindachner, 1870	1	1	1	1	1	1	1	1	1	0	1	1	1	1	0	1	1	1	0	Es
	Eleotris vittata Duméril, 1858	0	0	0	0	1	1	0	0	1	0	1	0	0	0	0	0	1	0	0	Es
	Elops senegalensis Regan, 1909	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	0	0	Ma
Elopidae	*Elops lacerta* Valenciennes, 1846	0	0	0	0	0	0	1	1	1	1	0	1	1	0	1	1	0	0	0	Ma
Gerreidae	*Gerres nigri* Günther, 1859	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0	Es
	Eucinostomus melanopterus (Bleeker, 1863)	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	0	ME
	Awaous lateristriga (Duméril, 1861)	1	1	1	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	ES
	Bathygobius soporator (Valenciennes, 1837)	1	1	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	Es
Gobiidae	*Gobioides sagitta* (Günther, 1862)	1	1	0	0	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	Es
	Gobionellus occidentalis (Boulenger, 1909)	0	1	0	0	0	0	0	1	1	1	1	1	1	0	0	1	1	0	0	Es
	Periophthalmus barbarus (Linnaeus, 1766)	0	1	0	0	0	0	1	1	1	1	1	1	1	0	0	1	1	1	1	Es
	Porogobius schlegelii (Günther, 1861)	1	1	0	0	0	1	1	1	1	1	1	1	1	0	0	1	1	0	0	Es
Haemulidae	*Pomadasys jubelini* (Cuvier, 1830)	0	1	0	0	0	0	0	1	1	1	1	1	1	0	0	1	1	0	0	Em
	Pomadasys peroteti (Cuvier, 1830)	0	1	0	0	0	0	0	1	1	1	0	1	1	0	0	1	1	0	0	Em
Hemiramphidae	*Hyporamphus picarti* (Valenciennes, 1847)	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	Ma
Hepsetidae	*Hepsetus odoe* (Bloch, 1794)	0	1	0	0	0	0	0	0	1	1	1	1	1	0	0	1	1	0	0	Ce
	Lutjanus agennes Bleeker, 1863	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	0	0	0	Ma
Lutjanidae	*Lutjanus endecacanthus* Bleeker, 1863	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	1	1	1	1	Ma
	Lutjanus goreensis (Valenciennes, 1830)	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	1	1	1	1	Ma
Megalopidae	*Tarpon atlanticus* (Valenciennes, 1846)	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	Mo
Mochokidae	*Synodontis nigrita* Valenciennes, 1840	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	0	0	0	0	Co
	Synodontis schall (Bloch et Schneider, 1801)	1	1	1	1	1	1	1	0	0	0	0	0	0	1	0	0	0	0	0	Co
Monodactylidae	*Monodactylus sebae* (Cuvier, 1829)	0	0	0	0	1	1	1	1	0	0	1	1	1	1	0	1	1	1	1	Es
Mormyridae	*Mormyrops anguilloides* (Linnaeus, 1758)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	Co
Mugilidae	*Liza falcipinnis* (Valenciennes, 1836)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	Em
	Mugil cephalus Linnaeus, 1758	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	ME
	Dalophis boulengeri Blache et Bauchot, 1972	1	0	0	0	1	1	0	0	0	0	0	0	0	0	1	1	0	0	0	Ce
Ophichthyidae	*Dalophis cephalopeltis* (Bleeker, 1863)	0	1	0	0	0	0	0	1	1	1	0	0	1	0	0	0	0	0	0	Ce

Fish Families	Genera / Species	*Lake Ahémé*						*Tihimey Channel*		*Ahô Channel*			*Grand Popo Lagoon*				*Ouidah Lagoon*				*Ecological Category*
		Stations						*Stations*		*Stations*			*Stations*				*Stations*				
		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	ES
Osteoglossidae	*Heterotis niloticus* (Cuvier, 1829)	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	Co
Paralichthyidae	*Citharichthys stampflii* (Steindachner, 1894)	1	1	0	0	1	1	1	1	1	0	1	1	1	0	0	1	1	1	1	Em
Polypteridae	*Polypterus senegalus senegalus* Cuvier, 1829	1	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	ME
	Polypterus endlicheri endlicheri Heckel, 1849	1	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	ME
	Galeoides decadactylus (Bloch, 1795)	0	1	0	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	0	ME
Polynemidae	*Polydactylus quadrifilis* (Cuvier, 1829)	0	1	0	0	0	0	0	0	1	1	1	1	1	0	0	1	0	0	0	ME
Protopteridae	*Protopterus annectens annectens* (Owen, 1839)	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	Co
Schilbeidae	*Schilbe intermedius* Rüppell, 1832	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	0	1	1	1	Ce
	Schilbe mystus (Linnaeus, 1758)	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	Ce
Sciaenidae	*Pseudotolithus senegalensis* (Valenciennes, 1833)	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	Ma
Scombridae	*Scomberomorus tritor* (Cuvier, 1832)	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	Ma
Serranidae	*Epinephelus aeneus* (Geoffroy Saint-Hilaire, 1817)	0	0	0	0	0	0	0	0	1	1	1	1	1	0	0	1	0	0	0	ME
Soleidae	*Dagetichthys lakdoensis* Stauch et Blanc, 1964	0	1	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	0	0	Es
	Synaptura lusitanica Capello, 1868	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	Ma
Tetraodontidae	*Tetraodon pustulatus* Murray, 1857	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	Ma
Total		28	38	27	27	30	29	34	37	42	42	43	42	40	26	25	34	31	16	13	

Legend: A=Agatogbo; B=Ahouandjigo-Codji; C=Vonvio D=Yèmè; E=Agonsa; F=Zounta; G=Dohi H=Tihimey; I=Gbêzounmè; J=Hounklou; K=Djondji; L=Sodomè; M=Avlo-Embouchure; N=Gbècon; O=Onkouihoué; P=Ayido; Q=Djègbadji; R=Avlékété; S=Togbin; EC=Ecological Category; 1=Presence; 0=Absence;

Fish species Richness in the stations

Species richness varied according to the stations. Thus, at Lake Ahémé stations, 28 and 38 species were recorded respectively at the Agatogbo and Ahouandjigo-Codji stations during the study period, as against 29 and 30 species respectively at the Agonsa and Yèmè stations (Table 2). In the Tihimey Canal, 34 species were recorded at Dohi, compared to 37 at the Tihimey station. In the Ahô channel, 42 species were recorded at each of the Gbèzounmè and Hounklou stations, compared to 43 species at Djondji during the study period. In addition, the Sodomè and Avlo-Embouchure stations have low specific in the Grand-Popo lagoon, with respectively 26 and 25 recorded species, compared to 40 and 42 recorded species respectively for the Gbècon and Onkouihoué stations. In the end, the Togbin resort has the lowest species richness with 13 recorded species followed by Avlekete at 16 species in the Ouidah lagoon. In this lagoon, the highest species richness was recorded at Ayido with 34 species, while 31 species were recorded at the Djègbadji station during the study period (Fig. 4).

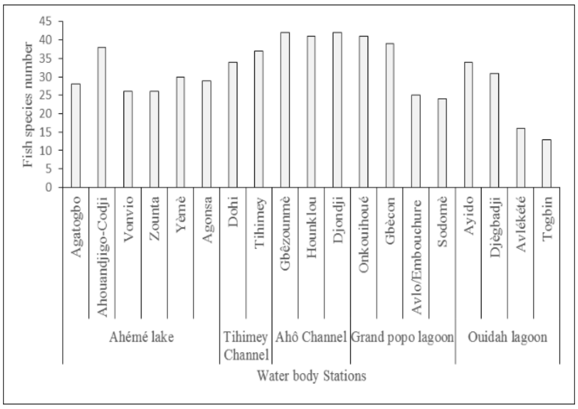

Fig. 4. Variation in (fish) species richness per station.

Among the recorded fish families, the Gobiidae are more represented with 6 species, the Carangidae and Cichlidae have 5 species each, the Clupeidae has 4 species, the Eleotridae, Clariidae and Lutjanidae each have 3 species (Fig. 6); then come the Elopidae, Cyprinidae, Claroteidae, Gerreidae, Haemulidae, Mochokidae, Mugilidae, Ophichthyidae, Polynemidae, Polypteridae, Soleidae and Schilbeidae with 2 species each. The Acanthuridae, Anabantidae, Belonidae, Centropomidae, Channidae, Cynoglossidae, Dasyatidae, Hemiramphidae, Hepsetidae, Megalopidae, Monodactylidae, Mormyridae, Osteoglossidae, Paralichthyidae, Protopteridae, Sciaenidae, Scombridae, Serranidae, and Tetraodontidae close the list with one species each during the study (Table 2).

Estimates of species richness

In this collection, no singleton was observed; however, one duplicate was recorded, representing 1.37% of the total species richness in the study area (Fig. 5).

The absence of singletons and the presence of a single duplicate in cumulative time series samples indicates that the inventory was more or less complete. Thus, the maximum species richness was estimated at 73.02 per ACE, 73 per Chao 1 ± 1, 73.92 ± 1 per Jack 1 and 73.94 per Bootstrap (Fig. 6). The predicted maximum average specific richness was then 74 ± 1; which allowed the deduction that 97.3 to 99% of the species are currently collected.

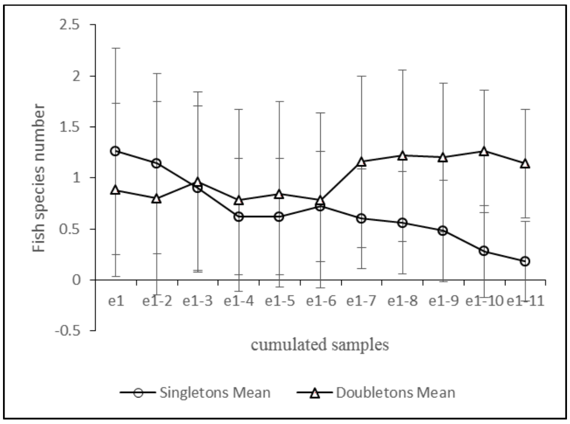

Fig. 5. Singletons and duplicates curves in the samples of the 11 cumulative chronological collect campaigns.

e1 = sample of the first campaign, e1-n = cumulate of the samples of the first campaign with n ranging from 2 to 11.

Frequency of fish species obtained during the study

The percentage of occurrence calculated from the presence-absence matrix was used to determine the frequency of fish species during the study period. Thus, 27 constant species and 19 accidental species were collected, a respective proportion of 36.98% and 26.02% (Fig. 7). In addition, 27 accessory species were collected and represent a proportion of 36.98%. There were no rare species recorded during the study period.

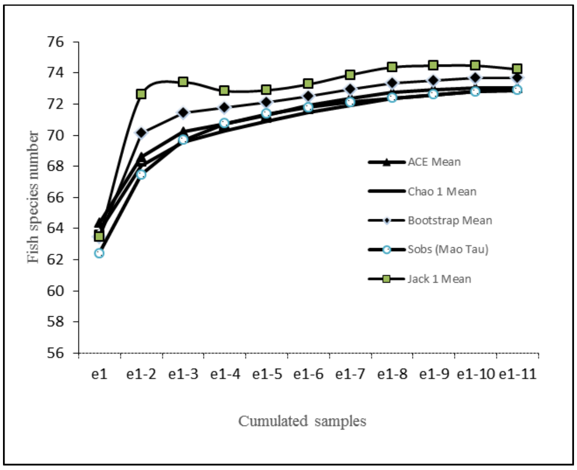

Fig. 6. Cumulating curves for the number of fish species in Lake Ahémé and its channels (Sreal) and species richness estimators (ACE, Chao 1, Jack 1, Bootstrap).

e1 = sample of the first campaign, e1-n = cumulate of the samples of the first campaign with n ranging from 2 to 11

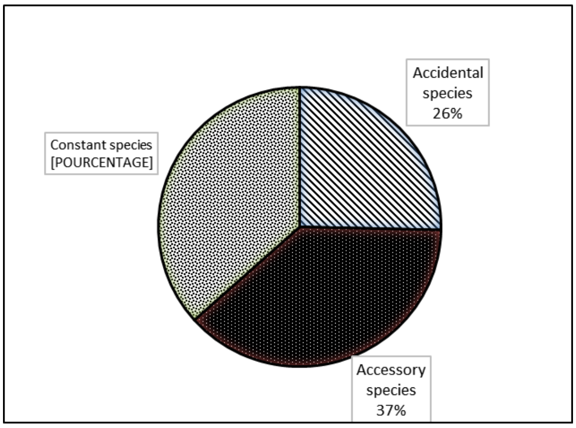

Fig. 7. Frequency of fish species.

Ecological status of the fish species

In relation to fish habitat, the species collected were divided into three major groups [20]: Continental Species, Estuarine Species, and Marine Species. Within these groups, eight subgroups were identified. This classification revealed that the strict Estuarine species (E) dominate the fish population with 87.67% (n = 64) (Figs 8 and 9). The Estuarine marine species (E.m.) and the Marines Estuarine (M.E.) each represent 53.43% (n = 39) of the total species richness within the area during the study period. In addition, Marine Accessory Species (M.a.) accounted for 49.31% (n = 36), compared to 2.74% (n = 2) for occasional Marine species (M.O.). Finally, 36.73% (n = 29), 34.25% (n =

25) and 36.99% (n = 27) of the recorded species are respectively Continental occasional (CO), Continental Estuaries (C.e), and Estuarine continental (Ec) in the area during the study period.

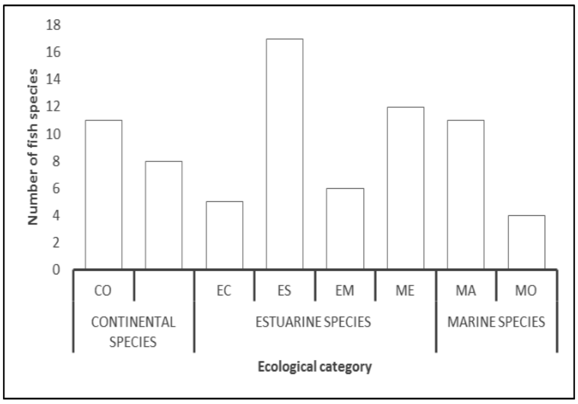

Fig. 8. Classification of fish species by ecological category.

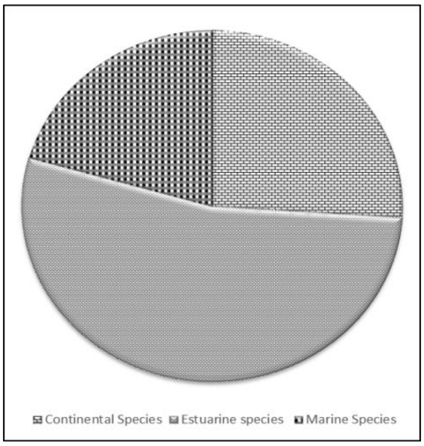

Fig. 9. Classification of fish species by water type.

Discussion

The inventory of fish fauna conducted from May 2016 to April 2017 in the waters of Lake Ahémé and its channels has identified 73 fish species, divided into 59 genera, and 38 families. These results are superior to previous inventories conducted in the study environment by different authors and represent 31.20% of all the known fish fauna in Benin 234 species (Lalèyè *et al.*, 2004). Moreover, the inventory work carried out by Hounkpè and Bonou (2001) in the waters of Lake Nokoué and the Porto-Novo Lagoon and (Lalèyè *et al.*, 2004) in the Ouémé river respectively identified 85 fish species distributed over 65 families and 122 species of fish divided into 87 genera and 50 families. These results are much higher than those obtained in Lake Ahémé and its channels during the study period.

Species richness varied, according to water bodies and sampling stations. At Lake Ahémé, the stations located in the North (Agonsa n = 30 and Yèmè n = 27) recorded a significant specific richness. This is justified by the waters of the Couffo River flowing into the lake. These waters come into the lake with mostly freshwater fish species. The same situation was observed by Djiman *et al.*, (2018) in Lake Nokoué and in the Porto Novo Lagoon. Similarly, the stations situated in south of the lake recorded a high specific richness (Ahouandjigo-Codji n = 38 and Agatogbo n = 28). This situation is due to the fact that the lake connects to the coastal lagoon through the Ahô channel to the south. Thus, these waters flow into Lake Ahémé with fish species. This situation is confirmed by the research work carried out in 2005 by Lalèyè and Akélé, within the study area. The Tihimey channel stations showed a high specific richness (Dohi n = 34 and Tihimey n = 37). This situation is justified by this channel communicating, on the one hand, with the freshwater lake Tikpan and, on the other hand, with the Ahô channel with brackish water. These results are significantly higher than those obtained in (2014) by Amoussou *et al in* these ecosystems, where 25 and 30 species were respectively recorded. In the Ahô channel, the highest species richness was obtained at the Djondji station (n = 43). Indeed, this station is the junction between three ecosystems (Grand-Popo Lagoon, Ouidah Lagoon, and the Ahô channel). The location of this station makes it the main migration zone for fish species between the sea, the lake, and the lagoons. These results confirm the work of Lawani (2011) on estuarine lagoon environments. The high species richness observed at the stations of the Ouidah and Grand-Popo coastal Lagoons can be explained by the presence of a mangrove (bushier and more protected than the other stations) and some relict forests where fishing is forbidden or prohibited (Avlékététin). In addition, their proximity to the sea and the presence of the mouth which is in the Grand-Popo Lagoon puts the area under the influence of the six-hour periodic tides (Degbe, 2015). Thus, every six hours, we observe the alternation of a high tide and a low tide. These phenomena influence fish species. Indeed, they allow catadromous and anadromous species to complete their life cycles (Sohou, 2016). However, the Togbin station in the Ouidah Lagoon has recorded the lowest species richness during the study period (n = 13). This situation is due to the anthropization of the environment (which leads to the destruction of natural spawning grounds), the installation of economic infrastructures, and the overexploitation of fish populations due to demographic pressure.

In addition, it should be noted that some species mentioned by the Fisheries Department in its report for 2002, were not found in this study. These are *Brycinus nurse*, *Malapterurus electricus* and *Carcharhinus leucas*. However, some species not reported in the works for Viaho (2014) in the study area, were found in this study. These are: *Trachinotus goreensis, Selene dorsalis, Chrysichthys auratus, Labeo senegalensis, Elops lacerta, Polypterus senegalus senegalus, Polypterus endlicheri endlicheri, Protopterus annectens annectens, Schilbe mystus, Scomberomorus tritor, Synaptura lusitanica* and *Tetraodon pustulatus*.

Salinity is the main distribution factor for fish species in the study area (Cardona, 2000). Thus, 53.42% of the species collected are estuarine, 20.55% are marine and 26.02% are freshwater species. These results show the influence of tides and seawater on the richness of the fish fauna in estuarine lagoon environments, according to Sohou (2016). These estuaries and marine species are found in the stations near the mouth of the Grand-Popo Lagoon, in the Ahô channel, the Ouidah Lagoon, south of Lake Ahémé, and north of the Tihimey channel. Moreover, freshwater species are found north of Ahémé Lake, instead of the falling water, Couffo River, and west of the Grand-Popo Lagoon, which receives the waters of the Mono River.

Depending on the abundance of species during the study period, constant and accessory species account for 37% each. The accidental species collected represent 26% and there were no rare species. These results are similar to those obtained by Dudgeon *et al*, 2006 in freshwaters for West Africa. The Djondji station, despite its high species richness, did not have good distribution of specific populations or good distribution of individuals within species.

In general, *Sarotherodon melanotheron*, *Mugil cephalus* and *Ethmalosa fimbriata* dominate in all stations. These are species of estuarine origin, which confirms by these results, the presence in an estuarine environment, which is the coastal lagoon. The Agatogbo and Ahouandjigo-Codji (Lake Ahémé) stations have at least three abundant species in their catches; which would justify the fact that one observes a better distribution of the individuals within the population species at these stations.

No singleton was observed in the collection; however, 1 duplicate was recorded, representing 1.37% of the study area's total species richness. The absence of singletons and the presence of a single duplicate in cumulative time series samples indicates that the inventory was more or less complete. Thus, the maximum species richness was estimated at 73.02 per ACE, 73 per Chao 1 ± 1, 73.92 ± 1 per Jack 1 and 73.94 per Bootstrap. The predicted maximum average specific richness was then 74 ± 1; which allowed the deduction that 97.3 to 99% of the species are currently collected. These results are similar to those obtained by Ahouansou (2011) in the Pendjari River, where 99.1% of the fish species is collected.

Conclusion

An inventory of the fish fauna in Lake Ahémé and its channels, conducted from May 2016 to April 2017, has identified 73 species of fish, divided into 59 genera and 38 families. These results are superior to previous inventories conducted in the study environment by different authors and represent 31.20% of all of the known fish fauna in Benin. The species richness varied depending on the water body. Thus, the coastal Grand-Popo Lagoon has the highest species richness, followed by Lake Ahémé. This is explained by the presence of the mouth "Bouche du Roy" in this lagoon and the waterfalls of the Mono River. As for Lake Ahémé, it receives the waters from Couffo River in the north and those of the lagoons through the Ahô channel. The ecological status of the species reveals that strict estuarine species (E) dominate the fish population at a percentage of 87.67%.

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