INNSPUB

Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 21, No. 5, p. 172-184, 2022
http://www.innspub.net

RESEARCH PAPER OPEN ACCESS

Preliminary ichthyological inventory of Fresco lagoon (Côte d'Ivoire, West Africa)

N'guessan Akissi Emmanuelle, Yao Stanislas Silvain*, Bédia Aké Théophile, Kpan Zingbé Anderson

Department of Natural Environments and Biodiversity Conservation, Félix Houphouët-Boigny University (UFHB), Abidjan, Côte d'Ivoire

Article published on November 20, 2022

Key words: Ichthyofauna, Diversity, Abundance, Seasonal variations, Fresco lagoon

Abstract

The first fish inventory of the Fresco lagoon (Côte d'Ivoire, West Africa) took place from August 2018 to July 2019. Overall, 134590 specimens comprising 21 orders, 37 families, 57 genera, 75 species and 8 ecological categories were recorded. The ichthyological fauna is largely dominated by Cichlidae, the ecological category of strict estuarine forms and the species *Sarotherodon melanotheron*. The dominance of these taxa is reflected in low Shannon diversity and Pielou's evenness indices. The closure of the pass during the long dry season induces a significant variation between the fish assemblages of the two long seasons. Our catches increased after the opening of the pass at the beginning of the long rainy season.

***Corresponding Author:** Yao Stanislas Silvain ✉ yaosilvain@yahoo.com

Introduction

Côte d'Ivoire, located in West Africa, benefits from a vast network of brackish waters (Varlet, 1978). This network includes three lagoon systems (the Aby, Ebrié and Grand-Lahou lagoons) and the Fresco lagoon (also called the Gbôkle or Nyi or N'Gni lagoon) (Anoh, 2010; Durand and Skubich, 1982; Kambiré *et al.*, 2012). The Fresco lagoon communicates with the Atlantic Ocean through the non-permanent channel of Fresco (Anoh, 2010). Indeed, this channel closes during the long dry season (December to March) and is opened by the resident populations. In addition to the closure of the pass (Egnankou, 1997; Tetra Tech, 2018), the Fresco lagoon is under pressure from various anthropogenic actions. In addition to fishing, resident populations dump household waste and effluent from surrounding farms without prior treatment, as well as faecal matter.

They wash their clothes and dishes and bathe in it (Kouadio, 2014). This lagoon could also be the receptacle of pesticides used in the surrounding plantations. It also suffers the effects of deforestation and mangrove destruction (Egnankou, 1987, 2009). If not contained in time, the closure of the channel and these anthropogenic actions will have adverse effects on the fish fauna. Indeed, species will disappear from this lagoon environment. Fish stocks will decrease, with negative socio-economic implications.

Faced with these threats, it is essential to know the qualitative and quantitative composition of the ichthyofauna of this lagoon, as well as its structure. Indeed, this information will serve as reference data for future studies and for the necessary establishment and implementation of conservation policies for this ichthyofauna. In Côte d'Ivoire, the ichthyological faunas of several lagoons have been studied. This is the case of the Ono (Eyi *et al.*, 2016), Grand Lahou (Coulibaly *et al.*, 2016), Potou (Bédia *et al.*, 2017), Aghien lagoons (Assi *et al.*, 2019) and the Aby-Tendo-Ehy lagoon complex (Koffi *et al.*, 2014). Unlike the aforementioned lagoons, information on the ichthyological population of Fresco lagoon is not available. Indeed, previous studies on this lagoon have focused instead on Teredinidae (Mollusks, lamellibranchs) (Rancurel, 1971), wetlands and mangroves (Egnankou, 1985; Nicole *et al.*, 1987; Sankaré *et al.*, 1999; Egnankou *et al.*, 2004), physico-chemical characteristics of the water (Issola *et al.*, 2008a), chemical characteristics (N'Guessan *et al.*, 2013) and quality of sediments (Issola *et al.*, 2008b, 2009), microbial pollution (Kouadio *et al.*, 2011), algae (Konan *et al.*, 2019) and zooplankton (Etilé *et al.*, 2018).

The present work was therefore carried out to collect the first data on the qualitative, quantitative and structural characteristics of the fish population of Fresco lagoon.

Materials and methods

Study area

Fresco lagoon (Fig. 1) is located between longitudes 5°32' and 5°38' West and latitudes 5°40' and 5°70' North. It stretches, from East to West, over a length of about 6 km and has a width of between 2 and 4 km with an average depth of 4 m.

It covers an area ranging from 17 to 29 km² and receives mainly two coastal rivers: the Bolo and the Niouniourou (Sankaré *et al.*, 2014). The climate, a humid tropical type, is characterized by four seasons (Egnankou *et al.*, 2004): a long rainy season (April to July), a short dry season (August and September), a short rainy season (October and November) and a long dry season (December to March).

Fish sampling

The capture of fish specimens took place in 7 stations spread over the entire lagoon of Fresco (Fig. 1). Fish were sampled from August 2018 to July 2019, in 12 monthly surveys. Experimental fishing was conducted with a battery of eight weighted monofilament gill-nets (mesh sizes 10, 15, 20, 25, 30, 40, 50 and 60mm), each net measuring 30 m by 1.5m deep. During each sampling campaign, in each station, all nets were set at 5:00 p.m. and fish removed at 7:00 a.m. and again at 12:00 a.m. Captured fish were identified using the identification keys of Charles-Dominique and Raffray (1985), Paugy *et al.* (2003 a and b) and Fishbase

(Froese and Pauly, 2019). Ecological categories of species were determined according to Albaret *et al.* (2004), Chabanne (2007) and Fishbase (Froese and Pauly, 2019). Each specimen was weighed to the nearest 0.1 g using an Adam HCB electronic balance.

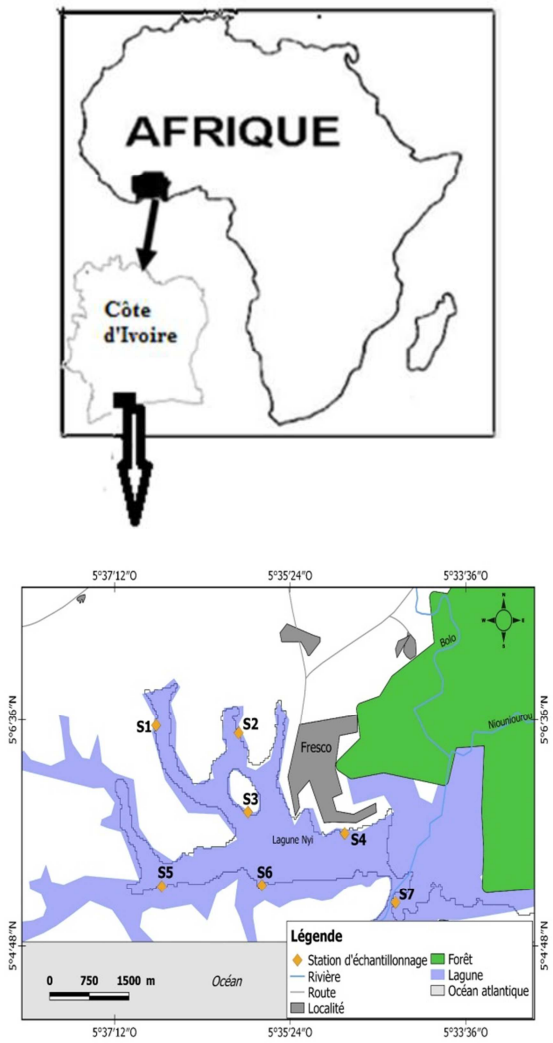

Fig. 1. Sampling stations on the Fresco lagoon.

Data processing

The analysis of the fish assemblage was carried out using the following indices.

(1) The frequency or percentage of occurrence F quantifies the number of times a species is observed in the samples.

$$F = (F_i / F_T) \times 100$$

Where F_i is the number of samples in which species i appeared and F_T the total number of samples. The classification of species on the basis of their percentage of occurrence was made according to Dajoz (2000): accidental species (F < 25%), accessory species (25 ≤ F < 50%) and constant species (50% ≤ F).

(2) The numerical percentage N is the number of individuals (n) in a taxonomic group (family or species) in relation to the total number of individuals surveyed (N_T) multiplied by one hundred.

$$N = (n / N_T) \times 100$$

(3) The weight percentage P is the ratio of the biomass (p) of a taxonomic group (family or species) to the total biomass (P_T) of the sample.

$$P = (p / P_T) \times 100$$

(4) The Shannon diversity index H' (Shannon and Weaver, 1963) was used to measure the degree of organization of the fish assemblage (Amanieu and Lasserre, 1982).

$$H' = -\sum_{i=1}^{i=S} p_i \times \log_2 p_i$$

With: S = total number of species

Pi = proportion of the ith species (i varying from 1 to S) = n_i / N or b_i / B

n_i = number of individuals in species i,

N = total number of individuals,

b_i = biomass of species i,

B = total biomass.

H' is expressed in units of information per individual or bits/individual. H' is zero if the sample is composed of a single species and maximum (in the order of 5) if all species of the community are equally represented in the sample (Ludwig and Reynolds, 1988). A low Shannon index (H' < 2.6) results from the dominance of a few species over all other taxa (Yabi *et al.*, 2013).

(5) The Pielou's evenness index (E) based on Shannon diversity index were used to measure the evenness of species distribution (Hill, 1973) and to assess the quality of fish community organization (Dajoz, 2000; Barbault, 2000).

$$E = \frac{H'}{\log_2 S}$$

With: H' = Shannon diversity index

S = specific richness

The Pielou's evenness index (E) varies between 0 and 1. It is 0 when a single species dominates the settlement and 1 when all species have the same abundance. A low evenness index results from the dominance of a few species over all other taxa (Dajoz, 2000). The Shannon diversity H' and the Pielou's evenness index E were calculated with species numbers on the one hand and weights on the other (Kouamélan, 1999).

Statistical analysis

The Mann-Whitney test was used to compare the indices calculated respectively with the numbers and those calculated with the weights. The analyses were carried out using the STATISTICA 7.1. Significance of seasonal variations in the fish community was assessed with Fisher's exact test. Data were analyzed using STATA version IC13.1 (StataCorp., College Station, Texas).

Results

Qualitative analysis of fish assemblages

The ichthyological population inventoried in the Fresco lagoon is composed of 75 species distributed between 57 genera, 37 families, 21 orders and 8 ecological categories (Table 1). Four orders make up most of the species richness of this assemblage: Perciformes (19 species), Carangiformes (10 species), Cichliformes (8 species) and Siluriformes (6 species). The most diverse families are the Carangidae (10 species) and the Cichlidae (8 species). The other families have 1 to 5 species. The dominant ecological categories are marine-estuarine (ME, 17 species), marine occasional in estuary (Mo, 16 species) and estuarine of marine origin (em, 14 species). They are followed by the occasional continental (Co, 8 species), marine accessory (Ma, 7 species), estuarine of continental origin (Ec, 5 species), strict estuarine (Es, 5 species) and continental with estuarine affinity (Ce, 3 species).

Table 1. Ecological categories and percentage of occurrence (F) of fish species sampled in Fresco lagoon from August 2018 to July 2019. SDS = short dry season; SRS = short rainy season; LDS = long dry season; LRS = long rainy season; Ce = continental species with estuarine affinities; Co = continental species occasional in estuaries; Ec = estuarine species of continental origin; Em = estuarine species from marine origin, Es = strictly estuarine species; Ma = marine species accessory in estuaries; ME = marine-estuarine species; Mo = marine species occasional in estuaries; * = introduced.

		Seasons and number of samples where the species is present					
Orders and Families	Species	SDS	SRS	LDS	LRS	F (%)	Occurrence classes
Myliobatiformes Dasyatidae	*Fontitrygon margarita* (Em)	1	1		1	25	Accessory
Siluriformes Clariidae	*Heterobranchus isopterus* (Ce)				3	25	Accessory
	Heterobranchus longifilis (Ce)			2		17	Accidental
Ariidae	*Carlarius latiscutatus* (ME)	2	2			33	Accessory
Claroteidae	*Chrysichthys johnelsi* (Ce)		2			17	Accidental
	Chrysichthys maurus (Ec)	2	2	4	4	100	Constant
	Chrysichthys nigrodigitatus (Ec)	2	2	4	4	100	Constant
Pleuronectiformes Cyclopsettidae	*Citharichthys stampflii* (Em)	2			4	50	Constant
Cynoglossidae	*Cynoglossus monodi* (Mo)		2	2		33	Accessory
	Cynoglossus senegalensis (Em)		1	3	4	67	Constant
Perciformes Sparidae	*Pagellus bellottii* (Mo)				1	8	Accidental
	Dentex angolensis (Mo)	1				8	Accidental
Polynemidae	*Galeoides decadactylus* (ME)		2	4	1	58	Constant
	Polydactylus quadrifilis (ME)	2	2	4	4	100	Constant
Sphyraenidae	*Sphyraena afra* (ME)	2	2	4	4	100	Constant
	Sphyraena guachancho (ME)	2	2		3	58	Constant
Gerreidae	*Eucinostomus melanopterus* (ME)	1				8	Accidental
	Gerres nigri (Es)	2	1		4	58	Constant
Monodactylidae	*Monodactylus sebae* (Es)	2	2	3	4	92	Constant
Sciaenidae	*Pseudotolithus typus* (ME)		1			8	Accidental

Orders and Families	Species	Seasons and number of samples where the species is present				F (%)	Occurrence classes
		SDS	SRS	LDS	LRS		
	Pseudotolithus senegalensis (Ma)	1	1	1	2	42	Accessory
Serranidae	*Epinephelus aeneus* (ME)	1	2	4	4	92	Constant
Haemulidae	*Plectorhinchus macrolepis* (Em)		1			8	Accidental
	Pomadasys incisus (Ma)		2			17	Accidental
	Pomadasys jubelini (Em)	2	2	4	4	100	Constant
	Pomadasys perotaei (Em)	1				8	Accidental
	Pomadasys rogerii (Mo)	1	2	1		33	Accessory
Lutjanidae	*Lutjanus dentatus* (Mo)	1	1	1	1	33	Accessory
	Lutjanus goreensis (Ma)	1	1	1	2	42	Accessory
Rajiformes Rajidae	*Raja miraletus* (Mo)	1				8	Accidental
Carcharhiniformes Carcharhinidae	*Rhizoprionodon acutus* (Mo)	1				8	Accidental
Triakidae	*Mustelus mustelus* (Mo)	1				8	Accidental
Carangiformes Carangidae	*Alectis alexandrina* (Mo)				1	8	Accidental
	Alectis ciliaris (Mo)	1				8	Accidental
	Caranx hippos (ME)	2	2	4	4	100	Constant
	Caranx senegallus (ME)	2			1	25	Accessory
	Caranx crysos (Mo)		1			8	Accidental
	Chloroscombrus chrysurus (ME)	2		2		33	Accessory
	Lichia amia (Ma)		1			8	Accidental
	Selene dorsalis (ME)	2	2	3		58	Constant
	Trachinotus ovatus (Ma)		1	2		25	Accessory
	Trachinotus teraia (Em)	2	1	4	3	83	Constant
Cichliformes Cichlidae	*Chromidotilapia guntheri* (Co)		1			8	Accidental
	Coptodon guineensis (Es)	2	2	4	4	100	Constant
	Coptodon zillii (Co)	1	1	1	1	33	Accessory
	Hemichromis fasciatus (Ec)	2	2	3	3	83	Constant
	Pelmatolapia mariae (Ec)				3	25	Accessory
	Sarotherodon melanotheron (Es)	2	2	4	4	100	Constant
	Tylochromis intermedius (Co)	1		1	1	25	Accessory
	Tylochromis jentinki (Es)	2	1	3	3	75	Constant
Acanthuriformes Drepaneidae	*Drepane africana* (ME)		2		2	33	Accessory
Lobotidae	*Lobotes surinamensis* (Mo)	1	1		1	25	Accessory
Mugiliformes Mugilidae	*Chelon dumerili* (Em)	2	2		3	58	Constant
	Mugil cephalus (ME)	2	2	1	3	67	Constant
	Mugil curema (Em)	2	1		1	33	Accessory
	Neochelon falcipinnis (Em)	2	2	4	4	100	Constant
	Parachelon grandisquamis (Em)	2	2			33	Accessory
Mulliformes Mullidae	*Pseudupeneus prayensis* (Mo)	1				8	Accidental
Characiformes Hepsetidae	*Hepsetus odoe* (Co)	1		1	1	25	Accessory
Anabantiformes Anabantidae	*Ctenopoma petherici* (Co)				2	17	Accidental
Beloniformes Belonidae	*Strongylura senegalensis* (Em)	2	2	3		58	Constant
Ophidiiformes Ophidiidae	*Brotula barbata* (Mo)		1			8	Accidental
Clupeiformes Pristigasteridae	*Ilisha africana* (Em)	1				8	Accidental
Clupeidae	*Ethmalosa fimbriata* (Em)	2	2	1	3	67	Constant
	Pellonula leonensis (Ec)	1	1	2	1	42	Accessory
	Sardinella aurita (Ma)	1	1	2	1	42	Accessory
	Sardinella maderensis (ME)	2	2	4	4	100	Constant
Cypriniformes Cyprinidae	*Labeo coubie* (Co)		1			8	Accidental
	Labeobarbus sacratus (Co)		1			8	Accidental
Elopiformes	*Elops lacerta* (ME)	2	2	4	4	100	Constant

Orders and Families	Species	Seasons and number of samples where the species is present				F (%)	Occurrence classes
		SDS	SRS	LDS	LRS		
Elopidae							
Osteoglossiformes Osteoglossidae	*Heterotis niloticus** (Co)		1	1	1	25	Accessory
Scombriformes Scombridae	*Sarda sarda* (Mo)		1			8	Accidental
Trichiuridae	*Trichiurus lepturus* (ME)			1		8	Accidental
Tetraodontiformes Balistidae	*Balistes capriscus* (Mo)		1			8	Accidental
Tetraodontidae	*Lagocephalus laevigatus* (Ma)	1				8	Accidental
Total number of species		50	53	37	43		
21 orders 37 families	57 genera 75 species	68 species for the 2 short seasons		51 species for the 2 long seasons			

Percentages of occurrence (Table 1) revealed 22 accessory, 26 constant and 27 accidental species. Among the constant species, 11 are present in all samples (F = 100%). These species are *Chrysichthys maurus*, *C. nigrodigitatus*, *Polydactylus quadrifilis*, *Sphyraena afra*, *Pomadasys jubelini*, *Caranx hippos*, *Coptodon guineensis*, *Sarotherodon melanotheron*, *Neochelon falcipinnis*, *Sardinella maderensis* and *Elops lacerta*.

Quantitative analysis of fish assemblages

A total of 134590 specimens were captured, weighing 9370.05kg. In terms of numerical abundance, the Cichlidae (62.43%) largely dominate the families (Fig. 2). They are followed by Clupeidae (12.38%), Mugilidae (9.88%), Claroteidae (5.18%), Carangidae (3.43%) and Haemulidae (2.35%). All the other families grouped together 4.35% of the total number of fishes.

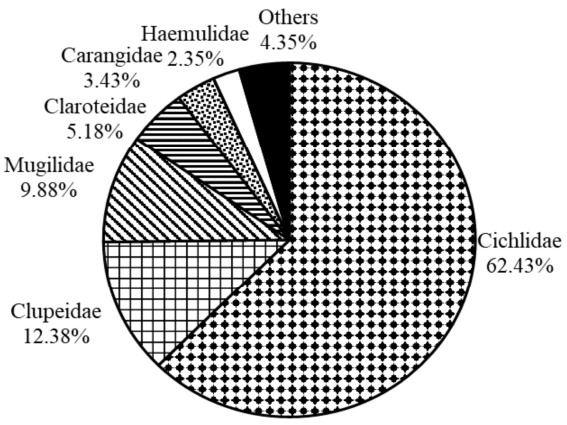

Fig. 2. Numerical percentages of fish families sampled in the Fresco lagoon.

The species *Sarotherodon melanotheron* (59.23%) represents more than half of the samples (Fig. 3). It's followed by *Sardinella maderensis* (9.59%), *Neochelon falcipinnis* (8.48%), *Chrysichthys nigrodigitatus* (3.87%) and *Caranx hippos* (3.32%). Each of the other species accounts for less than 3% of the total sample size.

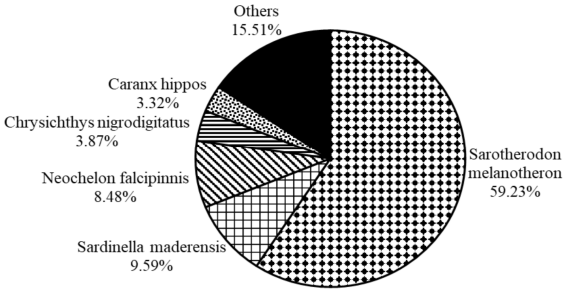

Fig. 3. Numerical percentages of fish species sampled in the Fresco lagoon.

Four ecological categories gather 95.35% of the fish specimens (Table 2). These are the much more abundant strict estuarine forms (60.66%), marine-estuarine (16.27%), estuarine of marine origin (12.99%) and estuarine of continental origin (5.43%). The numerical proportion of each other biecological category is less than 3%.

In terms of weight abundance, the families (Fig. 4) are still dominated by Cichlidae (61.20%), Mugilidae (13.04%), Clupeidae (7.85%) and Claroteidae (4.53%). The weight of each of the other families represents less than 3% of the total weight.

Table 2. Numerical (N) and weight (W) percentages of ecological categories of fish species sampled in Fresco lagoon. Es = strict estuarine species; ME = marine-estuarine species; Em = estuarine species of marine origin; Ec = estuarine species of continental origin; Ma = marine species accidental to estuaries; Co = continental species occasional in estuaries; Mo = marine species occasional in estuaries; Ce = continental species with estuarine affinity.

Ecological categories	All seasons		Short dry season		Short rainy season		Long dry season		Long rainy season	
	N	W	N	W	N	W	N	W	N	W
Es	60.66	59.63	51.18	52.97	47.41	48.15	54.99	48.09	72.82	61.41
ME	16.27	14.01	32.77	26.83	28.17	23.55	14.08	13.85	6.75	6.67
Em	12.99	15.34	11.72	13.01	15.70	15.90	6.45	12.34	13.17	24.21
Ec	5.43	4.75	2.21	2.38	3.94	4.61	12.48	10.18	4.99	4.29
Ma	2.45	2.74	1.15	1.89	2.36	3.78	2.29	2.91	1.97	2.49
Co	1.80	2.21	0.21	0.46	1.69	1.70	9.60	12.04	0.05	0.08
Mo	0.36	1.21	0.76	2.46	0.48	1.87	0.10	0.36	0.24	0.82
Ce	0.04	0.11	0.00	0.00	0.25	0.44	0.01	0.23	0.01	0.03

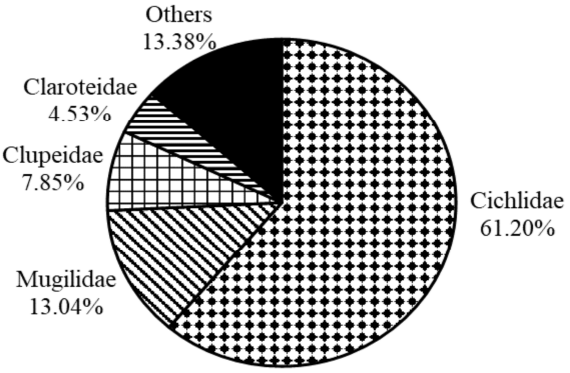

Fig. 4. Weight percentages of fish families sampled in Fresco lagoon.

The largest weights are noted in the 4 most abundant species (Fig. 5). These are *Sarotherodon melanotheron* whose weight constitutes more than half of that of all samples at 58.06%, *Neochelon falcipinnis* (10.99%), *Sardinella maderensis* (6.05%) and *Chrysichthys nigrodigitatus* (3.41%). The weight percentage of each of the other species is less than 3%.

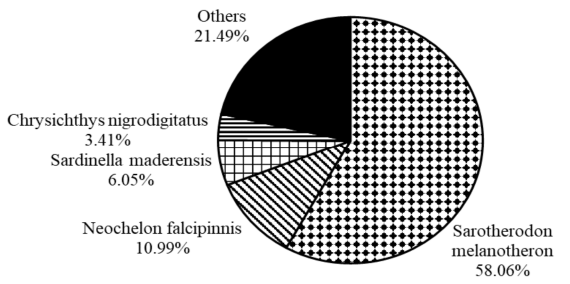

Fig. 5. Weight percentages of fish species sampled in Fresco lagoon.

The 4 most abundant ecological categories also have the highest weight percentage at 93.73% (Table 2). The weight percentage of strict estuarine forms (59.63%) is much higher than those of estuarine of marine origin (15.34%), marine-estuarine (14.01%), and estuarine of continental origin (4.75%). The weight proportion of each other ecological category is less than 3%.

The values obtained on the basis of species numbers are 1.70 bits/ind for the diversity index and 0.31 for the evenness index. The values obtained on the basis of weights are 1.83 bits/ind and 0.35. The differences between the indices calculated respectively with the numbers and those calculated with the biomasses are not significant (Mann-Whitney Test: $p > 0.05$).

Seasonal variations

A total of 68 species were sampled in the two short seasons (Table 1). The species richness recorded during the short rainy season (n = 53 species) was slightly higher than that of the short dry season (n = 50 species). A total of 46623 specimens were collected during the two short seasons, 28167 specimens during the short dry season (60.41%) and 18456 specimens during the short wet season (39.59%). From the analysis by season (Fig. 6), it appears that during the short dry season, *Sarotherodon melanotheron* (48.96%) dominates the population. It's followed by *Sardinella maderensis* (18.72%) and *Neochelon falcipinnis* (15.70%). The contribution to the population of each of the other species is equal or less than 2%. The ichthyological population of the short rainy season is also dominated by the species *Sarotherodon melanotheron* (36.78%),

Neochelon falcipinnis (19.35%) and *Sardinella maderensis* (17.58%). The ecological categories most represented during the short dry season (Table 2) were strict estuarine forms (51.18%), marine-estuarine forms (32.77%) and estuarine forms of marine origin (11.72%). During the short rainy season, the same ecological categories are also the most abundant; namely strict estuarine forms (47.41%), marine-estuarine forms (28.17%) and estuarine forms of marine origin (15.70%).

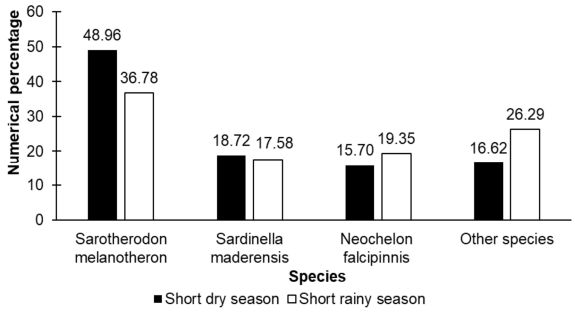

Fig. 6. Seasonal variations in numerical percentages of fish species sampled during the short seasons in the Fresco lagoon.

The similarities observed between the fish communities of the two short seasons are significant (Fisher's exact test; $p > 0.001$), both on the basis of numerical percentages of species and those of ecological categories.

The total weight of fish caught during the two short seasons is 3118.04kg, of which 1796.66kg is for the short dry season (57.62%) and 1321.38kg for the short rainy season (42.38%). In the short dry season (Fig. 7), the species with the highest weight proportion is *Sarotherodon melanotheron* (42.73%). It's followed by *Sardinella maderensis* (19.55%) and *Neochelon falcipinnis* (17.26%). The weight percentage of each of the other species is less than or equal to 2%. In the short rainy season, the species with the highest weight percentages are also *Sarotherodon melanotheron* (37.19%), *Neochelon falcipinnis* (22.32%) and *Sardinella maderensis* (19.65%). The weight percentage of each of the other species is less than 7%. During the short dry season, the ecological categories (Table 2) with the highest weight proportions are the strict estuarine forms (52.97%), the marine-estuarine forms (26.83%) and the estuarine forms of marine origin (13.01%). During the short rainy season, the ecological categories with the highest weight percentages are also strict estuarine forms (48.15%), marine-estuarine forms (23.55%) and estuarine forms of marine origin (15.90%).

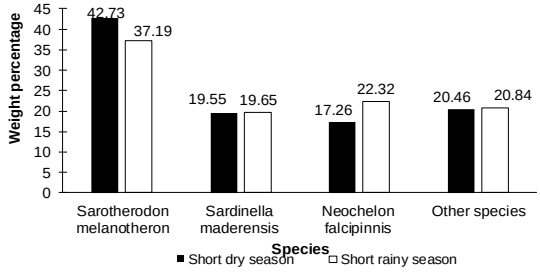

Fig. 7. Seasonal variations in weight percentages of fish species sampled during short seasons in the Fresco lagoon.

The fish communities of the two short seasons are significantly similar on the basis of weight percentages of species and ecological categories (Fisher's exact test; $p > 0.001$).

A total of 51 species were captured during the two major seasons (Table 1). The species richness recorded during the main rainy season (n = 43 species) was higher than that recorded during the main dry season (n = 37 species). In all, the two major seasons totaled 87967 specimens, of which 20960 specimens for the great dry season (23.83%) and 67007 for the great rainy season (76.17%). During the long dry season (Fig. 8), the species *Sarotherodon melanotheron* dominates the population at 52.76%; followed by *Chrysichthys nigrodigitatus* (28.80%) and *Sardinella maderensis* (8.94%). The contribution of each of the other species is less than 2%. During the long rainy season, the species *Sarotherodon melanotheron* (55.34%) is always largely represented, but this time it's followed by the species *Neochelon falcipinnis* (34.47%). The numerical proportion of each of the other species is less than or equal to 3%. During the long dry season (Table 2), the ecological categories with higher numerical percentages are strict estuarine forms (54.99%), marine-estuarine

forms (14.08%), estuarine forms of continental origin (12.48%) and occasional continental forms (9.60%). During the main rainy season, the numerical percentage of strict estuarine forms is also much higher at 72.82%. They are followed by estuarine forms of marine origin (13.17%). The contribution to numerical abundance of each of the other ecological categories is less than 7%.

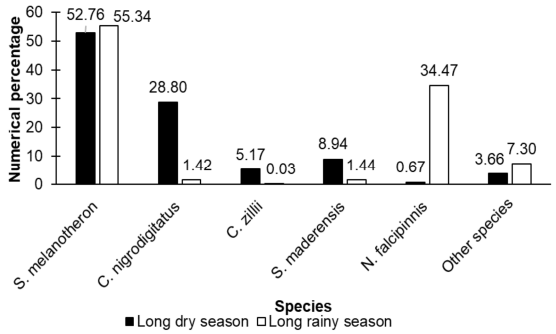

Fig. 8. Seasonal variations in numerical percentages of fish species sampled during long seasons in the Fresco lagoon.

The Fisher's exact test shows that the populations of the two major seasons are significantly different when considering the numerical proportions of the species on the one hand and those of the ecological categories on the other (Fisher's exact test; $p < 0.001$).

The total weight of the samples from the two major seasons is 6252.01kg, of which 1429.41kg is from the major dry season (22.86%) and 4822.60kg from the major rainy season (77.14%). In the long dry season (Fig. 9), the species with the highest weight proportions are *Sarotherodon melanotheron* (50.04%) and *Chrysichthys nigrodigitatus* (25.73%). The contribution of each of the other species is less than 8%. The strict estuarine forms (Table 2) dominate the other ecological categories at 48.09%. They are followed by marine-estuarine forms (13.85%), estuarine of marine origin (12.34%), occasional continental (12.04%) and estuarine of continental origin (10.18%). During the main rainy season (Fig. 9), the weight percentage of *Sarotherodon melanotheron* (55,77%) is much higher than the other species whose maximum value is 29.20% (*Neochelon falcipinnis*).

The strict estuarine forms (Table 2) still dominate the other ecological categories at 61.41%. They are followed by estuarine forms of marine origin (24.21%). The proportion of each of the other ecological categories is less than 7%.

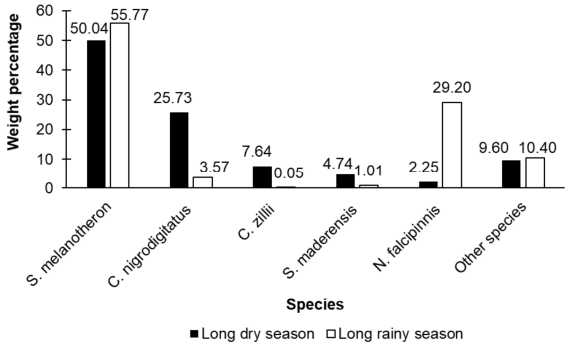

Fig. 9. Seasonal variations in weight percentages of fish species sampled during long seasons in the Fresco lagoon.

According to Fisher's exact test, the population of the long dry season and the long rainy season differ significantly ($p < 0.001$).

Discussion

The present study helps establish 75 fish species in the Fresco lagoon. In Côte d'Ivoire, this species richness is higher than that found in the Aby-Tendo-Ehy lagoon system (n = 67 fish species) by Koffi *et al.* (2014), as well as in the Grand-Lahou lagoon (n = 47) by Coulibaly *et al.* (2016). However, these two hydrosystems are much larger - 424 km² for the Aby-Tendo-Ehy lagoon system (Koffi *et al.*, 2014) and 190 km² for the Grand-Lahou lagoon (Ted *et al.*, 2017) - than the Fresco lagoon [17 to 29 km² (Sankaré *et al.*, 2014)]. Thus, species richness is not only related to the area of the hydrosystem. Indeed, even if a larger area implies a greater diversity of habitats in the hydrosystem, the specific richness observed during a study is the result of several factors. These include physico-chemical parameters and water quality, the ecological requirements of the various fish species, the existence or not of anthropic pressures (pollution, overfishing, etc.), the period, means and techniques of sampling, as well as the location of the study environment. Concerning this last factor, the high specific richness of the Fresco lagoon is favored by its

location between the Atlantic Ocean and the Bolo and Niouniourou rivers.

Overall, the species *Sarotherodon melanotheron* represents more than half of the ichthyofauna, both numerically (59.23% of total abundance) and by weight (58,06% of the total weight). It also dominates the population during each of the four seasons. Moreover, it presents a maximum occurrence (100%). This result agrees with the classification of *Sarotherodon melanotheron* in the fundamental lagoon population by Albaret (1999). This strong presence of *Sarotherodon melanotheron* indicates that it enjoys favorable living conditions in the study environment. In particular, it finds zooplankton (Etilé *et al.*, 2018) and algae (Konan *et al.*, 2019) which constitute a food source (Diouf, 1996).

It also has physiological and biological characteristics that allow it to adapt to various environments including lagoons and estuaries. Indeed, it is characterized by an opportunistic diet that varies according to environmental conditions (Amoussou *et al.*, 2016). It is eurythermal (Jennings and Williams, 1993) and euryhaline (Ouattara *et al.*, 2009). This high abundance also gives this species an economic importance in the fishery.

The 8 ecological categories determined by Chabanne (2007) are represented among the collected specimens. Indeed, in addition to the strict estuarine species (Es), there are also species with continental affinity and species with marine affinity in all the samples. The presence of species with continental affinity [estuarine species of continental origin (Ec), continental species with estuarine affinity (Ce) and occasional continental species in estuaries (Co)] is favored by both rivers. That of the species with marine affinity - that is, estuarine species of marine origin (Em), marine-estuarine species (ME), accessory marine species in the estuary (Ma) and occasional marine species in the estuary (Mo) - is linked to the communication between the lagoon and the Atlantic Ocean through the pass.

The Shannon diversity index and the Pielou's evenness index are low. These low values are inherent to the fact that a few species concentrate the majority of numerical and weight abundances in the environment. These are *Sarotherodon melanotheron*, *Sardinella maderensis* and *Neochelon falcipinnis*.

In contrast to the ichthyological populations analyzed during the short seasons, those of the long seasons are significantly different. This temporal variation results from the closure of the channel during the long dry season when ocean-origin swells override the river current (Tetra Tech, 2018) and cause the environment to silt up. Thus, the reduction and then the absence of communication between the lagoon and the ocean induces changes in the physico-chemical parameters of the lagoon that affect the ecological characteristics and aquatic life (Egnankou *et al.*, 2004). Under these conditions, only species capable of adapting to the changes in physicochemical factors can continue to live and thrive in the lagoon. This is the case of *Sarotherodon melanotheron*. In addition, the closed channel also constitutes a barrier to the movement of fish from the ocean to the estuary. The two phenomena combined (changes in physicochemical parameters and obstruction) result in the lowest specific richness observed during the long dry season out of the 4 seasons studied. According to fishermen, this period is also marked by a decrease in fish production, which is one of the reasons that push them to open the pass themselves in April, at the beginning of the main rainy season. The results of our work concur with this opinion of the fishermen. Indeed, after the opening of the channel, our catches increased from the great dry season to the great rainy season, passing from 20960 to 67007 specimens for respective weights of 1492.41 and 4822.60kg.

Conclusion

This study allowed to know the fish community of Fresco lagoon. This fish fauna is relatively rich in species and diversified in terms of ecological categories thanks to the fluvial inputs and the communication with the Atlantic Ocean.

It is therefore dependent on the opening of the channel, which must be subject to a sustainable maintenance mechanism. The results of the present study constitute reference data for the implementation and conduct of conservation policies for this ichthyofauna.

Acknowledgements

The authors would like to thank fishermen of Fresco for their support and their participation in the fishing activities.

References

Albaret JJ, Simier M, Darboe FS, Ecoutin JM, Raffray J, de Morais LT. 2004. Fish diversity and distribution in the Gambia estuary, West Africa, in relation to environmental variables. Aquatic Living Resources **17,** 35-46. https://doi.org/10.1051/ alr:20

Albaret JJ. 1999. Les peuplements des estuaires et des lagunes. In : Lévèque C and Paugy D, Eds. Les poissons des eaux continentales africaines : diversité, biologie, écologie, utilisation par l'Homme. IRD, Paris 325-249.

Amanieu M, Lasserre G. 1982. Organisation et évolution des peuplements lagunaires. Oceanologica Acta, N° SP: 201-213.

Amoussou TO, Toguyeni A, Imorou TI, Chikou A, Youssao AKI. 2016. Caractéristiques biologiques et zootechniques des tilapias africains *Oreochromis niloticus* (Linnaeus, 1758) et *Sarotherodon melanotheron* Rüppell, 1852: une revue. International Journal of Biological and Chemical Sciences **10(4),** 1869-1887.

Anoh KP. 2010. Stratégies comparées de l'exploitation des plans d'eau lagunaire de Côte d'Ivoire. Les Cahiers d'Outre-Mer **251,** 347-364.

Assi SR, Konan KF, Kouamé KM, Boussou KC, Aliko NG, Gourène G. 2019. Diversity and trophic guilds structure of fish assemblages from Aghien Lagoon (Côte d'Ivoire). Aquaculture, Aquarium, Conservation and Legislation - International Journal of the Bioflux Society **12(3),** 977-988.

Barbault R. 2000. Ecologie générale : structure et fonctionnement de la biosphère. 5e édition, Edition Dunod, Paris 326 p.

Bédia AT, Etilé NR, Blahouakg, N'Douba V. 2017. Diversité, structure du peuplement ichtyologique et production d'une lagune tropicale ouest africaine : lagune Potou (Côte d'Ivoire). International Journal of Innovation and Applied Studies **19(2),** 449-462.

Chabanne D. 2007. Les catégories bioécologiques des espèces de poissons des estuaires et lagunes de l'Afrique de l'Ouest. Master en Sciences et Technologies, Université des Sciences et Techniques du Languedoc de Montpellier 2, 18 p.

Charles-Dominique E, Raffray J. 1985. Guide de détermination des poissons des lagunes de Côte d'Ivoire. Archives Scientifiques du Centre de Recherches Oceanologiques **11(1),** 85 p.

Coulibaly B, Tah L, Joanny-Tapé GT, Koné T, Kouamélan EP. 2016. Fish assemblage structure in the tropical coastal lagoon of Grand Lahou (Côte d'Ivoire, West Africa). International Journal of Fisheries and Aquaculture **8(1),** 1-13. DOI :10.5897/IJFA15.0537

Dajoz R. 2000. Précis d'écologie. 7e édition, Editions Dunod, Paris, 615 p.

Diouf PS. 1996. Les peuplements de poissons des milieux estuariens de l'Afrique de l'Ouest : l'exemple de l'estuaire hyperhalin du Sine-Saloum. Université de Montpellier II. Thèses et Documents Microfiches No.156. ORSTOM, Paris 267 p.

Durand JR, Skubich M. 1982. Les lagunes ivoiriennes. Aquaculture **27**, 211-250.

Egnankou WM, Sankaré Y, Conarams CI. 2004. Fiche descriptive sur les zones humides Ramsar (FDR), Fresco (Côte d'Ivoire) 18 p.

Egnankou WM. 1985. Etude des mangroves de Côte d'Ivoire : aspect écologique et recherches sur les possibilités de leur aménagement. Thèse de Doctorat de 3è Cycle : Université Paul-Sabatier Toulouse III, N° 3196, 176 p.

Egnankou WM. 1987. La mangrove ivoirienne en voie de disparition. Annales de l'Université d'Abidjan Ecologie **XIX,** 9-27.

Egnankou WM. 1997. La fermeture de la passe de Fresco et ses conséquences sur la productivité de la lagune N'Gni. In : Björn K, Luiz DL and El Hadji SD, Eds. Mangrove ecosystem studies in Latin America and Africa. UNESCO, Paris 271-283.

Egnankou WM. 2009. Réhabilitation des mangroves comprises entre Fresco et Grand Lahou en Côte d'Ivoire : zones importantes pour la pêche. Nature et faune **24(1),** 86-93.

Etilé NR, Aka NM, Blahouakg, Kouamélan EP, N'douba V. 2018. Zooplankton diversity and distribution in a Fresco Lagoon (West Africa, Côte d'Ivoire). International Research Journal of Environmental Sciences **7(10),** 9-20.

Eyi AJ, Konan KJ, Tano K, N'Da K, Atsé BC. 2016. Étude préliminaire des communautés itchyofauniques de la lagune Ono (Côte d'Ivoire). Journal of Applied Biosciences **104,** 9894 - 9906. DOI: 10.4314/jab.v104i1.1

Froese R, Pauly D. 2019. Fishbase. World Wide Web electronic publication. www.fishbase.org.Version (06/2019).

Hill MO. 1973. Diversity and evenness: a unifying notation and its consequences. Ecology **54,** 427-432.

Issola Y, Kouassi AM, Dongui BK, Adingra AA, Biemi J. 2009. Concentration en métaux lourds des sédiments d'une lagune côtière tropicale : lagune de Fresco (Côte d'Ivoire). Journal of Applied Biosciences **18,** 1009-1018.

Issola Y, Kouassi AM, Dongui BK, Biemi J. 2008a. Caractéristiques physico-chimiques d'une lagune côtière tropicale : lagune de Fresco (Côte d'Ivoire). Afrique Science **04(3),** 368-393.
DOI: 10.4314/afsci.v4i3.61696

Issola Y, Kouassi AM, Messoum FG. 2008b. Evaluation de la qualité chimique des sédiments de la lagune de Fresco, Côte d'Ivoire. Fiches Techniques et Documents de Vulgarisation 27-31.

Jennings DP, Williams JD. 1993. Factors influencing the distribution of blackchin tilapia, *Sarotherodon melanotheron*, in the Indian River system, Florida. Northeast Gulf Science **12(2),** 111-117.

Kambiré O, Adingra AA, Kakou AC, Koffi-Névry R. 2012. Indicateurs de pollution fécale dans une lagune tropicale à forte influence continentale (Lagune Aby, Côte d'Ivoire). Agronomie Africaine **24(2),** 89-100.

Koffi BK, Aboua BRD, Koné T, Bamba M. 2014. Fish distribution in relation to environmental characteristics in the Aby-Tendo-Ehy lagoon system (Southeastern Côte d'Ivoire). African Journal of Environmental Science and Technology **8(7),** 407-415.

Konan ES, Aka NM, Adon MP. 2019. Les diatomées pennales de la lagune de Fresco (Côte d'Ivoire). International Journal of Biological and Chemical Sciences **13(3),** 1354-1365.
DOI: 10.4314 /ijbcs.v13i3.12

Kouadio ANC. 2014. Influence de quelques facteurs abiotiques et anthropiques sur la diversité biochimique et génétique de souches de *Escherichia coli* de la lagune de Fresco (Côte d'Ivoire). Thèse Unique de l'Université Nangui Abrogoua, Abidjan, Côte d'Ivoire, 168 p.

Kouadio N, Dadié A, Adingra A, Aké Y, Djè K. 2011. Biotypes de *Escherichia coli* isolés des poissons et de l'eau de la lagune de Fresco, Côte d'Ivoire. Journal of Applied Biosciences **38,** 2523-2530.

Kouamélan EP. 1999. L'effet du lac de barrage Ayamé (Côte d'Ivoire) sur la distribution et l'écologie alimentaire des poissons Mormyridae (Teleostei, Osteoglossiformes). Thèse de Doctorat de Katholieke Universiteit Leuven, Belgique 221 p.

Ludwig JA, Reynolds JF. 1988. Statistical ecology: a primer on methods and computing. John Wiley & Sons, New York 352 p.

N'Guessan YA, Adopo KL, Amani EM, Konan KB, Touré M, Mondé S, Aka K. 2013. Etude bathymétrique, sédimentologique et environnement de dépôt des sables superficiels de la lagune de Fresco (zone ouest du littoral ivoirien). Journal of Asian Scientific Research **3(3),** 308-320.

Nicole M, Egnankou WM, Schmidt M. 1987. Les zones humides côtières de Côte d'Ivoire. Abidjan, Orstom 73 p.

Ouattara NI, Iftime A, Mester LE. 2009. Age et croissance de deux espèces de Cichlidae (Pisces): *Oreochromis niloticus* (Linnaeus, 1758) et *Sarotherodon melanotheron* Rüppell, 1852 du lac de barrage d'Ayamé (Côte d'Ivoire, Afrique de l'Ouest). Travaux du muséum national d'histoire naturelle «Grigore Antipa» **LII,** 313-324.

Paugy D, Lévêque C, Teugels GG. 2003a. Faune des poissons d'eaux douces et saumâtres de l'Afrique de l'Ouest. Tome 1. IRD (Paris), MNHN (Paris), MRAC (Tervuren) 457 p.

Paugy D, Lévêque C, Teugels GG. 2003b. Faune des poissons d'eaux douces et saumâtres de l'Afrique de l'Ouest. Tome 2. IRD (Paris), MNHN (Paris), MRAC (Tervuren) 815 p.

Rancurel P. 1971. Les Teredinidae (Mollusques Lamellibranches) dans les lagunes de Côte d'Ivoire. Mémoires ORSTOM 47, Paris 212 p.

Sankaré Y, Amalatchy NJ, Koffie-Bikpo CY. 2014. Etude comparative des captures de crabes nageurs *Callinectes amnicola* (Decapoda, Portunidae) des lagunes ivoiriennes (Afrique de l'Ouest). Revue CAMES. Sciences de la vie, de la terre et agronomie **01(1),** 75-84.

Sankaré Y, Avit J-BLF, Egnankou WM, Saenger P. 1999. Étude floristique des mangroves des milieux margino-littoraux de Côte d'Ivoire. Bulletin du Jardin botanique national de Belgique **67,** 335-360.

Shannon EC, Weaver W. 1963. The mathematical theory of communication. University of Illinois press 117 p.

Ted EW, Yao MN, Konan PM, Koffi-Bi FK, Monde S, Kouamé RA. 2017. Analyse morphologique de la lagune Tagba de Grand-Lahou (littoral Sud-Ouest de la Côte d'Ivoire). International Journal of Innovation and Scientific Research **30(1),** 34-41.

Tetra Tech. 2018. USAID/West Africa Biodiversity and Climate Change (WA BiCC), report on climate change vulnerability assessment of the Fresco lagoon landscape, Côte d'Ivoire, 2nd Labone Link, North Labone, Accra, Ghana 98 p.

Varlet F. 1978. Le régime de la lagune Ebrié (Côte d'Ivoire), traits physiques essentiels. Travaux et Documents Orstom **83,** 164 p.

Yabi I, Yabi BF, Dadegnon S. 2013. Diversité des espèces végétales au sein des agro-forêts à base d'anacardier dans la commune de Savalou au Benin. International Journal of Biological and Chemical Sciences **7(2),** 696-706. DOI : 10.4314/ijbcs.v7i2.24