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Characterization of the Ichthyological Population of Hydrosystemes in the Lagoon Area of the Azagny National Park (Ivory Coast)

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Abstract

The conservation of protected areas is nowadays one of the concerns of international and national institutions. This study aims to contribute to better conservation of the ichthyological fauna of the lagoon area of the Azagny National Park (PNA). This national park has been dealing with the harmful effects of human activities for years. Thus, from March 2019 to February 2020, sampling campaigns were carried out to characterize this space, for better conservation. The results obtained are based on the analysis of abiotic and biotic (fish) data collected at 6 stations. The physicochemical parameters were measured using a multiparameter and the fish population collected using 10 gillnet batteries of 10, 25, 30, 35, 40 and 50 mm mesh void. The analysis of the ichthyological population of the lagoon area reveals a diversity of 53 species belonging to 30 families and 12 orders. 11 species were newly collected while 31 species previously recorded in these hydrosystems were not captured in the present study. The Shannon (H'> 2) and Equitability (E> 0.5) indices calculated reflect a good organization and stability of the ichthyological population of the hydrosystems of the PNA lagoon zone. The

Monte-Carlo test indicates that the variables rate of nitrate, width, rate of dissolved oxygen, water temperature, alkalinity, salinity, rate of dissolved solid and phosphorus are those which discriminate specific richness, abundance and the distribution of the stand.

Keywords: Ichthyofauna, Environmental Variable, Distribution, Azagny National Park

Introduction

Global warming and human activities have degraded the environment for centuries and resulted in substantial loss of habitat and biodiversity (Young *et al*., 2005). In order to protect this biodiversity, in Côte d'Ivoire, a vast network of protected areas made up of Nature Reserves and National Parks has been set up (Koffi *et al*., 2015). The Azagny National Park (PNA), among many others, ensures the maintenance and conservation of biological diversity. It is adjacent in its south-eastern part by sector VI of the Ébrié lagoon and the artificial Azagny Canal serving as a connection between the Ébrié lagoon and the estuary of the Bandama river (Koffi *et al*., 2014). The PNA offers many habitats for the development of animal species, including fish. In fact, the hydrosystems of the PNA lagoon zone, mainly mangroves, are known to serve as nursery areas for fish and promote the repopulation of surrounding rivers (Getzner and Islam, 2020). Despite its protected area status, the hydrosystems of the PNA lagoon area are directly or indirectly affected by the harmful effects of human activities. These human activities such as the destruction of mangroves by the riparian population, the pressure from fishing and the pollution of water by the use of pesticides and fertilizers in nearby farms, attempt to violate the protection of the aquatic resources of the lagoon area of the PNA (Bleu *et al*., 2011). These disturbances profoundly transform habitats, modify the aquatic environment, weaken the overall functioning of ecosystems as well as their various biological compartments (Chouti *et al*., 2010). They have negative consequences on the aquatic community in general, but particularly on fish (Wu *et al*., 2011). With regard to the environmental consequences that human activities could cause, there is therefore a real need to put in place a good policy for the sustainable management of aquatic ecosystems of the PNA. This management policy requires knowledge of the physico-chemical environment and the ichthyological population. Several studies (Kouamé *et al*., 2010; Bleu *et al*., 2011; Koffi *et al*., 2015), have been carried out in the PNA and its surroundings, on the ichthyological population of the Grand-Lahou lagoon, on the contamination of fish by heavy metals in the lagoon of Grand-Lahou and on the vegetation within the national park of Azagny. To the current state of knowledge, no study has been carried out on the ichthyological fauna of the hydrosystems of the lagoon zone of the Azagny

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National Park, even less that which characterizes its population. This study aims to characterize the ichthyological population of the lagoon area of the Azagny National Park in order to effectively contribute to the conservation of these natural resources. This requires a characterization of the physicochemical environment, of the ichthyological population and of the demonstration of the influence of environmental variables on the distribution of the ichthyological population. The results of this work will serve as a basis for managers of protected areas to take appropriate measures for better conservation of aquatic fauna.

Material and methods

Study area

The lagoon area of the Azagny National Park lies between longitudes 3 ° 47 'and 5 ° 29' West and latitudes 5 ° 02 'and 5 ° 42' North. Sector VI of the Ébrié lagoon constitutes the eastern limit of the PNA and opens onto the localities of Azagny village and Gboyo located in the sub-prefecture of Grand-Lahou. It is connected to the estuary of the Bandama river and to the ocean by the Azagny canal. Sampling was carried out at 6 sites (Ca1, Ca2, Ca3, Eb1, Eb2, Eb3), located in sector VI of the Ébrié lagoon as well as its extension into the Azagny canal (figure 1).

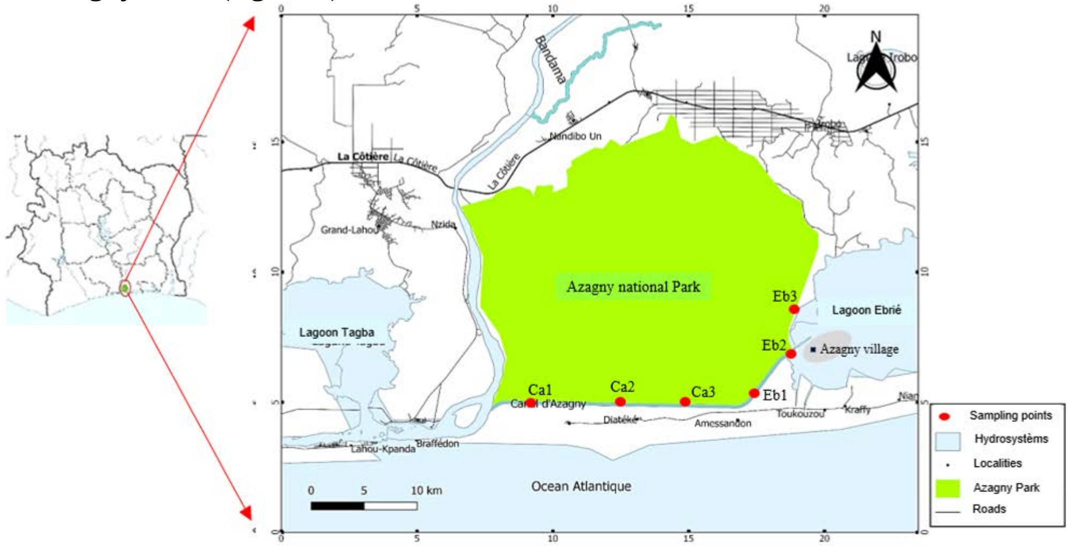

Fig 1 : Sampling points in the hydrosystems of the lagoon area of Azagny National Park. (Ca1: Canal entrance; Ca2: Noumouzou; Ca3: N'guessandon; Eb1: canal end; Eb2: Mangrove Canal; Eb3: Mangrove Azagny)

Data gathering

From March 2019 to February 2020, sampling of the physicochemical parameters and the fish were carried out monthly.

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The environmental variables (water temperature, pH, dissolved oxygen, conductivity, rate of dissolved solids) were determined using an AQUAmeter type multiparameter and AQUARed brand. These in-situ measurements of environmental variables were taken twice a day between 8-9 a.m. in the morning and 12- 02 p.m. in the afternoon for two days. The hydrosystem transparency measurement was made using a Secchi disk. The determination of nutrient salts (ammonium, ammonia, nitrite, phosphate and phosphorus) and the measurement of alkalinity were carried out ex-situ using a Hanna brand miniphotometer according to the Beer Lambert principle. The rate of canopy closure, aquatic plant cover and substrate were visually estimated and expressed as a percentage (Kamelan *et al*. 2013).

The fish samples were taken with nets and traps. Two batteries of net with 10, 25, 30, 35, 40 and 50 mm mesh void were used for the collection of fish. Fish were taken according to two types of fishing; the nets were set at 5 p.m. and visited at 7 a.m. for night fishing, replaced then raised at 12 p.m. for day fishing. Sampling of ichthyological fauna with the traps consisted of placing them in the aquatic environment for two days before picking them up and harvesting the fish trapped inside. The fish harvested are identified from the key of Paugy *et al*. (2003 a and b) and the names have been updated in Fishbase (Froese and pauly, 2019). Identified fish are weighed to the nearest gram, measured and placed in storage bags with a recognition label and stored in a barrel containing 10% formaldehyde.

Data analysis

The numerical percentage (N) is the ratio of the number of individuals (n_i) of a taxonomic group i (species, family or order) to the total number of individuals (N_t) (N'Zi *et al*., 2008). The expressions are the following:

$$\mathbf{N = \frac{n_i}{N_t} \times 100}$$

With: n_i = Number of individuals of a taxonomic group (species, family or order), N_t = Total number of individuals.

The frequency of occurrence is the percentage of samples in which a taxon is present (Gbenyedji *et al*., 2011). It is obtained by the following formula:

$$\mathbf{F\% = \frac{S_i}{S_t} \times 100}$$

Where, Si: number of stations where species *i* was captured and St: total number of stations examined. The classification of Djakou and Thanon (1988) was used for this study. It is established as follows: 80% ≤ F ≤ 100%: very common species; 60% ≤ F ≤ 79%: Common species; 40% ≤ F ≤ 59%: fairly frequent species; 20% ≤ F ≤ 39%: Auxiliary species; F <20%: accidental species.

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The structure of the fish community was analyzed using two indices (Shannon and Wiener diversity index and equity) to express the degree of uniformity distribution of individuals among the taxa of the study area. (Imoobe and Adeyinka, 2009). The Student *t*-test ($P > 0.05$) was carried out to check the significance of the variation of the different indices and the specific richness recorded on the different stations. The influence of environmental factors on fish species assemblages was demonstrated by a Redundancy Analysis (RDA), carried out using the CANOCO 4.5 program.

Results

Environmental variables

The results of the environmental variables measured in this study are given in Table I. The mean values of the physicochemical parameters vary significantly from one station to another (Anova; P <0.05). The pH is maximum (6.48 ± 1.10) at station Eb1 and minimum (5.75 ± 1.21) at station Eb3. The dissolved oxygen level is higher (6.48 ± 0.56 mg / L) at the Ca1 station and low (5.26 ± 1.83 mg / L) at the Eb1 station. The waters are relatively warmer (29.62 ± 2.23 ° C) at station Ca2 and cooler (28.17 ± 2.18 ° C) at station Eb2. The salinity is maximum (16.98 ± 22.44) at station Ca2 and minimum (3.61 ± 7.32) at station Eb2. The dissolved solid levels and the electrical conductivity are lower (240.90 ± 330.77 mg / L; 1412.17 ± 2786.14 µS / cm) at the Ca1 station and higher (1737.91 ± 1511.57 mg / L; 3611.17 ± 1950.24 µS / cm) at station Eb3.

Table I: Average values and standard deviations of the physicochemical parameters measured in the ecological zones of the hydrosystems of the PNA from March 2019 to February 2020

Stations	Desc	T°C	pH	O_2(mg/L)	Sal (‰)	TDS (mg/L)	Cond (µS/Cm)
Ca1	Avg	29.39 [a]	6.21[a]	6.48 [a]	15.47[a]	240.90 [c]	1412.17 [c]
	E(n-1)	1.75	1.19	0.56	25.39	330.77	2786.14
Ca2	Avg	29.62 [a]	6.38 [a]	5.99 [ab]	16.98[a]	688.58[bc]	2430.08[bc]
	E(n-1)	2.23	1.03	0.48	22.44	1788.58	3573.71
Ca3	Avg	28.90 [ab]	6.26 [a]	6.07 [ab]	13.70[ab]	875.71[bc]	2081.67[bc]
	E(n-1)	1.63	1.63	1.57	18.31	2308.99	3408.01
Canal	**Avg**	**29.3**	**6.28**	**6.18**	**15.38**	**601.73**	**1974.64**
	E(n-1)	**0.37**	**0.09**	**0.26**	**1.64**	**326.19**	**517.327**
Eb1	Avg	28.83 [ab]	6.48 [a]	5.26 [b]	4.13[c]	1366.83 [ab]	3561.42 [a]
	E(n-1)	2.05	1.1	1.83	9.50	2085.06	3325.15
Eb2	Avg	28.17 [b]	6.38 [a]	6.15 [ab]	3.61[c]	1668.50 [a]	3122.67[ab]
	E(n-1)	2.18	1.09	1.46	7.32	2522.79	3225.01

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Eb3	Avg	28.8 [ab]	5.75 [a]	5.68 [ab]	5.28[bc]	1737.91 [a]	3611.17 [a]
	E(n-1)	2.41	1.21	1.07	13.06	1511.57	1950.24
Ebrié	**Avg**	**28.6**	**6.2**	**5.7**	**4.338**	**1591.08**	**3431.753**
	E(n-1)	**0.37**	**0.39**	**0.44**	**0.86**	**197.28**	**268.83**
Lagoon area	**Avg**	**28.95**	**6.24**	**5.93**	**9.861**	**1 096.41**	**2 703.20**
	E(n-1)	**0.51**	**0.26**	**0.42**	**5.62**	**593.10**	**879.15**

Avg = Average; E (n-1) = Standard deviation; T = Temperature; pH = Hydrogen potential; O2 = dissolved oxygen; Sal = Salinity; TDS = Rate of dissolved solid; Cond = Conductivity; values having a letter (a, b or c) in common do not differ significantly (Anova: *P*> 0.05).

Stand analysis

Qualitative analysis of the stand

The analysis of the population sampled in the hydrosystems of the lagoon area of the Azagny National Park shows 53 species distributed between 30 families and 12 orders (Table I). This stand includes 23 freshwater species, 20 species with marine and estuarine affinity, 8 brackish water species, one introduced species and one hybrid. Of these, 11 species have been newly recorded while 37 previously recorded species are missing. The analysis of the stand in relation to data from the IUCN Red List indicates the presence of an almost threatened species (*Cynoglossus senegalensis*) in the hydrosystems of the lagoon area of the Azagny National Park. The ichthyological population of the lagoon zone is respectively dominated by the order of Perciformes (21 species or 38.18%), Siluriforms (8 species or 14.55%) and Characiforms (5 species or 9.09%) representing 61.82% of specific richness. The other orders represent 38.18% of the total specific richness. The most diverse families are respectively those of Cichlidae (10 species, i.e. 18.87%), Gobiidae (4 species, i.e. 7.55%), Clupeidae (3 species, i.e. 5.66%), Alestidae (3 species, i.e. 5.66%) and Clariidae (3 species or 5.66%) comprising 43.4% of the specific richness. The other families represent 56.60% of the ichthyological diversity sampled in the hydrosystems of the lagoon area of the Azagny National Park.

Table II: Fish populations inventoried in the hydrosystems of the lagoon area of the Azagny National Park (PNA) from March 2019 to February 2020.

N°	**SPECIES**	**Env**	**IUCN State**	Ca1	Ca2	Ca3	Eb1	Eb2	Eb3	F%
	Order : Elopiforms ; Family : Elopidae									
1	*Elops lacerta*** Valenciennes, 1847	M, B, F	LC	+	+	+	+	+	+	100
	Order : Clupeiforms ; Family : Clupeidae									
2	*Pellonula leonensis*** Boulenger, 1916	M, B, F	LC	+	+	+	+	+	+	100
3	*Pellonula vorax*** Günther, 1868	M, B, F	LC		+	+	+	+	+	83,33
4	*Ethmalosa fimbriata*** Bowdich, 1825	M, B, F	LC	+		+	+	+		66,67

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	Order : Osteoglossiforms ; Family : Osteoglossidae									
5	*Heterotis niloticus*** Cuvier, 1829	F	LC				+		+	33,33
	Family : Notopteridae									
6	*Papyrocranus afer* (Günther, 1868)	F	LC		+	+	+	+	+	83,33
	Family : Mormyridae									
7	*Marcusenius ussheri* (Günther, 1867)	F	LC	+		+				33,33
8	*Mormyrus rume* Valenciennes, 1847	F	NE	+	+					33,33
	Order : Characiforms ; Family : Hepsetidae									
9	*Hepsetus odoe (Bloch, 1794)*	F	LC	+	+	+	+	+	+	100
	Family : Alestidae									
10	*Brycinus longipinnis** (Günther, 1864)	B, F	LC	+	+				+	50
11	*Brycinus macrolepidotus* (Rüppell,1832)	B, F	LC		+				+	33,33
12	*Hydrocynus forskahlii* (Cuver, 1819)	F	LC	+	+					33,33
	Family : Distichodontidae									
13	*Distichodus rostratus* Günther, 1864	F	LC	+	+		+		+	66,67
	Order : Cypriniforms ; Family : Cyprinidae									
14	*Labeo coubie* Rüppell, 1832	F	DD	+	+	+	+	+	+	100
	Order : Siluriforms ; Family : Claroteidae									
15	*Chrysichthys maurus* (Valenciennes, 1840)	F	LC	+	+	+	+	+	+	100
16	*Chrysichthys nigrodigitatus* Lacepède, 1803	F	DD	+	+	+	+	+	+	100
	Family : Schilbeidae									
17	*Schilbe mandibularis* (Günther, 1867)	F	LC	+	+				+	50
	Family : Clariidae									
18	*Clarias gariepinus* (Burchell, 1822)	F	LC	+						16,67
19	*Clarias anguillaris* (Linnaeus, 1758)	F	LC	+						16,67
20	*Heterobranchus longifilis* Valenciennes, 1840	F	LC	+	+		+	+		66,67
	Family : Mochokidae									
21	*Synodontis punctifer* Daget, 1964	F	LC	+						16,67
22	*Synodontis schall* Daget, 1965	F	LC	+	+					33,33

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	Order : Syngnathiforms ; Family : Syngnathidae									
23	*Enneacampus ansorgii** (Boulenger, 1910)	B, F	LC						+	16,67
	Family : Synbranchidae									
24	*Monopterus boueti* (Pellegrin,1922)	F	LC	+	+			+		50
	Order : Perciformes ; Family : Gerreidae									
25	*Eucinostomus melanopterus*** Bleeker, 1863	M, B, F	LC	+	+	+	+	+	+	100
	Family : Cichlidae									
26	*Chromidotilapia guntheri* (Sauvage, 1882)	F	LC			+	+	+		50
27	*Hemichromis fasciatus* Peters, 1852	F	LC	+	+	+	+	+	+	100
28	*Oreochromis niloticus** (Linnaeus, 1758)	B, F	LC	+						16,67
29	*Coptodon hybride = Tilapia guineensis X Tilapia zillii*	-	LC	+	+	+	+	+	+	100
30	*Coptodon guinéensis*** (Bleeker in Günther, 1862)	M, B, F	LC			+	+	+	+	66,67
31	*Coptodon zillii** (Gervais, 1848)	B, F	NE			+	+	+	+	66,67
32	*Sarotherodon melanotheron*** Rüppell, 1852	M, B, F	NE	+	+	+	+	+	+	100
33	*Tylochromis jentinki** (Steindachner, 1894)	B, F	LC	+	+	+	+	+	+	100
34	*Tylochromis sudanensis* Daget, 1954		LC			+	+			33,33
35	*Pelmatolapia mariae** (Boulenger, 1899)	B, F	LC	+	+	+	+	+		100
	Family : Haemulidae									
36	*Pomadasys rogerii** lacepède,1802				+					16,67
37	*Pomadasys jubelini*** (Cuvier, 1830)	M, B, F	LC	+	+	+	+	+	+	100
	Family : Lutjanidae									
38	*Lutjanus agennes*** Bleeker, 1863	M, B	LC		+					16,67
39	*Lutjanus dentatus*** (Duméril, 1861)	M, B	DD	+						16,67
	Family : Monodactylidae									
40	*Monodactylus sebae*** (Cuvier, 1829)	M, B, F	NE	+	+	+	+	+	+	100
	Family : Polynemidae									
41	*Polydactylus quadrifilis*** (Cuvier, 1829)	M, B, F	LC	+	+	+	+	+		100

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	Family : Carangidae									
42	*Trachinotus teraia*** Cuvier, 1832	M, B, F	LC			+	+	+	+	66,67
	Family : Channidae									
43	*Parachanna obscura*** (Günther, 1861)	F	NE				+	+	+	50
	Family : Anabantidae									
44	*Ctenopoma petherici* Günther, 1864	F	LC				+		+	33,33
	Order : Mugilliforms ; Family : Mugilidae									
45	*Liza falcipinnis*** (Valenciennes, 1836)	M, B, F	DD	+	+		+	+	+	83,33
	Order : Gobiiforms ; Family : Sphyraenidae									
46	*Sphyraena guachancho*** Cuvier, 1829	M, B	LC	+	+				+	50
	Family : Gobiidae									
47	*Porogobius schlegelii*** (Günther, 1861)	M, B, F	LC			+	+	+	+	66,67
48	*Awaous lateristriga*** (Duméril, 1861)	M, B, F	LC	+	+	+	+	+	+	100
49	*Gobioides sagitta*** Günther, 1862	M, B, F	LC			+	+	+	+	66,67
50	*Gobionellus occidentalis*** (Boulenger, 1909)						+	+	+	50
	Order : Pleuronectiforms ; Family : Paralichthydae									
51	*Citharichthys stampfli*** (Steindachner, 1894)	M, B, F	LC	+	+	+	+	+	+	100
	Family : Synoglossidae									
52	*Cynoglossus senegalensis*** (Kaup, 1858)	M, B	NT		+	+	+	+	+	83,33
53	*Synaptura lusitanica*** (de Brito Capello, 1868)	M, B	LC		+					16,67

N = Numbers; Env = Living environments; F = Freshwater species; B, F = Brackish and freshwater species; M, B, F and M, B = Estuarine and / or marine species; IUCN = Status of the species in the red list of the International Union for the Conservation of the Nation; LC = Minor concern; DD = Missing data; NE = Not evaluated; NT = almost threatened; EN = Endangered species

Quantitative analysis of the stand

The most representative orders of the population are those of Perciforms (63.27%), Siluriforms (11.99%) and Gobiiforms (6.69%), comprising 81.95% of the global numerical abundance. The other orders account for 9.14% of the numerical abundance (Figure 2). The most representative Families from a numerical point of view with 67.74% are respectively those of Cichlidae

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(53.01%), Claroteidae (8.19%) and Gobiidae (6.54%). The other Families constitute 32.26% of the entire population (Figure 3).

Spatial variation of population

The analysis of the spatial variation in the specific richness of the samples collected at the different stations indicates that the highest specific richness was obtained in the Ca2 (35 species) and Eb1 (35 species) stations. They are followed by the stations Ca1 (34 species) and Eb3 (34 species). Then come the stations Eb2 and Ca3 which have respectively 31 species and 29 species. The Kruskall-Wallis test (P> 0.05), does not indicate any significant difference among the specific richness in the stations (Figure 4).

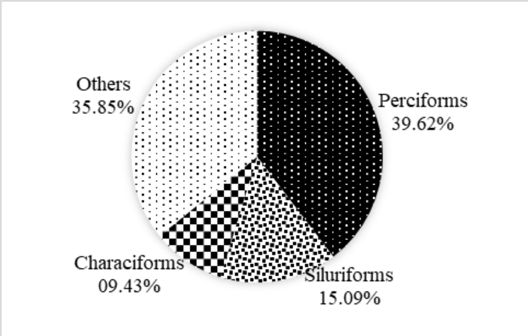

Figure 2: Spectrum of digital abundances of fish orders sampled in the hydrosystems of the PNA lagoon zone from March 2019 to February 2020

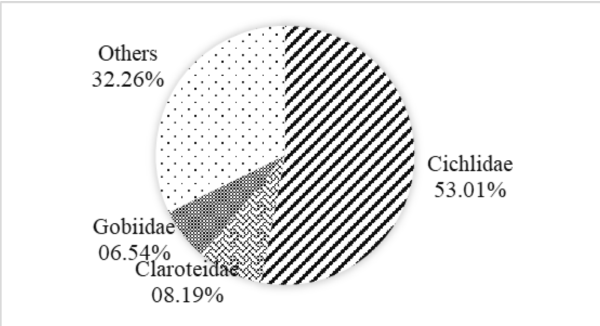

Figure 3: Spectrum of digital abundances of fish families sampled in the hydrosystems of the PNA lagoon zone from March 2019 to February 2020

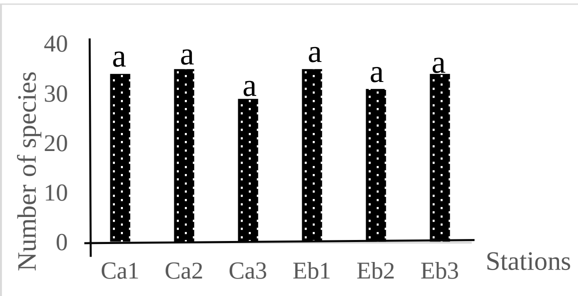

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Figure 4: Spatial variations in the specific richness sampled in the hydrosystems of the PNA lagoon zone between March 2019 and February 2020; the values having the letter "a" in common do not differ significantly (Student t-test: *P*> 0.05)

Occurrence of sampled species

The The analysis of the occurrence indicates 21 very frequent species including 17 species recorded on 6 stations, i.e. 100% and 4 species recorded on 5 stations out of 6, i.e. 83.33%, 9 frequent species collected at 4 stations out of 6, i.e. 66, 67%, 7 fairly frequent species listed in 3 out of 6 stations, i.e. 50%, 8 species recorded at 2 stations, i.e. 33.33% and 8 species recorded at 1 station, i.e. 16.67%.

Structure of stand

The Shannon and Equitability indices calculated in the lagoon area are recorded in (Table III). The mean value of the Shannon index of the PNA lagoon area is 2.97 ± 0.36. It is minimum (2.2) at station Eb3 and maximum (3.04) at station Ca3. Those of fairness with an average value of 0.75 ± 0.10. Maximum Fairness (0.89) was obtained at station Eb1 and minimum (0.63) at station Eb3. The Kruskal-Wallis test (P <0.05), indicates a significant variation between the median values of the Shannon index and the Fairness from one station to another.

Table III: Shannon diversity index (H’) and equity (E) of fish populations inventoried in the lagoon area of the Azagny National Park (PNA).

	Digital abundance	
	H'	E
Canal entrance (Ca1)	2.69[ab]	0.76[ab]
Noumouzou (Ca2)	2.79[a]	0.82[a]
N’Gessandon (Ca3)	3.04[a]	0.87[a]
Mangrove canal (Eb1)	3.03[a]	0.68[b]
Canal end (Eb2)	2.27[b]	0.89[a]
Mangrove Azagny (Eb3)	2.2[b]	0.63[b]
Lagoon area	**2.97 ± 0.36**	**0.75 ± 0.10**

H '= Shannon index; E = Fairness Index; the median values of the indices having a letter (a or b) in common do not differ significantly (Kruskal-Wallis: *P*> 0.05).

Fish community and environmental variables

The Monte-Carlo test indicates that the variables rate of nitrate, width, rate of dissolved oxygen, water temperature, alkalinity, salinity, rate of dissolved solid and phosphorus are the variables which have more influence on the distribution of ichthyological fauna.

Axes I and II carrying the largest cumulative variable make it possible to highlight three groups of species (**Figure 5**). The first group consists of the species *Synodontis schall*, *Brycinus macrolepidotus*, *Mormyrus rume*,

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Marcusenius ussheri, *Lutjanus agennes*, *Lutjanus dentatus*, *Sarotherodon melanotheron*, *Distichodus rostratus*, *Oreochromis niloticus*, *Synodontis punctifer*, *Clarias anguillaris*, *Hemichromis fasciatus* and *Monopterus boueti*, positively correlated on Axis1 with the variables nitrate level, width, dissolved oxygen level, water temperature, alkalinity and salinity. The second group includes the species *Ethmalosa fimbriata* (Efi), *Heterotis niloticus* (Hni), *Pellonula vorax* (Pvo), *Chrysichthys maurus* (Cma), *Enneacampus ansorgii* (Ean), *Chromidotilapia guntheri* (Cgu), *Hemichromis fasciatus* (Hfa), *Coptodon hybride* (Thy), *Coptodon guinéensis* (Tgu), *Coptodon zillii* (Tzi), *Sarotherodon melanotheron* (Sme), *Tylochromis jentinki* (Tje), *Tylochromis sudanensis* (Tsu), *Trachinotus teraia* (Tte), *Parachanna obscura* (Pob), *Ctenopoma petherici* (Cpe), *Porogobius schlegelii* (Psc), *Awaous lateristriga* (Ala), *Gobioides sagitta* (Gsa), *Gobionellus occidentalis* (Goc), *Citharichthys stampfli* (Cst) et *cynoglossus senegalensis* (Cse), positively correlated on Axis2 with the dissolved solids rate variables. The third group consisting of species *Papyrocranus afer*, *Labeo coubie*, *Hepsetus odoe*, *Liza falcipinnis*, *Heterobranchus longifilis*, *Brycinus longipinnis*, *Monodactylus sebae*, *Elops lacerta*, *Polydactylus quadrifilis*, *Pelmatolapia mariae*, *Chrysichthys nigrodigitatus* (Cni), *Eucinostomus melanopterus* (Eme), *Pomadasys jubelini* (Pju) et *Pellonula leonensis* are negatively correlated on both axes with the phosphate rate variable.

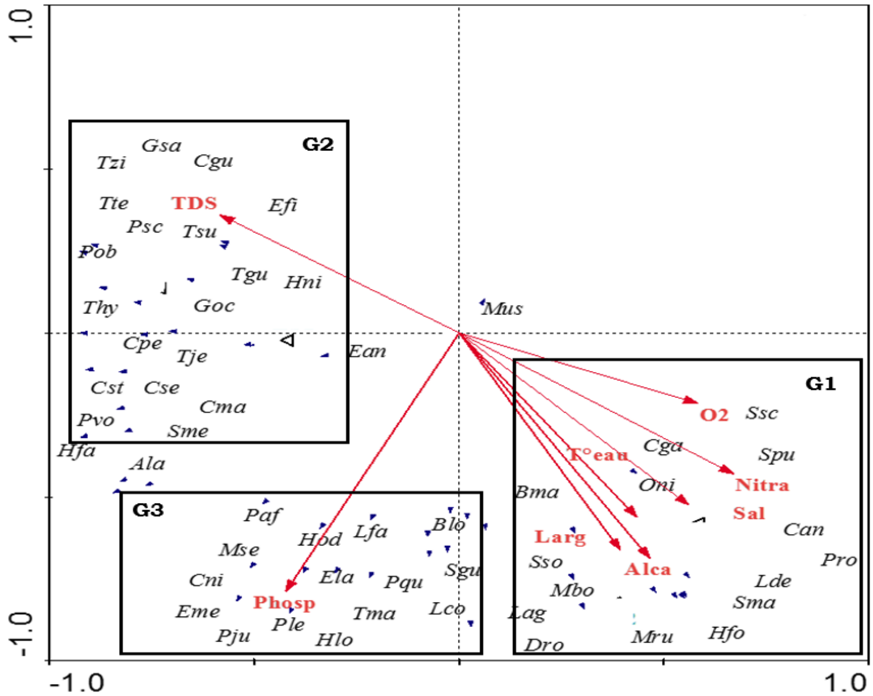

Figure 5: Redundancy analysis (RDA) applied to environmental variables and fish species collected in lagoon hydrosystems in Azagny National Park from March 2019 to February

2020 (Width: width; Alca: Alkalinity; TDS: Dissolved Solids rate; O2: dissolved oxygen concentration; Nitra: nitrate rate; T°eau: water temperature; Sal: salinity; Phosp: phosphate content).

Discussion

Analysis of environmental variables indicates that the hydrosystems of the lagoon area of Azagny National Park are acidic. The acidity of hydrosystems indicates an aquatic environment under the influence of human pressures (Diomandé *et al*., 2019). The water from the PNA hydrosystems crosses several terrains, a watershed that abounds in several agricultural activities and feeds on organic and mineral matter. This would increase the biological mineralization processes and strongly influence the pH of these hydrosystems. These same observations were made by Eyi *et al*. (2016), in the Ono Lagoon. The waters of the PNA lagoon area are well oxygenated. The minimum oxygen concentration in a healthy aquatic ecosystem is 4 mg / L (Bensafia et al., 2020). The average dissolved oxygen values measured in the PNA hydrosystems are greater than 4 mg / L. According to several authors (Villeneuve *et al*., 2006; Konan *et al*., 2013), the dissolved oxygen level in aquatic ecosystems is linked to several parameters including mechanical (temperature, wind, speed) and biological (photosynthesis, respiration, mineralization). On average, the hydrosystems of the PNA lagoon area are hot with an average temperature of 28.47 ± 2.18 ° C. These observations join those of Yoboue *et al*. (2018) showing a temperature fluctuation between 26 ° C and 29 ° C in the Ébrié lagoon. The hydrosystems of the PNA lagoon zone show high values of conductivity. This could be justified by the nutrient inputs resulting from the leaching of agricultural inputs used in the surrounding plantations and upwelling seawater. Indeed, the hydrosystems of the PNA cross different soil, climates, hydrological regimes and are affected by upwelling. Water intrusions (fresh, brackish, salty), added to the phenomenon of mineralization and upwelling from the sea increasing salinity are the main causes of this irregularity in conductivity. The authors (Welcomme, 1985; Winemiller *et al*., 2008), indicate that water intrusions influence the water balance on which the values of conductivity depend. According to Albaret and Diouf (1994), seawater upwelling in the estuaries of rivers and lagoons increases their salinity and strongly influences conductivity. Those of Winemiller *et al*. (2008), indicate that the increase in conductivity is linked to low water renewal rates and the inputs of organic matter increasing the rate of mineralization in hydrosystems. These results are superior to those of Traoré (2016) in the lagoons of Aghien and Potou (164.75 µS / cm) and of Eyi *et al*. (2016) in the Ono lagoon (25.22 µS / cm).

The specific richness (53 species) of the present study turns out to be greater than that listed by Albaret and Ecoutin (1989) in the Ébrié lagoon (48 species), by Eyi *et al*. (2016) in the Ono lagoon (39 species) and by Bédia *et*

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al. (2017) in the potou lagoon sector (38 species). This important specific wealth could be explained by the protected aspect of the park and the multitude of ecosystems. Indeed, the protected aspect of the study area and the presence of several types of ecosystems (freshwater, brackish water, marine) offer an intact habitat diversity, allowing all species as well as prey by highlighting lay out the substrate and the foodstuffs necessary for their development. According to N'Douba *et al*. (2003), the diversity of ecosystems increases the diversity of habitats, which has a positive influence on the number of species present in the aquatic environment. According to Diouf (1996), lagoons, being expanses of brackish water where masses of continental and marine water mix, promote significant biological diversity with rich and complex food chains.

The new presence of species could be justified by the variability of habitats as previously explained and reproduction needs. Indeed, several marine species with lagoon reproduction and freshwater species colonize the lagoons in order to reproduce and achieve larval development. According to several authors (Albaret, 2006; Koné *et al*, 2021), estuaries are environments that are rich in food resources, allowing species that recruit there to successfully develop larvae. On the other hand, the absence of species for the most part stenohaline is linked to their sensitivity to fluctuations in salinity in the environment. In fact, the communication of the hydrosystems of the lagoon zone of the Azagny National Park with those of the estuarine zone of the Bandama river from the Azagny channel, induces a seasonal fluctuation of the salinity in the environment. The increase in salinity forces stenohaline species to migrate to less salty areas. According to (Diouf, 1996; Shervette *et al*., 2004), estuarine environments are areas with high seasonal variability in salinity levels, thus favoring the presence of euryhaline species which adapt to these salt fluctuations.

The qualitative analysis of the ichthyological population of the lagoon hydrosystems of the Azagny National Park reveals the predominance of the order Perciformes, Siluriformes and the family Cichlidae. The representativeness of these taxa is justified by the physicochemical and hydromorphological similarity offered by Ivorian hydrosystems and their resistance to environmental variations in the environment. The predominance of the order Perciformes, Siluriformes and the Cichlidae family in hydrosystems in Côte d'Ivoire has been demonstrated by several authors: Bédia *et al*. (2017), in the Ébrié lagoon; Kamélan *et al*. (2013), in the hydrosystems of Taï National Park; Yao *et al*. (2019), in the hydrosystems of Banco National Park; Aboua *et al*. (2010), in the Bandama River.

Stand stability was assessed on the basis of Shannon diversity indices (H') and fairness (E). The diversity index (H') measures the degree of organization of the population and fairness allows us to assess the characteristics of this organization (Imoobe and Adeyinka, 2009). The values of the Shannon index

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(H') and the Equitability (E) recorded in the majority of the stations of the lagoon area of the national park of Azagny are respectively higher than the average of 2 and close to 1. This result shows a well structured and stable population, reflecting an environment conducive to the maintenance and development of all the listed species. Moreover, the values of the Shannon index and the Equitability recorded in the stations near the village of Azagny are fair. This shows an environment impacted by destructive activities of the aquatic environment inducing a moderate imbalance in the organization and structuring of the fish population. Thus, the more resistant species will carry the highest numerical abundance (Kamelan *et al*., 2013).

The Monte-Carlo test indicates that the variables rate of nitrate, width, rate of dissolved oxygen, water temperature, alkalinity, salinity, rate of dissolved solid and phosphorus are those which have the most influence on the distribution of the stand. These results agree with those of Aboua *et al*. (2010) in the upper and middle reaches of the Bandama River, Kamelan *et al*. (2014) in the hydrosystems of Taï National Park and Koné *et al*. (2021) in the estuarine zone of the Bandama River in Azagny National Park, indicating that the environmental variable influences the species richness, abundance and distribution of fish species. The work of Aboua *et al*. (2010), indicates that each of these variables strongly influences, directly or indirectly, the distribution of fish populations in hydrosystems. According to the authors (Dedjiho *et al*., 2013; Koné *et al*., 2021), the average variation in the dissolved oxygen level, the dissolved solid level (TDS), conductivity and salinity are the factors that influence the abundance and the temporal distribution of fish in aquatic ecosystems. Yao *et al*. (2019), indicate a particular influence of parameters linked to mineralization (pH, conductivity and salinity) on the specific richness of aquatic environments.

Conclusion

The current study allowed us to characterize the ichthyological population of the hydrosystems of the lagoon area of the Azagny National Park. The ichthyological population has 53 species of fish, including an introduced species, a hybrid species and a near threatened species. The present study reports 11 species recorded for the first time in sector VI of the Ebrié lagoon, the PNA and the absence of 37 species previously recorded by several authors. The population of the lagoon area is well organized and stable. In addition, the strong anthropization of the peripherals of the PNA requires the establishment of a monitoring grid focused on the environment variables of the milieu and the population in order to follow the evolution of the physicochemical environment and the state of conservation of the ichthyological population.

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