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Biological Indicators: Tools For The Assessment Of Fishing On Ichthyological Population In Sector IV Of The Ebrié Lagoon (Ivory Coast)

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Abstract:
Background: *The study of the fish population in sector IV of the Ebrié lagoon is intended to constitute an approach for determining indicators of fisheries in the lagoon environment, from a resource management perspective and to facilitate the interpretation of biological phenomena.*
Materials and Methods*: Sampling was carried out from February 2014 to January 2015 using monofilament nets at four stations (Layo, N'djem, Songon and Taboth) in sector IV of the Ebrié Lagoon.*
Results*: The results showed that Cichlidae dominate the population, with four species at all stations, but the most abundant species are Chrysichthys sp., Tylochromis jentinki, Ethmalosa fimbriata and hybrid Coptodon. Although the Shannon-Weaver and Piélou Equitability indices indicate that sector IV of the Ebrié lagoon appears to be stable and balanced due to its diverse population and good organisation, the ABC curve shows ecosystem dynamics that can be described as slightly disturbed at N'Djem and disturbed at Layo, Songon and Taboth. Furthermore, the size spectrum revealed a steeper slope at the Layo station and less steep slopes at the other stations. Trophic dynamics revealed four trophic groups with an abundance of omnivorous species, hence the very high correlation between abundance and omnivores. Analysis of the Pearson correlation coefficient between abundance and the various biological indicators reveals a very high correlation between abundance and slope and also the intercept. For biomass, a highly significant correlation is observed between biomass and primary consumers.*
Conclusion: *It therefore appears that sector IV of the Ebrié lagoon is ecologically stressed due to the high presence of omnivores and is therefore showing signs of disturbance caused by heavy fishing pressure.*
Key Word: *Fish populations, diversity indices, size spectrum, trophic dynamics, brackish water system, Ivory Coast.*

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I. Introduction

Fishing contributes to people's well-being through the provision of a very nutritious diet, as well as generating employment and while bringing income that is important for individuals, communities and the national economy[1]. Inland fishing and its value chains offer income and employment for more than 60 million people worldwide in 2009[2]. In sub-Saharan Africa, it provides employment for local young people and participates in the fight against food insecurity within communities[3]. For the[4], continental artisanal fishing is very important for African communities to achieve food sovereignty.

In the Ivory Coast, fishing provides almost 70,000 direct jobs and supports more than 400,000 people. Indeed, fish is the main source of animal protein for Ivorian consumers, accounting for 50%, and represents between 15 and 16 kg/year of per capita consumption[5]. However, a general decline in the resource is observed and certain fish stocks are already depleted[6]. The collapse of these fish stocks is more often due to a lack of knowledge of the dynamics of fishing than to a lack of knowledge of the fisheries resource[7]. To overcome these difficulties and management inadequacies, new approaches have been developed, such as fisheries assessment, which was based until the end of the 1980s on the analysis of fishing statistics using global models[8,9]. In another respect, analytical methods of yield per recruit[10] and stock-recruitment models have been developed[11]. Despite these monitoring and management tools, most fisheries are in a situation of degradation or overexploitation[12,13]. It is therefore appropriate to opt for alternatives that respond effectively to present fishery management requirements. In this context, it would be appropriate to ask whether biological indicators could not constitute an alternative for managing fish catches ?

Indeed, biological indicators are cheaper, simpler and more effective methods of establishing a link between a disturbance and its effect on a biological system[14,15,16]. This approach is also attracting growing interest in fisheries biology, and many studies have focused on indicators as a tool for assessing the effects of fishing[17,18,19]. Thus, this study aims she proposes to show the influence of fishing on the structure of fish populations in a brackish environment with a view to ensuring food self-sufficiency. To do this, the objective of the present study was to calculate biological indicators and establish correlations between biological indicators and fish catches.

II. Material And Methods

Study area

The Ébrié lagoon, on the basis of morphological and hydrological criteria, is divided into six sectors[20], including sector IV (**Figure 1**), which is the subject of this study. This sector, located between longitudes 4°14‘ and 4°23’ West and latitudes 5°16‘ and 5°17’ North in the department of Dabou, is an estuarine sector characterised by daily and seasonal instability due to the tide and flooding of continental waters. Seasonal variations in salinity range from 0.04 ‰ in the rainy season to 30 ‰ in the dry season[21]. Seasonal variations in dissolved oxygen at the surface and at the bottom show that there is a marked vertical gradient from January to May, because values rising from 5 mg/L at the surface to between 1 and 2 mg/L near the bottom[21]. Sector IV extends from Abidjan to Agnéby[22].

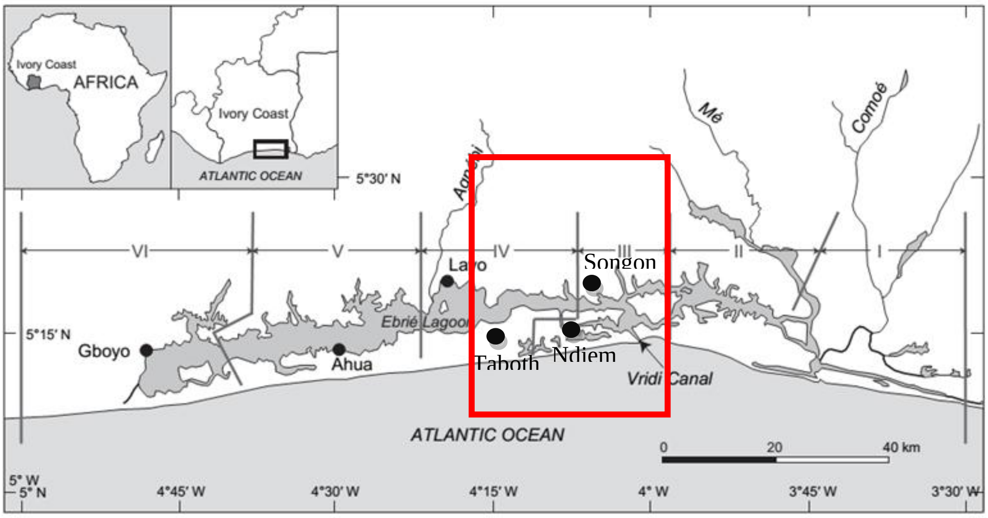

Figure 1: Geographical location of the six sectors of the Ébrié lagoon

Sampling and identification of fish

Fish were collected from February 2014 to January 2015 using monofilament nets at the four stations (Layo, N'djem, Songon and Taboth) in sector IV of the Ebrié Lagoon (**Figure 1**). These gillnets were set between 5pm and 6pm, visited between 7am and 8am for night fishing, then revisited and removed between 12pm and 1pm for day fishing. The fish sampled were identified using the identification keys of[23,24] and updated according Fishbase[25]. The fish were then weighed to the nearest gram using an electronic scale. The standard length of each specimen was measured to the nearest mm with an ichthyometer. Finally, the catches from each station were previously put in conservation bags with a label inside on which the code and name of the station and the date of sampling are marked, and then conserved in the drum containing formaldehyde at 10%.

Data analysis

In this study, only those species whose presence was noted at all the stations throughout the collection period were used. The data collected was analyzed using several indicators that have been defined. These were :

- Statistical descriptors :
- Specific Richness makes it possible to analyze the taxonomic structure of the population. It also makes it possible to distinguish between rich faunal sectors and poorer sectors[26].
- Numerical Abundance (NA) makes it possible to evaluate the proportion of a species, category, class or order (ni) in relation to the total number of individuals (tN)[27].

$$\mathbf{AN} = \frac{ni}{tN} \times 100$$

- Biomass (B) makes indicates the condition of the fish in its habitat[28]. It is the weight (wi) of individuals in a taxonomic group (species, family or order) in relation to the total weight of individuals (tW).

$$\mathbf{B} = \frac{\mathbf{wi}}{\mathbf{tW}} \times 100$$

- From the size spectrum :
- The Shannon-Weaver index makes to express diversity by taking into account the number of species and the abundance of individuals within each species.

$$\mathbf{H'} = -\sum_{i=1}^{s} \mathbf{P_i \log P_i}$$

With pi = probability of capture of species i (i varying from 1 to s) and s = total number of species.

- Equitability index) of Piélou (J') make to measure the distribution of individuals within an ecosystem, independently of species richness.

$$\mathbf{J'} = \frac{\mathbf{H'}}{\mathbf{\log 2\ S}}$$

With H' = the Shannon-Weaver specific diversity index; S = taxonomic richness.

- The Clarke index[29] makes to verify the influence of anthropogenic activities on the environment.

$$\mathbf{W} = \sum_{i=1}^{s} (Bi - Ai)/[50(S - 1)]$$

With W = Clarke's statistical distance; Bi = ranks of species i for biomass; Ai = ranks of species i for abundance; S = number of species considered.

- The ecological stress index or Abundance/Biomass Comparison (ABC) curve makes to highlight the characteristics of these assemblages that may comme from stress (pollution) suffered by the ecosystem.

$$\mathbf{ABC} = \frac{\mathbf{Bi - Ai}}{\mathbf{N}}$$

with Bi = proportion in biomass of species i (ranked in descending order of proportion); Ai = proportion in abundance (number of individuals) of species i (ranked in descending order of proportion) and N = total number of species observed.

- From the size spectrum : it allows to know the modification in the size structure of a fish community subjected to exploitation. characterised by an equation of type :

$$\mathbf{y = ax + b}$$

With a = slope; b = intercept.

- Trophic dynamics (Consumers I, Consumers II, Terminal predators, Omnivores) : it helps explain how energy is on the move in an ecosystem from one organism to another.
- Pearson's correlation coefficient made it to study the relationship between catches (abundance and biomass) and diversity indices, size spectrum and trophic dynamics. This coefficient calculates the effect of a changing in one variable when the other variable changes[30].

III. Result

Composition and specific richness

The results of fish catches at the diffrent stations are recorded in **Table I**. A total of 15 species were frequently captured. These species belong to six orders and eleven families. The Perciformes, with nine species, are the most represented at the four stations in sector IV of the Ebrié Lagoon. They are followed by the Pleuronectiformes with two species. he other orders (Clupeiformes, Mugiliformes, Elopiformes and Siluriformes) are represented by one species each.

Specific richness is higher (15 species) in the Layo and N'Djem stations and lower (11 species) at the Taboth station.

Table I: List of species sampled at the four stations in sector IV of the Ebrié Lagoon from February 2014 to January 2015.

Orders	Families	Species	**Lay**	**N'dj**	**Son**	**Tab**
Siluriformes	Claroteidae	*Chrysichthys* sp.	+	+	+	+
Perciformes	Carangidae	*Trachinotus teraia* (Cuvier & Valenciennes, 1832)	+	+	+	+
	Gerreidae	*Eucinostomus melanopterus* (Bleeker, 1863)	+	+	+	+
		Gerres nigri (Günther, 1859)	+	+	+	+
	Haemulidae	*Pomadasys jubelini* (Cuvier, 1830)	+	+	+	+
	Monodactylidae	*Monodactylus sebae* (Cuvier, 1829)	+	+	+	
	Cichlidae	*Tylochromis jentinki* (Steindachner, 1894)	+	+	+	+
		Sarotherodon melanotheron (Rüppell, 1852)	+	+		
		Hemichromis fasciatus (Peters, 1857)	+	+	+	+
		Coptodon guineensis X Coptodon zillii (Günther, 1860)	+	+	+	+
Clupeiformes	Clupeidae	*Ethmalosa fimbriata* (Bowdich, 1825)	+	+	+	+
Pleuronectiformes	Bothidae	*Citharichthys stampflii* (Steindachner, 1894)	+	+	+	+
	Cynoglossidae	*Cynoglossus senegalensis* (Kaup, 1858)	+	+	+	
Elopiformes	Elopidae	*Elops lacerta* (Valenciennes, 1847)	+	+	+	+
Mugiliformes	Mugilidae	*Neochelon falcipinnis* (Valenciennes, 1836)	+	+	+	
6	**11**	**15**	**15**	**15**	**14**	**11**

Lay = Layo ; N'dj = N'djem, Son = Songon ; Tab = Taboth

Numerical abundance and biomass

Figure 2 presents the abundance and biomass results for individuals of fish captured in the different stations in sector IV of the Ebrié lagoon from February 2014 to January 2015. At the Layo station, the number of individuals captured is superior than at the other stations. Regarding biomass, individuals from the N'Djem station have a higher biomass than individuals from the other stations.

The numerical abundance and biomass of the main fish species sampled are shown in **Figure 3**. The most abundant species are *Chrysichthys* sp., *Tylochromis jentinki*, *Ethmalosa fimbriata* and *hybrid Tilapia*. Just like numerical abundance, the biomass of the Chrysichthys sp. species is higher. It is followed by the biomass of *hybrid Tilapia*, *Tylochromis jentinki*, *Pomadasys jubelini* and *Ethmalosa fimbriata*.

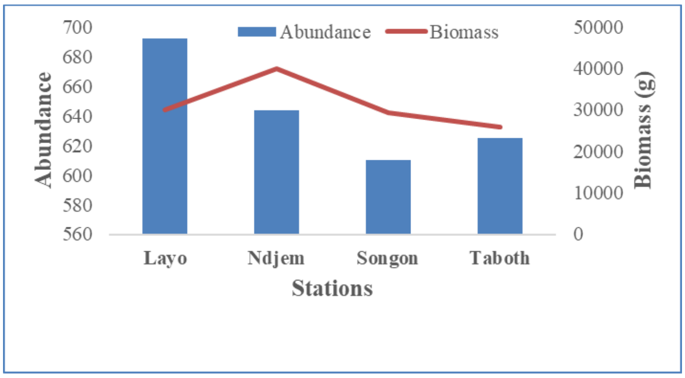

Figure 2: Abundance and biomass of fish individuals sampled at the four stations of sector IV of the Ebrié Lagoon from February 2014 to January 2015.

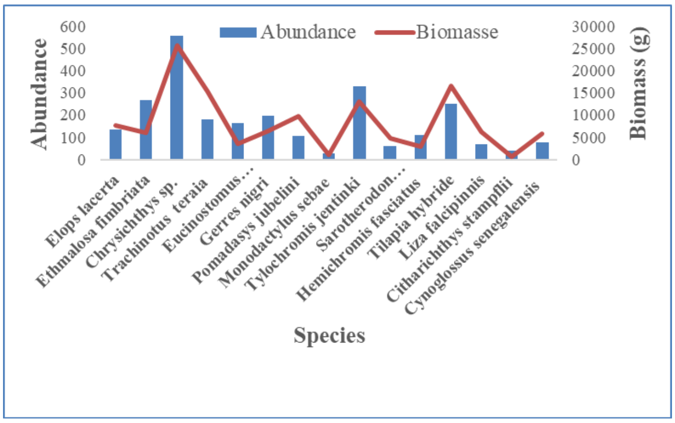

Figure 3 : Abundance and biomass of the main fish species sampled in sector IV of the Ebrié Lagoon from February 2014 to January 2015.

Diversity indexes

The results of the Shannon-Weaver and Piélou Equitability indexes for the four stations in sector IV of the Ebrié Lagoon are recorded in **Table II**. The Shannon-Weaver index is higher (H'= 2.169) at the N'Djem station and lower (H' = 1.738) at Taboth. Regarding the Piélou Equitability index, the index is the highest (J'= 0.7656) at the N'Djem station and the lowest (J'= 0.6835) at the Layo station.

Table II: Monthly values of diversity indexes in the four stations of sector IV of the Ebrié Lagoon from February 2014 to January 2015.

	Diversity indexes	
Stations	Shannon-Weaver (H')	Piélou Equitability (J')
Layo	1,895	0,6835
N'Djem	2,169	0,7656
Songon	2,055	0,7111
Taboth	1,738	0,6995

ABC comparison curves

Analysis of the comparative distribution of abundance and biomass (**Figure 4**) shows that abundance is slightly above biomass at the Layo, Songon and Taboth stations. This distribution is more marked at the Songon station, with a Clarke index of (W= - 0.084), whereas it is less marked at the Layo and Taboth stations, whose Clarke index is W= - 0.065. At the N'Djem station, the Clarke index (W= - 0.016) shows that large species with a important biomass are becoming rarer in the catches. So abundance and biomass are almost confused (**Figure 4**). Furthermore, the ABC method shows ecosystem dynamics which can be described as slightly disturbed in N'Djem and disturbed in Layo, Songon and Taboth.

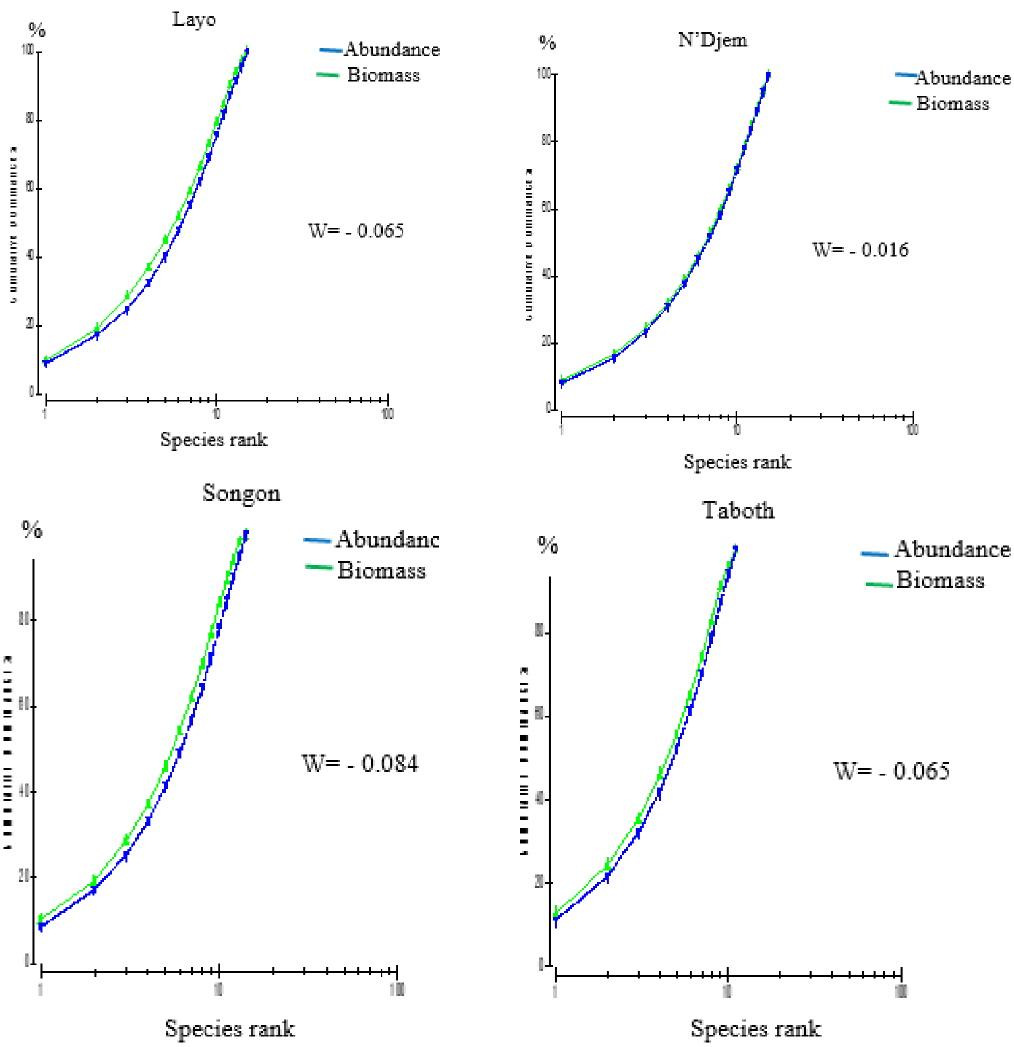

Figure 4: Comparisons of abundance and biomass distributions (ABC curves) of catches at the four stations in sector IV of the Ebrié lagoon.

Least squares fitting of the linear model to the size spectrum

The results, regarding the size spectra (**Table III**) of the four stations, show that the steepest slope is at Layo (-0.2143). The slopes at Taboth (-0.1626), N'Djem (-0.1489) and Songon (-0.1343) are less steep. Analysis of the coefficient of determination (Layo: R^2 = 0.9027; N'Djem: R^2 = 0.9584; Songon: R^2 = 0.8532; Taboth: R^2 = 0.7252) indicates that the fit is of good quality.

Table III: Size spectra at the four stations of sector IV of the Ebrié Lagoon.

Stations	Slope (a)	Intercept (b)	Coefficient of determination (R^2)
Layo	- 0,2143	2,453	0,9027
N'djem	- 0,1489	2,3189	0,9584
Songon	- 0,1343	2,0763	0,8532
Taboth	- 0,1626	1,7863	0,7252

Trophic dynamics

Trophic dynamics in sector IV of the Ebrié lagoon shows that of the 15 species sampled, the largest trophic category in terms of number of species is that of omnivores, which represent 40% of taxa. Next in descending order secondary consumers (26.66%), terminal predators (20%) and primary consumers, which represent 13.33% of taxa (**Table IV**).

Analysis of trophic dynamics at the four stations in sector IV of the Ebrié Lagoon (**Table V**) shows that omnivores are most abundant at the Layo and Taboth stations, with percentages of 45.38% and 47.36% respectively. This trophic category is followed by secondary consumers (38.29% at the Layo station and 39.04% at the Taboth station) and terminal predators (14.16% at Layo and 13.6% at Taboth). The trophic category of primary consumers was not sampled at the Taboth station. At the Layo station, it represented 2.17% of the percentage. At the N'Djem station, the categories of omnivores and secondary consumers are substantially equal, with percentages of 39.44% and 39.91% of taxa respectively. They are followed by terminal predators (12.27%) and, finally, primary consumers (8.39%) of the taxa. Secondary consumers dominate the Songon station population. They represent 45.25% of taxa. The omnivores category comes in second place with 36.56% of taxa and terminal predators (18.03%) come in third position. Primary consumers represent less than 1% of taxa.

Table IV: Trophic composition of sector IV of the Ebrié Lagoon

Trophic category (%)	Zone IV of the Ebrié Lagoon	
	Number of species	Percentage (%)
Primary Consumers	2	13,33 %
Secondary Consumers	4	26,66 %
Terminal Predators	3	20 %
Omnivores	6	40 %
Total	15	100

Table V: Trophic composition in the four stations in sector IV of the Ebrié Lagoon

Trophic category (%)	Stations			
	Layo	N'Djem	Songon	Taboth
Primary Consumers	2,17	8,39	0,16	0
Secondary Consumers	38,29	39,91	45,25	39,04
Terminal Predators	14,16	12,27	18,03	13,6
Omnivores	45,38	39,44	36,56	47,36

Relationship between fish catches and biological indicators

Analysis of the Pearson correlation coefficient between abundance and the different biological indicators (**Table VI**) shows that there is a weak correlation between abundance and the Shannon-Weaver index (-0.1049) and between secondary consumers (0.017), and also between abundance and terminal predators (-0.1257), Piélou equitability (-0.2847), the Clarke index (0.2197) and primary consumers (0.2860). Moreover, an average correlation was observed between abundance and species richness (0.5123) and a very high correlation between abundance and slope (-0.9277), intercept (0.7653) and omnivores (0.7336).

The results of the Pearson correlation coefficient between biomass and the different biological indicators (**Table VII**) show that there is no correlation between biomass and secondary consumers (0.0945). A low correlation was recorded between biomass and slope (0.2095). The correlation is just below average between biomass and terminal predators (-0.4676) and also omnivores (-0.3309). It is high between biomass and species richness (0.6862) and between the intercept (0.5964), and very high between the Shannon-Weaver index (0.8537), Piélou equitability (0.8836), Clarke index (0.8737) and primary consumers (0.9722). There was also a highly significant correlation ($p < 0.05$) between biomass and primary consumers.

Table VI: Results of the Pearson correlation between abundance and the different biological indicators of sector IV of the Ébrié lagoon

Abundance	Biological indicators									
	RS	H'	J'	W	a	b	CP	CS	PT	OM
Correlation r	0,5123	-0,1049	-0,2847	0,2197	**-0,9277**	**0,7653**	0,2860	0,017	-0,1257	**0,7336**
p-value	0.488	0.895	0.715	0.780	0.072	0.235	0.714	0.998	0.874	0.266

Significant correlations marked at p <0.05

Table VII: Results of the Pearson correlation between biomass and the different biological indicators in sector IV of the Ébrié lagoon

Biomass	Biological indicators									
	RS	H'	J'	W	a	b	CP	CS	PT	OM
Correlation r	0,6862	**0,8537**	**0,8836**	**0,8737**	0,2095	0,5964	**0,9722**	0,0945	-0,4676	-0,3309
p-value	0.314	0.146	0.116	0.126	0.791	0.404	**0.028**	0.906	0.532	0.669

Significant correlations marked at *p <0.05*

RS = Specific Richness; H'= Shannon-Wiener index; J' = Piélou Equitability index; W = Clarke index; a = slope; b = intercept; PC = Primary Consumers; SC = Secondary Consumers; TP = Terminal Predators; OM = omnivores.

IV. Discussion

The Cichlidae family is the most represented, with four species in all the stations in sector IV of the Ebrié Lagoon. These results are due to the fact that the major condition for the proliferation of almost all the species in this family is their ability to reproduce in this environment, which would be disturbed by the strong pressure of anthropogenic activities. Indeed, homes built on the riverbank, rubber plantations, fertilisers and pesticides commonly used in large agro-industrial farms, sanitary built on stilts in the lagoon and acadjas would lead to the degradation of this environment. In addition, Cichlidae have a great capacity to resist stress and are most of them omnivorous or phytophagous[31]. [32]indicated a very strong eutrophication of estuarine waters in the Ebrié lagoon due to very high nitrogen compound and phosphate ion loads. Furthermore, certain species of Cichlidae are known for their dietary plasticity[33].

The number of individuals captured at Layo station is greater than the numbers of individuals captured at other stations. These results could be explained by the vegetation at the edge of this station. Indeed, the presence of aquatic plants also constitutes a spawning ground and a source of food for most fish species[34]. [35]noted that environmental requirements, particularly in terms of salinity, are generally very low, hence the ability of certain species such as *Ethmalosa fimbriata* and *Pomadasys jubelini* to reproduce in two different environments (sea and lagoon). In another respect, individuals from the N'Djem station had a higher biomass than individuals from the other stations. These results would be due to the high number of Primary Consumers at the N'Djem station compared with the other stations. Also, the high value of Primary Consumers would she translate the large number of macrophytes and phytoplankton in this station which are a source of food for these species.

The Shannon-Weaver indexes at the N'Djem and Songon stations are higher than those at the Taboth and Layo stations. This is due to the fact that the N'Djem and Songon stations have a good organization of their population[36]. However, the Taboth and Layo stations, which have a low value of H', indicate an imbalance in their environment[37].

According to **[38]**and**[39],** low equitability translates the predominance of a few species over all the other taxa and constitutes an imbalance in the population. However, the Piélou equitability results for the four stations vary from 0.68 to 0.71. These results would indicate that no one species predominates in the population at these stations. Thus, these results are corroborated by the assertion that a community dominated by a single species will have a lower coefficient than a community in which all the species are co-dominant[26].

Analysis of the comparative distribution of abundance and biomass shows that the abundance curve is slightly above than the biomass curve at the Layo, Songon and Taboth stations. These results would mean that these three stations would show signs of disturbance due to high fishing pressure. [40]indicate that fishing pressure influences the size structure of the population, which would be dominated by small individuals. However, at the N'Djem station, the abundance and biomass curves are almost megred. This observation could suggest a slight stress at this station[41].

In another respect, the results concerning the size spectra of the four stations show that the steepest slope is that of Layo. These results would to be due to the strong fishing pressure exerted at this station. According to [17]and[42], fishing pressure, both direct and indirect, are translated on the size spectrum by a steeper slope and a higher intercept. As for [43]and[42], fishing primarily affects large species, which are becoming rare in catches and landings. In addition to fishing pressure, the size spectrum is also influenced by environmental factors such as temperature or biological factors such as recruitment[45,45].

Trophic dynamics in sector IV of the Ebrié lagoon show that the sector is dominated by omnivores, precisely at the Layo and Taboth stations. The high presence of omnivores in an aquatic environment could mean that this environment would be ecologically stressed. Indeed, omnivores with opportunistic habits feed according to the abundance of certain elements[46] because they are capacity to adapt and exploit these resources in a polluted environment. According to[47], disturbances favor the development of species whose feeding habits are more flexible or diversified, such as omnivores. In addition, the cumulative proportion curves (ABC curve) show that abundance is slightly above than biomass at the Layo, Songon and Taboth stations. These results are conforms with the results of the work of[48] on the trophic structures of fish populations in small dams.

Analysis of the Pearson correlation coefficient between abundance and the different biological indicators reveals a very high correlation between abundance and the slope, the intercept and between omnivores. These results show that omnivorous individuals contribute to the increase in fish populations in sector IV. However, a steeper slope and a high intercept, which are indicators of significant fishing pressure, lead to a decrease in fish population abundance. The results of the Pearson correlation coefficient between biomass and the different biological indicators show a strong correlation between diversity indexes and primary consumers, the latter, in another respect, very significant. These results could suggest that primary consumers have a positively influence on the total mass of ichthyofauna. Indeed, the fish would be in good physiological condition and they would find enough resources necessary for their development and growth[49,50]. They are therefore well adapted to the environmental and biological conditions in this sector of the Ebrié Lagoon.

V. Conclusion

The study carried out at four stations in sector IV of the Ebrié lagoon has allowed that Cichlidae dominate the population, with four species at all stations and a higher number of individuals at the Layo station. The Piélou Equitability results in the four stations show that no single species predominates in the population at these stations. The abundance and biomass curves show that the abundance curve is slightly above the biomass curve at the Layo, Songon and Taboth stations, except at the N'Djem station, which are curves almost identical. Regarding size structures, changes were observed in the size spectrum with a steeper slope at the Layo station compared to the other stations. Analysis of the Pearson correlation coefficient between abundance and the different biological indicators reveals a very high correlation between abundance and slope, intercept and omnivores, and a significant correlation between biomass and primary consumers.

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