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Food and feeding behavior of *Pellonula leonensis* (Boulenger, 1916) in Taabo Lake catchment areas (Bandama; Cote d'Ivoire)

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ABSTRACT

Food and feeding behavior of *P. leonensis* was studied by analyzing the stomach contents of 864 individuals caught in the two main catchment areas in Taabo Lake, notably, at Taabo city and Antonio. Food items data were analyzed by using the three following methods: Relative Importance Index (IRI), Food Index of Geistdoerfer (Q) and Principal Component Analysis of Occurrence Index. The results of our study showed, that *P. leonensis* is zooplanktonophagus. Its diet also includes Diptera (Ceratopogonidae, Chaoboridae), Ephemeroptera (Baetidae, Libellulidae), Trichoptera and Hymenoptera (Formicidae). The Food Index of Geistdoerfer indicates, that the diet of this Fish species is composed of two main preferential preys: Copepods and Cladocerans. Furthermore, Chironomidae are frequent secondary preys and the others items are secondary order complementary preys. At least, the results of the principal component analysis of items occurrences show, that the prey frequency is function of *P. leonensis* catchment area or sub-area in Taabo Lake, and evolve inversely, according to climatic seasons.

Keywords: *P. leonensis*, feeding behavior, catch area, Taabo Lake, Côte d'Ivoire.

INTRODUCTION

Nutrition in all living beings is a vital necessity. Thus, any living organism, to provide all of its vital needs, must ingest food. These help to ensure growth, vital functions and, also, to compensate energy losses due to foraging, migration and reproduction activities (Gandega et al., 2007). Also, fish food ecology researches provide information on the trophic potential of the environment and is essential for understanding the relationships between different species in an aquatic ecosystem (Hajisamae et al., 2003). According to Brose et al. (2005), trophic relationships can be influenced by environmental changes in time and space. Indeed, according to Yang et al. (2008), organic communities are governed by seasonal variations in food availability.

Thus, any information on this variability allows us to evaluate the behavior of fish populations in time and space.Indeed, the work of Diomande et al. (2013) showed a

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difference in the diversity of micro-organisms in the different areas of Lake Taabo.In this context, the study of the food spectrum of *Pellonula leonensis* Boulenger, 1916 only species of Clupeidae in Lake Taabo (Aboua et al., 2010), will help to understand the trophic and migratory activity of this Fish species in this reservoir. This will help, on the one hand, to characterize its trophic behavior in the different catchment areas at Taabo lake, and in the other hand, to acquire the necessary information for the establishment of a co-management plan for *P. leonensis* resource with has significant socio-economic value for fishery riverine community of Taabo village and surrounding areas (Kraidy et al., 2014; Yao et al., 2015).

The objective of this work was, therefore, to identify the preys consumed by *P. leonensis* caught in the two main catchment areas, one on the left bank and the other on the right bank, and to analyze its seasonal variability in relation to fishing production.

MATERIALS ANDMETHODS

Study area

The study area is located about 110 km downstream of the confluence of Bandama and Marahoue and 120 km downstream of Lake Kossou (Kouassi et al., 2007). Taabo Lake (Figure 1) is located between 06°20' and 6°40' North latitude and between 5° and 5°30' West longitude (Kaiser Engineers and constructor, 1980). Two areas, namely Antonio (Ant) on the right bank and Taabo city (TC) located on the left bank according to upper to down stream flow, are the main catching areas from which the examined samples in our study come from. Due to its position, the annual hydrological cycle of this hydroelectric dam has two main phases: water supply and water isolation (Groga, 2012).

Sampling of *P. leonensis* specimens and analysis of stomach contents

The catches of *P. leonensis* landed by the fishing units from the catchment areas of Antonio and Taabo city were studied on an annual cycle from 2014 to 2015. A total of 864 specimens of *Pellonula leonensis* were collected and stored in 10% formalin for laboratory analysis. For the examination of the stomach contents, the collected fishes were previously classified by size and catching area, measured (Standard Length, LSmm) and weighed using an electronic precision scale 0.01 g. Sexual stages of maturity were determined by direct observation of the gonad after dissection. Then, the stomachs removed were emptied of their contents into a Petri dish. Each prey item is weighed and then counted. Prey identification was performed using a binocular loupe, following the systematic identification key of Dejoux et al. (1981) and Paugy et al. (2003 a and b).

Data processing

For the diet analysis of examined *P. leonensis* specimens, three parameters were considered. These are the emptiness index, the Relative Importance Index (IRI) and the Geistdoerfer dietary coefficient (Table 1). Empty stomachs were also examined, in order to estimate the emptiness coefficient (Cv). This index allows determining the food activity of the studied individuals.

The relative importance index calculated for each prey is used to compare the samples of the two zones. The dietary coefficient of Geistdoerfer (1975) proposes groupings using the food coefficient Q of a prey. It divides the preys into three categories, each subdivided into two sub-categories using both food coefficient Q and frequency index F as following: *Main prey Q> 100, preferential F> 30, occasional F <30;Secondary prey: 10 <Q <100; Frequent F> 10; accessory F <10; Additional pre: Q <10, first order F> 10, second order F <10.*

This method establishes a ranking of the species, based on the values of the indices of importance of a given prey in each sample.

Statistical analysis

Spearman rank correlation test was performed to compare feeding behavior by area, season and size of fish. Statistical analyzes were done using Statistica Version 7.1 software and the similarities were considered significant at $p < 0.05$.

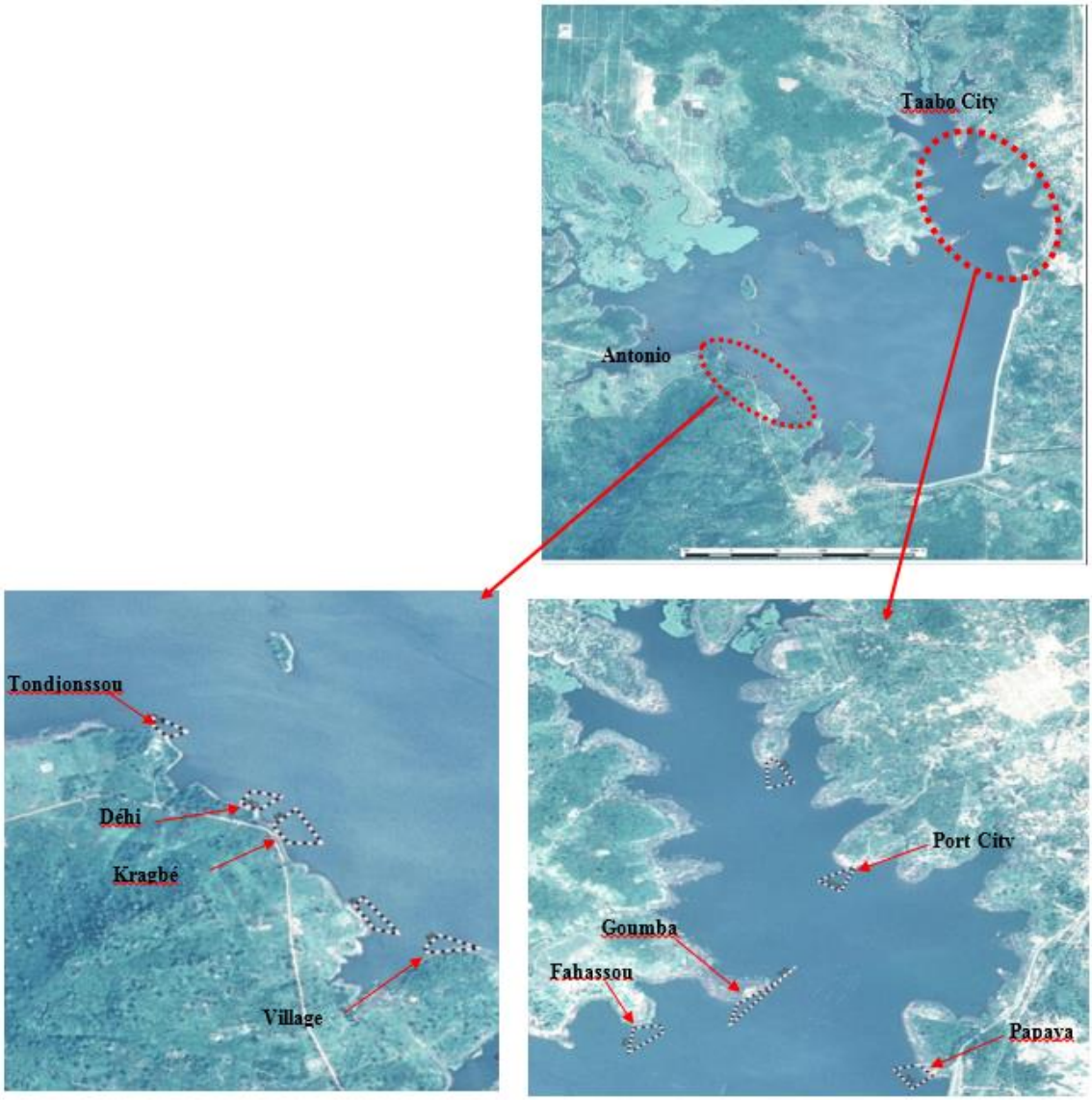

Figure 1: Map of the study area showing *Pellonula leonensis*' fishing areas in Taabo Lake.

Table 1: Parameters used for the diet analysis of *P. leonensis*

	Equation	Equation terms	References
Vacuity Index	**Cv = Ev/Nee**X**100**	**Ev** : number of empty stomachs	Rosecchi (1983)
Relative Importance Index	**IRI = %F*(%N+%P)**	**%F** : frequency of occurrence of a prey **%N** : numeric percentage **%P**: weight percentage of prey	Pinkas and al. (1971)
Food Index of Geistdoerfer	**Q = Cn% X Cp%**	**Cn%** = numeric percentage **Cp%** = weight percentage	Geistdoerfer (1975)

RESULTS

Coefficient of emptiness

Of the 864 examined stomachs, 199 are empty. This corresponds to a vacancy coefficient of 23.78%. The analysis of the filling rate of the stomach shows a difference of emptiness coefficient in the two sampled zones. In Taabo City area, 128 fish out of 505 had empty stomachs with an emptiness coefficient of 25.35%. In Antonio, 70 fish out of a total of 358 had empty stomachs. This gives an emptiness coefficient of 19.55%.

Diet analysis of *P. leonensis*

Taxonomic composition of *P. leonensis* diet

Stomach content analysis shows that the food spectrum of *P. leonensis* is composed of vertebrate and invertebrate organisms. Vertebrates are mainly represented by Fish species belonging to the family Clupeidae (*Pellonula leonensis*). Invertebrates are represented by insects and zooplankton. Insects include Diptera (Ceratopogonidea, Chaoboridae), Ephemeroptera (Baetidae, Libellulidae), Trichoptera, Plecoptera, Odonata and Hymenoptera (Formicidae).

Geistdoerfer index

The results of the analysis of the full stomachs of *P. leonensis* by the method of Geistdoerfer (1975) are presented in Table 2. This index allows classifying ingested preys by category, according to their importance in the diet of *P. leonensis* and to the degree of preference of this Fish species concerning these preys. This analysis shows that Copepods rank first with a high Q coefficient (Q > 100), followed by Cladocerans. They are, therefore, preferential main preys. Then, come Chironomidae, which are frequent secondary preys, followed by Baetidae, juveniles of *P. leonensis*, Plecoptera, Libellulidae, Trichoptera, Ceratopogonidae, Chaoboridae, Ostracoda, and Formicidae and Rotifera which are complementary preys of secondary order.

Seasonal variation of *P. leonensis'* diet by GEISTDOERFER Index

The analysis based on the climatic seasons (Table 3) shows a variation of the classification of the preys consumed by *P. leonensis* in Taabo Lake, according to the GEISTDOERFER index (1975). Over all climatic seasons, Copepoda and Cladocera were the main preferential preys of this Fish species. However, the ranking order of Chironomidae in the diet varies from season to season. Thus, this item being a preferential main prey in the short dry season becomes an occasional main prey in the long dry season, then, secondary prey frequents during the long rainy season. The other preys are, generally, considered throughout the seasons as complementary preys of secondary order. Spearman rank correlation test from (Q) prey indicates that there is a similarity in the feeding behavior of the species caught in the dry season and in rainy season ($N = 13$; $R = 0.614$; $p = 0.025$).

Diet based on fish size and sexual maturity

The study of *P. leonensis* feeding according to the size of the Fish species was carried out constituting the three following classes on the basis of sizes of sexual maturity ($L_{50} = 31.85$ mm and $L_{90\text{-}100} = 36.31$ mm): [16; 31.85 [, [31.85; 36.31 [and [36.31; 63.8 [, respectively, for Class 1, Class 2 and Class 3. The proportions of preys found in the stomach contents of this Fish species of different size classes are presented in Table 4. In class 1, only 7 food items were observed in the stomachs as following: Chironomidae, Ceratopogonidae, Formicidae, Baetidae and Zooplankton (Cladocerans, Copepoda and Ostracoda).On the other hand, in classes 2 and 3, a respective number of 10 and 11 items are noted, reflecting the existence of a broad food spectrum of *P. leonensis* specimens at the consideredsizes.These are Chironomidae, Cladocerans, Copepoda, Baetidae, Chaoboridae, Libellulidae, Trichoptera, Plecoptera, Ostracoda, Ceratopogonidae and fish larvae, respectively. Zooplankton is relatively common in all three size classes studied. Larger individuals (Class 2 and 3) appear to have a higher preference for Chironomidae with occurrence values of 15.55 and 38.89%, respectively, compared with 3.95% for the smaller size class. In addition, for

most insect preys, the percentage of the relative importance index increases as the fish grows.

At class 1 level, the sum of the percentage of the relative importance index of insects is 0.81% against 14 and 40.17% for fish in classes 2 and 3 respectively. The classification of preys on the basis of Geistdoerfer index values indicates that, in class 1, zooplankton is the main preferential prey (Q = 4015.95% F = 93.42) and Chironomidae are second-order complements prey (Q = 9.73% F = 3.95). For Classes 2 and 3, Chironomidae are, respectively, occasional main preys and preferential main preys. On the other hand, zooplankton has been reduced from primary preferred prey for Classes 1 and 2 to occasional primary prey for larger individuals of *P. leonensis* (Class 3). Spearman rank test from (Q) prey indicates that there is a similarity in the feeding behavior of *P. leonensis* individuals ranging in size from 31.85 to 36,31 mm and those from 36.31 to 63.8 mm (N = 9 ; R = 0.803 ; p = 0.009).

Distribution of prey ingested in catch zones according to the index of occurrence

According to the index of relative importance (Table 5), Chironomidae are more important in the contents of fish caught in the area of Antonio (IRI = 14.26). However, zooplankton constitutes the majority of the prey consumed by *P. leonensis* (IRI = 90.64). Spearman rank test from (IRI) prey indicates that there is a similarity in the feeding behavior of the species caught in the two fishing area (N = 13; R = 0,837; p = 0,000351).

A principal component analysis was carried out and based on indices of occurrence of preys consumed by *P. leonensis* in the different fishing zones. The results of this analysis on factorial 1-2, where axes 1 and 2 constitute 54.85% of total inertia, show four groups of preys (Figure 3).

Group 1 is composed of areas in which Rotifers are the most frequent prey. These are Goumba sub-zone of Taabo city catching area and Dehi sub-zone of Antonio zone.Group 2 includes the areas and sub-zones of which the frequent preys in the stomachs of *P. leonensis* are, mainly, Copepoda, Cladocera and Formicidae. These are Tondjonssou sub-zone of Antonio catching area, Papaya sub-zone of Taabo city fishing zone

At the level of Taabo Village, sub-zone of Antonio fishing area, the frequent preys are Trichoptera, Ceratopogonidae, Chironomidae. These constitute group 3. Group 4 brings together the sub-zones of Taabo city fishing area and one (Kragbe) of Antonio. Concerned Taabo city sub-zones are Fahassou and Port city. In these sub-areas, Plecoptera, Baetidae and *P. leonensis* larvae are the more common preys in the stomach contents of this Fish species.

Table 2: Classification of *P. leonensis* prey of the Taabo Dam Lake in prey categories according to the Geistdoerfer index (1975).

Preys	**Q**	**%F**	Prey categories
Copepoda	1709,589	39,63	Preferred main prey
Cladocera	740,135	43,58	Preferred main prey
Chironomidae	99,247	11,38	Frequent secondary prey
Baetidae	0,483	1,74	Second-ordrer complementary prey
Larva of *P.leonensis*	0,112	0,37	Second-ordrer complementary prey
Plecoptera	0,097	0,28	Second-ordrer complementary prey
Libellulidae	0,068	0,46	Second-ordrer complementary prey
Trichoptera	0,043	0,46	Second-ordrer complementary prey
Ceratopogonigae	0,027	0,46	Second-ordrer complementary prey

Chaoboridae	0,019	0,64	Second-ordrer complementary prey
Ostracod*a*	0,012	0,37	Second-ordrer complementary prey
Formicidae	0,001	0,18	Second-ordrer complementary prey
Rotifera	0,000	0,46	Second-ordrer complementary prey

Table 3: Seasonal variation of food preferences of *P. leonensis* at Taabo Lake.

Saisons	Items	Q	F	Categories of prey
PSS	Copepods	1102.40	52.94	Preferred main prey
	Cladocerans	518.40	57.65	Preferred main prey
	Chironomidae	182.94	43.53	Preferred main prey
	Plecoptera	0.75	3.53	Second-ordrer complementary prey
	P. leonensis	0.3512	0	Second-ordrer complementary prey
	Trichoptera	0.135	1.18	Second-ordrer complementary prey
PSP	Cladocerans	5583.26	96.30	Preferred main prey
	Copepods	638.63	79.63	Preferred main prey
GSS	Cladocerans	1044.73	56.90	Preferred main prey
	Copepods	975.42	49.14	Preferred main prey
	Chironomidae	216.04	21.98	Occasional main prey
	Baetidae	1.19	3.02	Second-ordrer complementary prey
	Ceratopogonigae	0.60	1.29	Second-ordrer complementary prey
	Chaoboridae	0.60	3.02	Second-ordrer complementary prey
	P. leonensis	0.332	0.86	Second-ordrer complementary prey
	Ostracods	0.27	1.72	Second-ordrer complementary prey
	Libellulidae	0.23	0.86	Second-ordrer complementary prey
	Trichoptera	0.10	1.72	Second-ordrer complementary prey
	Formicidae	0.02	0.43	Second-ordrer complementary prey
GSP	Copepods	3115.36	72.33	Preferred main prey
	Cladocerans	742.28	76.10	Preferred main prey
	Chironominae	19.24	11.32	Frequent secondary prey
	Baetidae	1.33	3.77	Second-ordrer complementary prey
	Libellulidae	0.154	0.94	Second-ordrer complementary prey
	Ceratopogonidae	0.011	0.63	Second-ordrer complementary prey
	Formicidae	0.002	0.31	Second-ordrer complementary prey
	Rotifers	0	1.57	Second-ordrer complementary prey

PSS: Little dry season; PSP: Little rainy season; GSS: Big dry season; GSP; Big rainy season

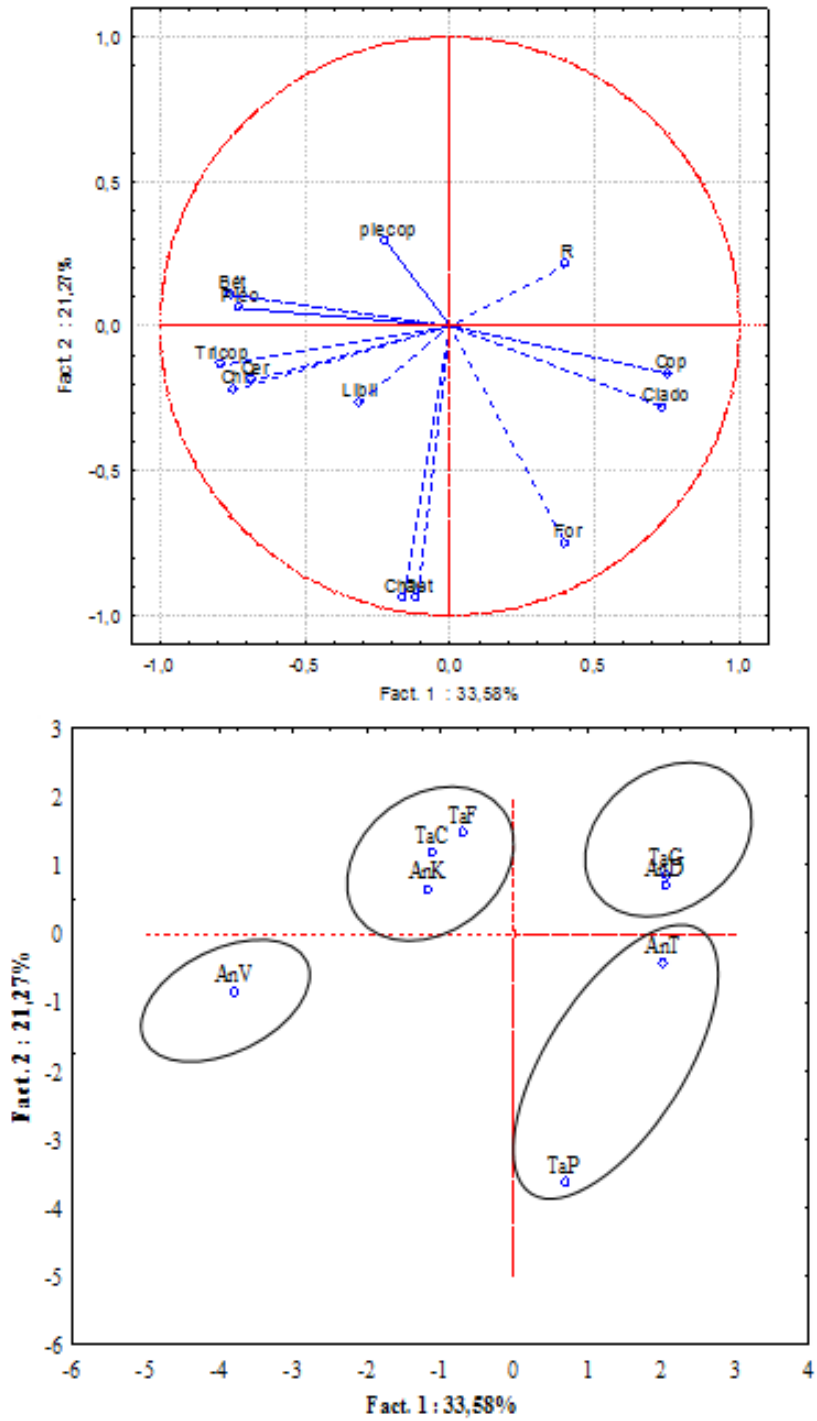

Figure 3: Principal component analysis of the occurrence of preys in the stomachs of *P. leonensis*of Antonio and Taabo city areas and their sub-zones.

TaF *= Taabo sub-zone Fahassou;* ***TaC*** *= Taabo sub-zone port City;* ***TaG****= Taabo sub-zone Goumba;* ***TaP****= Taabo sub-zone Papaya;* ***AnV****= Antonio sub-zone Village;* ***AnD****= Antonio sub-zone Dehi;* ***AnT*** *= Antonio sub-zone Tondjonssou;* ***AnK*** *= Antonio sub-zone Kragbé*

P. leo*= Pellonula leonensis;* ***Bet****= Baetidae;* ***Plecop****= Plecoptera;* ***R****= Rotifers;* ***Cop****= Copepods;* ***Clado****= Cladocerans;* ***For****= Formicidae;* ***Tricop****= Tricoptera;* ***Cer****= Ceratopogonidae;* ***Chir****= Chironomidae;* ***Libll****=Libellulidae;* ***Chao****= Chaoboridae.*

Table 4: Percentage of Relative Importance Index, Occurrence Percentage and Geistdoerfer Index of preys encountered in the stomach contents of *P. leonensis* caught at Taabo Dam Lake.

	Size Class (mm)								
Preys	**Class 1 [16 ; 31.85 [**			**Class 2 [31.85 ; 36.31 [**			**Class 3 [36.31 ; 63.80 [**		
	%IRI	**Q**	**%F**	**%IRI**	**Q**	**%F**	**%IRI**	**Q**	**%F**
Chironomidae	0.77	9.73	3.95	13.77	208.33	15.55	39.66	146.63	38.89
Cladocera	43.14	1198.75	49.34	42.51	854.39	41.02	23.45	604.81	20.37
Copepoda	56.05	2817.20	44.08	43.48	1102.24	37.00	35.79	1120.00	23.15
Baetidae	0.04	0.27	1.15	0.16	1.22	2.14	0.12	0.26	3.70
Ostracoda	0.00	0.00	0.16	0.00	0.00	0.27	0.03	0.07	1.85
Larvae of *P.leonensis*	-	-	-	-	-	-	0.59	0.43	3.70
Rotifera	-	-	0.82	-	-	-	-	-	-
Chaoboridae	-	-	-	0.04	0.24	1.88	-	-	-
Ceratopogonidae	-	0.04	0.16	0.00	0.01	0.54	0.07	0.12	1.85
Libellulidae	-	-	0.16	0.01	0.27	0.54	0.03	0.07	1.85
Trichoptera	-	-	-	0.02	0.19	0.80	0.05	0.15	1.85
Plecoptera	-	-	-	0.00	0.02	0.27	0.21	0.46	1.85
Formicidae	-	-	0.16	-	-	-	-	-	0.93

Table 5: Relative importance index and frequency of occurrence of identified preys in stomach contents of *P. leonensis* in Taabo city (TC) and Antonio (Ant) fishing areas.

	Frequency of occurrence (%)		**Relative importance Index (%)**	
Preys	Taabo city (TC)	Antonio (Ant)	Taabo city (TC)	Antonio (Ant)
Insects				
Diptera				
Chironominae	13.38	8.47	9.24	14.26
Ceratopogonidae	0.15	0	0.0001	0
Ephemeroptera				
Baetidae	2	1.37	0.084	1.5
Chaoboridae	0.77	0.46	0.003	0.42
Odonata				
Libellulidae	0.62	0.23	0.008	0.31

Hymenoptera				
Formicidae	0.15	0.23	0.003	0.21
Trichoptera	0.15	0.92	0.002	0.53
Plecoptera	0.62	0	0.008	0
Zooplankton				
Cladocerans	42.62	45.31	40.57	30
Copépods	38	42.33	50.07	51.09
Rotifers	0.77	0	0.0004	0
Ostracods	0.46	0.23	0.002	0.09
Fish				
Larvae of *P. leonensis*	0.31	0.46	0.015	1.61

DISCUSSION

Stomach analysis of *P. leonensis* showed, that the vacancy coefficient is relatively low (23.78%). The low rate of this coefficient indicates, according to Diaha et al. (2010), the availability of preys. It is more important for the samples collected in the Taabo city area than those of Antonio. This result reflects a lower food activity in the area of Antonio than Taabo city. Indeed, according to El Bakali et al. (2010), the weakness of this index in addition to translating the high availability of food can be an indicator of the frequency of trophic activities of the species. The food spectrum of *P. leonensis* in Taabo Lake is diverse. It consists of crustaceans, insects and Fish juveniles.

This broad food spectrum of *P. leonensis* has been observed in the reservoir of Buyo Lake (Kouame et al., 2006). These authors reveal, that the stomach contents of *P. leonensis* specimens are composed of insects, planktonic crustaceans, arachnids and fruit. The work of Koffi (2015) in the lagoon complex of Aby-Tendo corroborates these results on the diversity of prey consumed by *P. leonensis*. However, the dietary preference of *P. leonensis* in the lagoon complex differs from that of the present study and that obtained by Kouame et al. (2006) in Buyo Lake. According to these authors, this diversity of preys categories indicates food opportunism depending on the availability of the environment. With respect to the results of our study, these indicate that Copepoda (Q = 1709. 59; % F = 39.63), and Cladocerans (Q = 740. 14 ; % F = 43.48) are the prey most consumed by *P. leonensis*. These Items are the main preferential prey for this Fish species at Taabo Lake. However, in the lagoon complex Aby-Tendo, insects and fish are the most consumed preys by *P. leonensis*. According to Koffi (2015), this Fish species can be classified in the group of insectivorous and piscivorous omnivorous in the Aby-Tendo lagoon complex.

Insects are more frequent in the food spectrum of *P. leonensis* individuals caught in the fishing area of Taabo city (% F = 17.84) than in those of Antonio (% F = 11.68). In addition, Chironomidae are frequent secondary preys in Taabo city, and as secondary accessory preys in Antonio fishing area.

According to Gandega et al. (2009), the qualitative composition of the diet depends on the food preference and the abundance of the type of food present in the environment. This difference in abundance could be explained by the fact, that in areas visited by fish, the most consumed prey are those, that are most available. Furthermore, Millot and Bégout (2009) indicate, that in the natural environment, the availability of food is one of the most important environmental factors affecting the survival of organisms. For that concerns Taabo Lake, Dietoa et al. (2014)

observed an impact of environmental conditions on the availability of preys consumed by *P. leonensis.* For these authors, the feeding behavior of this Clupeidae is linked to the trophic opportunities offered by each habitat. Indeed, the ecological, environmental and physicochemical characteristics that affect the distribution of preys could explain the different variations observed in these fishing zones. During our work, we noted a spatio-temporal variability of the physico-chemical parameters of water in the considered fishing areas. The existence of a significant difference in oxygen, transparency and conductivity between the left bank (Antonio) and the right bank (Taabo city) could explain this variability.

Our study indicates, also, that feeding behavior in *P. leonensis* is a function of the size of the individuals. This difference observed in the stomach contents of *P. leonensis* specimens during their development, from juveniles to adults, could be explained by the inability of the smallest individuals to capture some categories of preys. Larger individuals have, generally greater mouth opening and higher speed movements, that allow them to capture larger preys.

In their study on the Clupeidae *Sardinella aurita* (Valenciennes, 1847), Diatta et al. (2016) indicate, furthermore, a significant variation in diet in relation to the size of individuals.What is not the case with *Sardinella maderensis* (Lowe, 1841). In addition, the order of preference of *P. leonensis* prey items changes from one season to another in the catchment areas of Taabo dam Lake. In fact, Chironomidae considered as preferential main preys in the short rainy season are occasional main preys and frequent secondary preys, respectively, during the long dry season and the long rainy season. According to the results of Diatta et al. (2016), seasonal food differences were noted, also, in *S. maderensis* and *S. aurita* diet. This seasonality of the feeding behavior of *P. leonensis* is related to the inflow of runoff water causing a large amount of organic matters and enriching nutrients in aquatic environments (Castillo-Rivera, 2013).

Conclusion

P. leonensis is characterized by an important food activity in Taabo Lake, given the low coefficient of emptiness of the stomach contents of the studied specimens. This is more important in Antonio fishing zone than in that of Taabo city. Regarding the feeding behavior of this Fish species, Copepoda and Cladocera are the main preferential preys. Chironomidae are the main preferential preys of the largest specimens captured. Insect Preys are more important in the area of Antonio. Finally, four groups of items are characteristic of *P. leonensis* capture areas. These are as following : Rotifers for the Goumba (Taabo city) and Dehi (Antonio) fishing sub-zones; Copepods, Cladocerans and Formicidae for Tondjonssou (Antonio) and Papayer sub-zones (Taabo), and Taabo city; Trichoptera, Ceratopogonidae, Chironomidae for Village sub-zone (Antonio); and Plecoptera, Baetidae and *P. leonensis* larvae for Fahassou and Port city fishing subzones of Taabo city area and Kragbe sub-zone (Antonio).

COMPETING INTERESTS

The authors declare that they have no competing interests.

AUTHORS' CONTRIBUTIONS

AKE conducted the field research work with DKS. DKS Conceptualized the study as well as managed the corrections of the manuscript sand prepared the first draft of the manuscript. DYM supervised the completion of the study, from the protocol to the writing of the manuscript. The other author contributed to the critical review of the article.

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