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Feeding Relationships Among *Tilapia zillii* (Gervais, 1848), *Tilapia guineensis* (Bleeker, 1862) and Their Hybrid in Ayamé Man-Made Lake, Côte d'Ivoire

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Abstract.- The stomach contents of 122 specimens of *Tilapia zillii*, 121 of *Tilapia guineensis* and 227 of their hybrid were studied in Ayamé man-made lake during two years between August 1995 and September 1997 in order to analyze their diet composition and interspecific diet overlap. The samples were taken using two gill-nets batteries with mesh size 10, 12, 15, 20, 25, 30, 35, 40 and 50 mm. Food items identified from stomach contents were analysed using the Index of Food Preponderance (IFP). The two parental species and their hybrids consumed a great variety of items preys from animal and plant origin. The insect Diptera and the macrophytes were the most important item in the diet of these species. In the food of parental species, Molluscs, Coleoptera and Zooplankton also consisted some important items. The food overlap analysis showed that *T. zillii*, *T. guineensis* and their hybrids share a wide range of prey types. The three species had a generalized feeding behaviour and the feeding strategy of the hybrid individuals is closer to this of *Tilapia zillii*. Competition for food is probably minimal, since the three fish species eat a wide range of foods and the abundance of main preys.

Key words: *Tilapia* species, hybrid, fish food composition, artificial lake, Côte d'Ivoire.

INTRODUCTION

Cichlid species are widely distributed in most east and west Afro-tropical hydrosystems (Daget, 1988) and belong to the commercially important inland fishes of Africa (Fagade, 1971). *Tilapia zillii* is a well known species from West Africa river system through Chad basin to the Nile (Trewavas, 1982; Negassa and Getahun, 2004). The natural distribution of the species included Lake Albert, Lake Turkana, Israel and Jordan Valley (Trewavas, 1982). *T. zillii* has been introduced throughout the world for production and vegetation control purposes (Spataru, 1978). *T. guineensis* is a euryhaline species found in estuaries and lagoons of West Africa (Philippart and Ruwet, 1982, Campbell, 1987).This species has gained an increasing interest for aquaculture purposes, particularly in the estuaries and extensive lagoon systems which constitute its natural range (Akinwumi, 2003; Akinrotimi, 2006). *T. zillii* and *T. guineensis* inhabit the brackish and fresh waters of West Africa. *T. zillii* frequents the upper waters whereas *T. guineensis* is generally found in the lower parts and in the lagoons (Philippart and Ruwet, 1982; Agnèse *et al.*, 1998). The artificial environment of the lake Ayamé has favoured the coexistence of *T. zillii* and *T. guineensis* (Thys van den Audenaerde, 1970). According to Pouyaud and Agnèse (1995), both species were genetically very close. Catches from the lake indicated the presence of specimens with intermediate coloration and genetic analysis confirmed the existence of the hybrid individuals with all possible combinations of hybrid genotypes (Agnèse *et al.*, 1998, Adépo-Gourène *et al.*, 2006). These authors reported that the hybrid specimens are perfectly fertileand have a non-negligible adaptive value. Fisheries data from the lake revealed the predominance (52%) of tilapia species in the

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different landings sites around the Lake (Vanga *et al.*, 2002). Hybrid individuals (*T. zillii* x *T. guineensis*) from the Lake have better growth performances under culture conditions than the parental species (Nobah *et al.*, 2008). Living in the same environment, these species likely share resources as well as reproduction habitats in Ayamé Lake. Sabagh and Carvalho-e-Silva (2008) indicated that the resource partition in a community is essential for the understanding of species interactions. In other respects, diets are a fundamental aspect of each niche, and it seems reasonable to assume that the structure of a community is based mostly on the way that food is shared among coexisting species (Sihand Christensen 2001).

In Africa, the diet of tilapia species have been subject of several studies (*e.g.*, Fryer *et al.*, 1955; Fagade, 1971, 1978; Lauzanne, 1988; Abdel-malek, 1972; Akinwumi, 2003; Winemiller and Kelso-Winemiller, 2003; Negassa and Getahum, 2004; Oso *et al.*, 2006; Shalloof and Khalifa, 2009; Agbabiaka, 2012). However, no study had concerned the feeding relationship between the parental species and their hybrid.

Particularly, *T. zillii* was considered as an opportunistic bottom feeder with a high proportion of the food consisting of plants parts (Nwadiaro, 1984; Akinwumi, 2003; Negassa and Getahun, 2004), insects larvae, zooplankton, small Crustacean and Molluscs (Lauzanne, 1988; Agbabiaka, 2012) while *T. guineensis* mainly feed on algal filaments, Diatoms, sand grain and unidentified organic material (Fagade, 1971). No data on *T. zillii* and *T. guineensis* hybrid diet is available. Nevertheless, feeding is one of the most important biological factors and its abundance and variety influence the structure and composition of fish populations (Aranha *et al.*, 2000). In addition, diet analysis of fishes allows us to understand their feeding strategy, their intra-or interspecific potential interaction (competition and predation) and indirectly indicate community energy flow (Ramirez-Luna *et al.*, 2008). The present study aims to understand the coexistence of the two species and their hybrid in a man-made lake. Food traits are discussed in the relation to the interspecific competition and dietary overlap of these fishes.

MATERIALS AND METHODS

Study area

The Ayamé Lake (5° to 7°5’ N and 2°6’ to 3°3’ W) is an artificial freshwater lake situated in the south-east region of Côte d’Ivoire (Fig. 1). The lake was built in 1959 in the river Bia and has an area comprised between 87 and 194 km^2 with a mean depth of 30 m. The lake level is subject to fluctuations depending on local rainfall and evaporation (Reizer, 1967; Jalabert *et al.*, 1971). The Ayamé Lake is a deep and open water characterised by muddy substrate and a low transparency with an annual mean Secchi disk of 110 cm (Kouamélan *et al.*, 1999). Fishes were sampled at two main sites in the lake (Bakro and Ayamé). The physic-chemical characteristics of sampling sites during study period were presented in Table I. The site study was characterized by four seasons: a long rainy season (May to July), a short dry season (August to September), a short rainy season (October to November) and a long dry season (December to March).

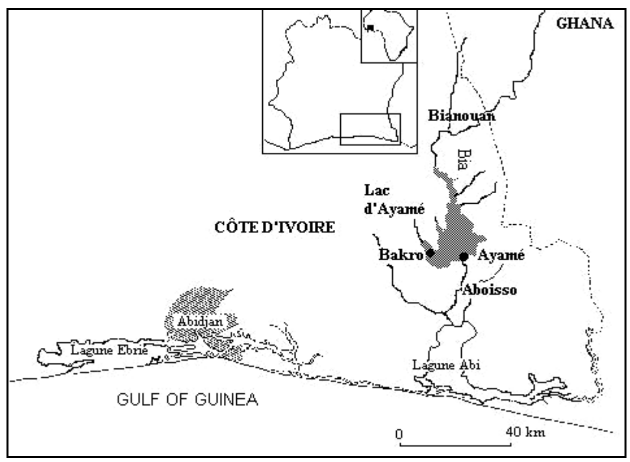

Fig. 1. Map of the Bia river showing the different sampling sites (•).

Sampling, hybrids identification and stomach contents analysis

A total of 470 specimens of *T. zillii*, *T. guineensis* and their hybrid (*T. zillii* x *T. guineensis)* were collected during two years between August 1995 and September 1997 using two batteries of gill-nets with mesh size 10, 12, 15, 20, 25, 30, 35,

Table I.- Physico-chemical characteristics of sampling sites in Ayamé Lake. The values are Mean±SD and these in brackets are range of values.

Sites	Seasons	Temp. (°C)	DO ($mg.L^{-1}$)	pH	Cond. (µS/cm)	Transp. (m)
Bakro	Rainy season	27.51 ± 0.97	6.13 ± 0.48	7.60 ± 0.50	64.16 ± 14.36	1.14 ± 0.10
		(26.2 - 29.3)	(5.5 - 6.7)	(7.05 - 8.47)	(41.00 - 93.20)	(1.05 - 1.27)
	Dry season	27.16 ± 1.12	4.28 ± 0.87	7.5 ± 0.20	61.36 ± 7.41	1.00 ± 0.05
		(25.9 - 28.5)	(3.2 - 5.5)	(7.23 - 7.8)	(49.4 - 69.4)	(0.93 - 1.05)
Ayamé	Rainy season	28.32 ± 0.87	6.67 ± 0.61	7.33 ± 0.22	82.90 ± 8.61	1.05 ± 0.34
		(26.70 - 29.60)	(6.00 - 7.70)	(6.98 - 7.58)	(64.5 - 99.90)	(0.54 - 1.57)
	Dry season	28.04 ± 1.15	6.37 ± 1.03	7.31 ± 0.28	81.68 ± 5.81	1.20 ±0.21
		(26.10 - 30.00)	(5.20 - 7.80)	(6.98 - 7.66)	(74.00 - 92.00)	(0.94 -1.53)

SD, standard deviation; Min, minimum; Max, maximum; Temp, temperature; DO, dissolved oxygen; Cond, conductivity; Transp, transparency.

40 and 50 mm. In the first year, fishes were sampled monthly between August 1995 and July 1996. During the second year, samples were also collected monthly from November 1996 to September 1996. Distribution per species is as follow: 122 for *T. zillii*, 121 for *T. guineensis* and 227 for hybrid. The hybrids were identified on the basis of the colour pattern of the caudal fin. These individuals were characterized by caudal fin bicoloured with dots. Genetic identification was made by Agnèse *et al*. (1997, 1998) and Adépo-Gourène *et al*. (2006). Recently, the use of the colour pattern of the caudal fin for hybrids identification was confirmed by Nobah *et al.* (2006). Standard length (SL) of fish caught was measured to the nearest 0.1 cm using a measuring board. The standard length ranged from 60 to 200 mm for *T. zillii*, 100 to 170 mm for *T. guineensis* and from 72 to 205 mm for *T. zillii* x *T. guineensis*. The stomach was then removed and preserved in pillbox containing 5% formolin for further examination in laboratory. In laboratory, the stomach contents of each specimen were placed in a Petri dish and aggregates were dispersed with a few drops of water and filtered through 1000, 500 and 100µm mesh size before microscopic examination. The different prey taxa were sorted, counted and weighed to the nearest 0.0001g. For each stomach, the food items were identified to the lowest possible taxonomic level using descriptions and keys from various sources (Lindley, 1970, 1975; Dejoux, 1974; Elouard and Levêque, 1977).

Data analysis

Calculation of indexes

The food of the three cichlids was assessed essentially by the relative frequency (RF) and relative dominance (RD) (King, 1989, 1991, 1994) according to the formulae:

$$RF = \frac{f_i}{\sum_{i=1}^{n} F_i} x100 \quad RD = \frac{d_i}{\sum_{i=1}^{n} D_i}$$

Where f_i = frequency of itemi; F_i = frequency of the nth item (sum of all f_i); d_i = frequency of item i as dominant dietary; D_i = frequency of nth dominant item (sum of all d_i). The RF and RD of all dietaries are then summed up to 100%. The RF is a modification of the occurrence method (Hyslop, 1980) commonly used in fish dietary studies. The RF method over-emphasizes the importance of the numerous small items while RD method over-emphasizes the importance of large items. An index of food preponderance (IFP) was calculated as the mean of % RF and % RD. Items with IFP ≥ 10% were considered as primary dietaries while those with IFP values comprised between 1 to 10% were considered as secondary. Items with IFP less than 1% were classified as incidental.

For food habits variation in relation to size and three classes *viz.*, juveniles, sub-adults and adults were determined as follows:

The smallest sexual mature individual was determined for each parental species and the hybrid;

The size at first sexual maturity was determined by fitting the fraction of mature female to a logistic function by non-linear regression according to the procedure described in Duponchelle and Panfili (1988). The average size at first maturation (L50) was determined for the parental species and the hybrid and considered as the standard length at which 50% of the females are in an advanced stage of the first sexual cycle during the reproductive season (Duponchelle and Legendre, 2000).

All specimens with size less than the size of the smallest sexual mature individual are considered as juveniles. From the size of the smallest sexual mature individual to L50, individuals are considered as sub-adults while specimens with sizes more than L50 are adults.

Concerning seasonal variation in diet composition, the months of the long and short rainy seasons were considered for the rainy season while the months of long and short dry season were considered for dry season.

The χ^2 was used to compare the variation in diet composition in relation to size classes and seasons.

Calculation of food overlap

Food overlap between species has been calculated, using the overlap measure of Morisita (1959) as modified by Horn (1966).

$$C_\lambda = \frac{2\sum_{i=1}^{S} X_i Y_i}{\sum X_i^2 + \sum Y_i^2}$$

Where S is the total number of food categories and Xi and Y_i are the proportion of total diet of species X and Y taken from a given category of food i.

Feeding strategy

To assess the feeding strategy along the studied period, the modified Costello (1990) graphical method (Amundsen *et al*., 1996) was used. In this method, the prey-specific abundance (%Pi) (y – axis) was plotted against the frequency of occurrence (F) (x - axis). The prey-specific abundance (Pi) has been expressed as:

$$\%Pi = \frac{\sum Si}{\sum Sti} * 100$$

Where Si is the number of prey i and Sti is the total number of prey in the stomachs containing prey i.

RESULTS

Overall food composition

The results of the food items recorded are represented in Table II. In Ayamé lake, *T. zillii* fed mainly on macrophytes (IFP, 15.89%), Diptera (IFP, 11.62%). Molluscs, Coleoptera, zooplankton, Ephemeroptera, mud, Trichoptera, and animal debris constituted the secondary preys (IFP, 1–10%) of this species.

Table II.- Overall food composition of *Tilapia zillii*, *Tilapia guineensis* and *Tilapia zillii* x *Tilapia guineensis* (hybrid) in Ayamé Lake.

Preys	Item number	IFP (%)		
		Tilapia guineensis **(n = 121)**	***Tilapia zillii*** **(n=122)**	***Tilapia*** **hybride (n=227)**
Diptera	1	13.07	11.62	14.56
Plecoptera	2	0.00	0.00	0.00
Hymenoptera	3	3.14	1.10	0.99
Ephemeroptera	4	2.49	2.46	4.01
Coleoptera	5	6.49	8.07	1.81
Lepidoptera	6	0.22	0.00	0.14
Odonata	7	0.22	0.00	0.00
Trichoptera	8	2.76	2.19	0.64
Hemiptera	9	0.00	0.00	0.00
Arachnids	10	0.06	0.41	0.11
Molluscs	11	9.03	8.49	0.68
Zooplankton	12	3.32	2.32	1.40
Fish	13	0.22	0.06	2.60
Macrophytes	14	9.41	15.89	25.63
Sand	15	1.63	0.00	1.61
Animal debris	16	2.16	1.78	1.45
Mud	17	6.27	2.47	6.73
Undetermined preys	18	0.22	0.41	0.77

n = number of specimens examined.

T. guineensis has a wide trophic spectrum of food constituted by 16 items preys. The most common food item in the stomach of *T. guineensis* is the insect Diptera (IFP, 13.07%). Secondarily, *T.*

guineensis fed on macropthytes, molluscs, Coleoptera, mud, zooplankton, Hymenoptera, Trichoptera, Ephemeroptera, animal debris and sand.

The overall food composition of hybrid individuals (*T. zillii* x *T. guineensis*) showed the utilization of a wide items preys which were primarily composed of macrophytes (IFP, 25.63%) and Diptera (IFP, 14.56%). The secondary preys of the hybrid were mud, Ephemeroptera, fish, Coleoptera, sand, animal debris and zooplankton.

Food in relation to fish size

The preponderance index of the major food items, for the various size classes are as shown in Figure 2. The adult specimens of the species mainly fed on insects (IFP, 34 – 43%) and macrophytes (IFP, 25 – 30%). In *T. zillii*, food of subadults was mostly composed of insects (IFP, 38%) and macrophytes (IFP, 30%). In addition to the both items, Mollusks were also abundant in the stomachs of juvenile. The sub adult specimens of *T. guineensis* mainly fed on Molluscs (IFP, 38%), insects (IFP, 25%) and macrophytes (IFP, 20%). The juvenile of this species also consumed principally insects (IFP, 38%) and Molluscs (IFP, 25%) and macrophytes (IFP, 18%). In the hybrid, insects and macrophytes constituted the preponderant diet of all size groups.

Only the feeding pattern of *T. guineensis* was significantly different between size classes (total χ^2: 23.117, ddl, 4, P < 0.0001).

Seasonal variation in diet composition

The food composition in relation to season is represented in Figure 3. In *T. Zillii*, the study of seasonal dynamics showed that Diptera, Ephemeroptera, Trichoptera, Molluscs, macrophytes fruits and scales were consumed in nearly the same quantities during both seasons. In the stomach of this species, Hymenoptera, Lepidoptera and mud were encountered in wet season while Coleoptera and Arachnids were present in dry season.

The diet of *T. guineensis* was mainly dominated by Diptera, Lepitoptera, Molluscs and mud in the wet season. In the dry season, it exhibited omnivore diet. The hybrid consumed macrophyta and Diptera in all seasons. The additional food composed of mud and Ephemeroptera were mainly consumed in wet season and dry season respectively.

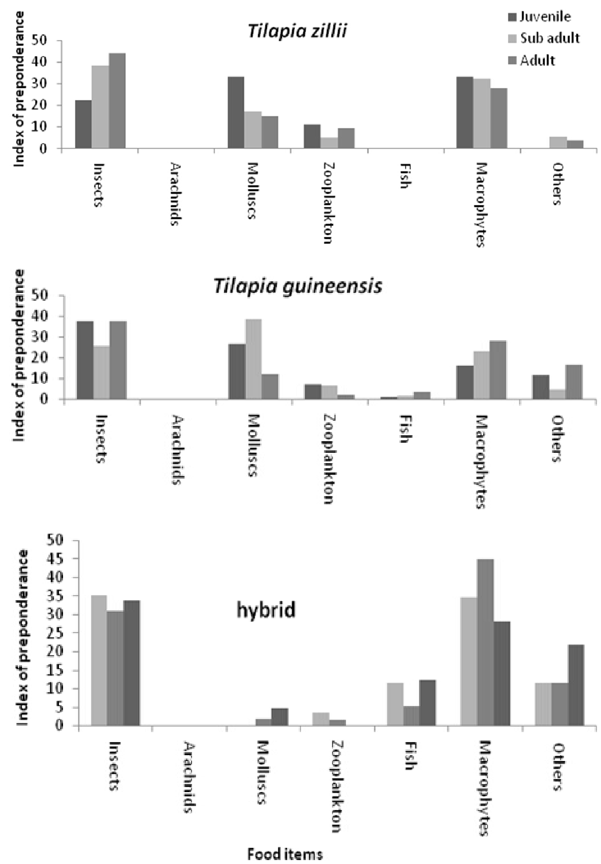

Fig. 2. Food variation in relation to fish size of *Tilapia zillii*; *Tilapia guineensis* and *Tilapia zillii* x *Tilapia guineensis* in the Ayamé Lake.

The feeding pattern was significantly different between the studied species in wet season (total χ^2: 43.65, ddl, 13, $P < 0.0001$) and dry season (total χ^2 : 58.24, ddl, 13, $P < 0.0001$).

Food similarity

Food similarity between the three species was presented in Table III. All values of Morisita index (C_λ) between them were superior than 0.6. A wide diet overlap between *Tilapia* species in Ayamé Lake was observed. The diet overlap was more important among the parental species, *T. zillii* and *T. guineensis* (0.98). The diet of the hybrid was more close to that of *T. zillii* (0.87) compared to *T. guineensis* (0.84).

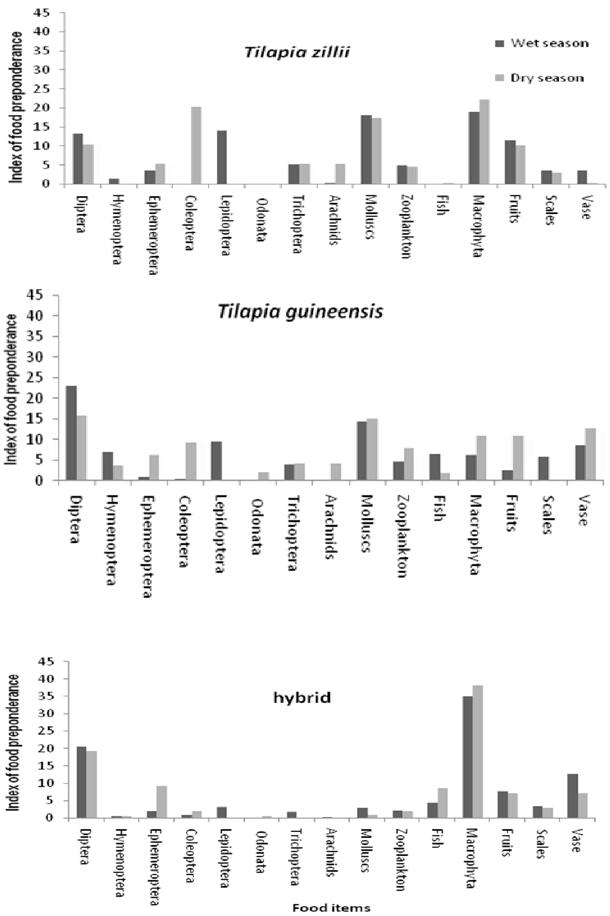

Fig. 3. Food variation in relation to season of *Tilapia zillii*, *Tilapia guineensis* and *Tilapia zillii* x *Tilapia guineensis* in Ayamé Lake.

Table III.- Food overlap index between the three species in Ayamé Lake.

Species	*Tilapia zillii*	*Tilapia guineensis*	*Tilapia* hybride
Tilapia zillii	1		
Tilapia guineensis	0.98	1	
Tilapia hybride	0.87	0.84	1

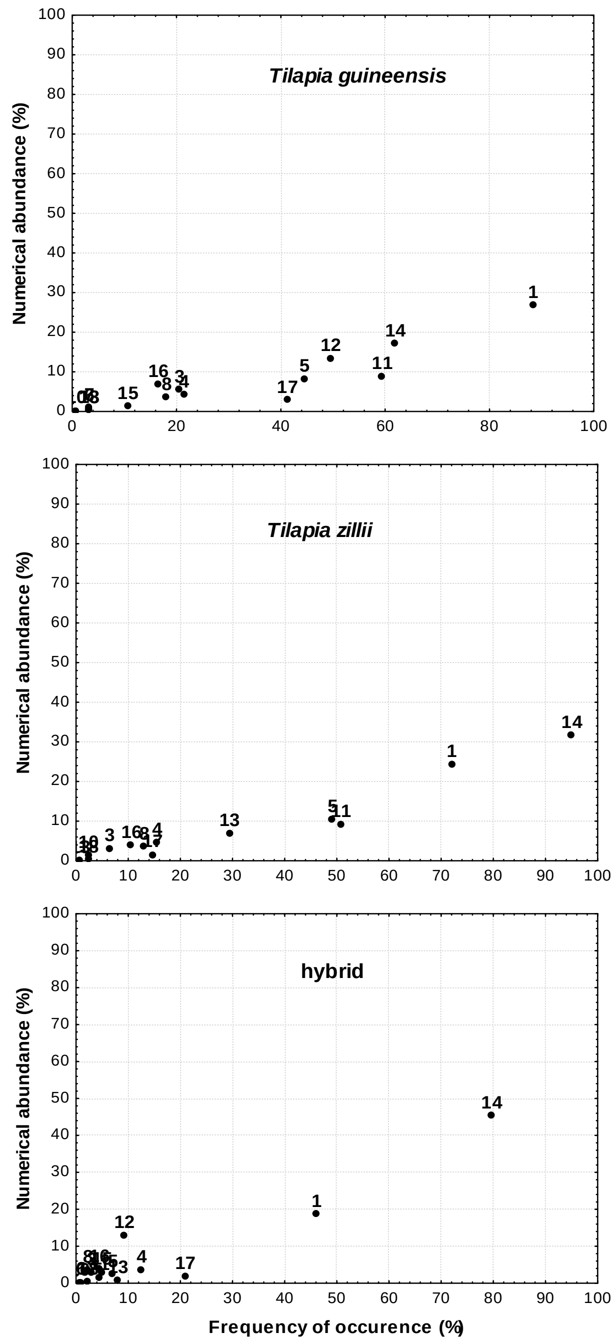

Fig. 4. Feeding strategy of individuals of *Tilapia zillii*, *Tilapia guineensis* and *Tilapia zillii* x *Tilapia guineensis* in Ayamé Lake (see Table I for item number).

Feeding strategy

Analysis of feeding strategy, based on the Amundsen's method (Fig. 4), showed that for the three species, almost all the preys were located below the prey importance axis indicating that these fishes exploited a broad niche with a generalized feeding behaviour. Considering the prey importance, *Tilapia zillii*'s diet is mostly dominated by the items 14 (macrophytes), 1 (Diptera), 11 (Molluscs) and 5 (Coleoptera). These preys were broadly consumed by all specimens of this species. The remaining items were eaten occasionally and in relative small amounts. For *T. guineensis*, diet was mostly based on 1, 14, 11 and 12 (zooplankton) which tend to be dominant preys. In the hybrid taxon from the previous species, the items 14 and 1 were the dominant preys. The other items are occasionally and rarely consumed.

DISCUSSION

Tilapia species have been reported to be plankton and deposit feeders (Adiase, 1969; Fagade, 1971, 1978, 1982; Fryer and Iles, 1972; Fagade and Olaniyan1973; Pauly, 1976; Buddington, 1979; Harbott, 1982; Akinwumi, 2003; Winemiller and Kelso-Winemiller, 2003; Negassa and Getahum, 2004; Oso *et al.*, 2006; Agbabiaka, 2012).The food of the species covers a wide spectrum. The major prey items of *T. zillii* and *T. guineensis* and their hybrid in the Ayamé Lake were mainly macrophytes, insects and Molluscs parts. From this point of view, the feeding habits of these species were similar to those reported by Fagade and Olaniyan (1973) in the Lagos lagoon on *T. guineensis* and *Sarotherodon melanotheron* and Fagade (1979) on *T. guineensis* from Lekki lagoon. In additional, a wide variety of invertebrates are taken as food by *T. zillii*, *T. guineensis* and their hybrid. As the Amundsen graphical shown it, the studied fishes exhibit a general feeding strategy. The same graphical also shown that hybrid individuals shared more preys with *T. zillii* than with *T. guineensis*. After the survey of the stomach contents of these species, it is possible to classify them into two broad feeding groups: (i) those feeding mainly on macrophytes and (ii) those whose food includes many insects. Stomach content analysis based on the index of food preponderance showed that in Ayamé Lake, *T. zillii*, *T. guineensis* and the hybrid (*T. zillii* x *T. guineensis*) feed on a wide range of food organisms that makes them euryphagous feeding with a food base comprising both plants and animals. *T. zillii* has been variously classified as plankton feeders, higher plant and algae feeders or macrophagous as well as mud suckers (Fagade, 1971**;** Brown and Colgan, 1984; Negassa and Getahun, 2004). Nevertheless, food of plant origin was the major component of the diet of *T. zillii* and the hybrid (*T. zillii* x *T. guineensis*) in this study. The same diet has been reported for *T. zillii* from Lake Victoria by Welcomme (1979), for fish from Lake Quarunby Abdel-Malek (1972) and from Nile canal by Khallafand Alne-na-ei (1987). For this reason, *T. zillii* were brought to Florida (USA) in 1961 by the Florida Game and Freshwater Fish Commission to investigate it`s potential use as a biological weed control (Courtenay and Robins, 1973). Because of its diet, covering a wide spectrum of food ranging from various types of plankton to invertebrate, *T. zillii* can be classified as an omnivorous. This characterization was reported for the same species by Spataru (1978) in Lake Kinneret (Israel) and for other fish as *Cyprinion mhalensis* (Ahmad *et al*., 2013)

Examination of the diet of *T. guineensis* and the hybrid showed that there was high index of food preponderance of Insects in their stomachs. The wide variety of items occurring in the stomachs of *T. zillii* (13 items preys), *T. guineensis* (16 items preys) and their hybrid (15 items preys) is an indication that there are non selective in feeding. Parental species and the hybrid are able to use many sources of protein as food. The ingestion of mud by *T. guineensis* (IFP, 6.27) and the hybrid (IFP, 6.73) could be attributed to the bottom feeding behaviour of the parental species and the hybrid. Apart from the major food items, studied fishes also picked a variety of other food items. Liem (1980) stated that teleost including cichlids are able to exploit more than one source. This ability to exploit different varieties of food makes *T. zillii*, *T. guineensis* and the hybrid as omnivorous fishes. The overlap measure C_λ is greater than 0.6. This result indicated a great food overlaps between species (Zaret and Rand, 1971). So, competition for food becomes possible. However, direct competition seemed to be avoided to some extent as a result of great food availability in Ayamé Lake. In fact, Ouattara *et al*. (2007) reported that the density of zooplankton in the Ayamé Lake was 116675ind/m3. In additional, the lentic conditions created by the lake are favorable to algal development. According to Spataru (1978), it is an important strategy for survival and an advantage over the species competing for a specific food item**.** The same observations were reported by Ahmed (2011) for the three sympatric species of Cyprinid fish larvae in Al-Huwaiza marsh (Southern Iraq). The similarity in ecological niche was also accompanied by some discrete differences in the selection of complementary food items. The difference noted in the diversity of supplementary food items of the two species and their hybrid may be an active and immediate response to interspecific competition or other habitat factors. *T. zillii* and *T. guineensis* were observed to be herbivorous having highest frequency of occurrence of great amounts of plants remains. The variety of items occurring in the stomachs of the 2 species shows that they are non selective in feeding and would appear that each species is capable of utilizing many sources of protein as food. Although some cichlids are known to feed entirely on fish scales (Fryer *et al*., 1955). The low occurrence of fish scales in the stomachs of these specimens of tilapia species suggests that this type of prey is not important in the diet of tilapia species in the Ayamé Lake.

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