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Occurrence of Gill Monogenean Parasites in Redbelly tilapia, *Tilapia zillii* (Teleostei: Cichlidae) from Lobo River, Côte d'Ivoire

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Key words: *Tilapia zillii*, Gill monogenean, infection level, River Lobo, Côte d'Ivoire.

1 ABSTRACT

A study was made on gill monogenean infestation of 231 *Tilapia zillii (Redbelly tilapia)* collected from Lobo River during August 2004 to July 2005. After recording biometric characteristics, common necropsy and parasitology methods were used. Three species belonging to genus *Cichlidogyrus* (*C. digitatus*, *C. aegypticus* and *C. vexus*) were recorded. An aggregated dispersion for all monogenean species was observed. There was a positive and significant correlation between the intensity of infection and the relative condition factor. The infestation exhibited seasonal fluctuation; the maximum intensities of parasite infection were recorded in the rainy seasons and the minimum in the dry seasons. The higher value of Shannon based evenness suggests that community structures show consistent distribution of all species during the seasons of the year. As to host size-related incidence, the differences in the number of the three species among the four-host size classes were significant ($p < 0.05$). No significant differences were found in the infrapopulations of the three parasite species between host sexes and in the distribution of these parasites among the left and right-hand gill sets ($p > 0.05$). In contrast, parasite species mostly concentrated in the middle arches ($p < 0.05$). This information is information will allow further researches on protocols for monitoring parasitic infection in intensive fish farming.

2 INTRODUCTION

Monogeneans are a group of parasitic flatworms that are commonly found on fishes and lower aquatic invertebrates (Reed *et al.*, 2012). Majority of them are ectoparasites and have direct life cycle. The larva is usually a small ciliated oncomiracidium, which hatches from the egg and swims to locate and infect another host (MonoDb, 2015). All monogeneans are oviparous (egg layers) except gyrodactylids which are viviparous (produce live offsprings) in nature (Paperna, 1996). According to Jalali and Barzegar (2006) and Tasawar *et al.* (2009), the adult stage of parasite is more dangerous to fish health depending on factors such as modes of attachment, the size and weight of host. Attachment of ectoparasites such as Monogeneans to gill and skin of fishes causes localized hyperplasia, disturbance of osmoregulation and mortality of the host (Piasecki *et al.*, 2004; Bednarska *et al.*, 2009). This can also result in secondary infections in the host from viruses, bacteria and fungi (.Tumbol *et al.*, 2001; Xu *et al.*, 2007). The parasites disease of fish reduces the amount of food available to people around the globe (Bichi and Ibrahim, 2009). The parasites usually affect the marketability of commercially produced fish, thus raising many public health concerns (Barson, 2004). *Tilapia zillii* (Gervais 1848) (Osteichthyes, Perciformes, Cichlidae) commonly referred to as Redbelly tilapia is among the several fish species found in the Lobo River, Côte d'Ivoire. It is used for aquaculture, commercial aquarium trade, as weed control agent and as a recreational fishery for many countries throughout the world (Adesulu and Sydenham, 2007; Elias *et al.*, 2014). Redbelly is used for controlling species of aquatic plants. It has also been used to control noxious aquatic insects, mosquitoes and chrinomid midges. Redbelly tilapia is a highly sought after, important recreational fishing species as well as important commercially. Redbelly tilapia is also a major source of cheaper protein hence studies on parasites occurrence are very important. Although much has been done on the taxonomy and biology of monogeneans on fish in Africa (Pariselle and Euzet, 2009), there is apparently little information on infection dynamics (Akoll *et al.*, 2012; Keremah and Inko-Tariat, 2013; Tombi *et al.*, 2014; Blahoua *et al.*, 2015; 2016). The only reports available of epidemiological studies in Ivoirian wild fish are those of Blahoua *et al.* (2015, 2016) carried out in a man-made Lake Ayamé I. However, there is no report on the occurrence of monogenean parasites on Redbelly tilapia in natural population of freshwater. Therefore, the aim of the present study is to survey monogenean gill infections of a natural-water fish, *Tilapia zillii* in Lobo River, Côte d'Ivoire.

3 MATERIALS AND METHODS

3.1 Study area: This stream is one of major primary tributaries of the Sassandra River Basin of the left shore (Girard *et al.*, 1971). According to Camus (1969), this River has its source at 340 m altitude near Séguéla. It is 290 km long and has a mean area of 12600 km^2 (Girard *et al.,* 1971; Anonyme, 2001). The river receives two major tributaries on the left shore namely Dé and Goré Rivers. The Lobo tributary is shaded by overhanging canopy of riparian vegetation (Figure 1). Two dry and two rainy seasons are recognized in the study area (Eldin, 1971). The long dry season (LDS) extends from November to February and the short one (SDS) from July to August. The long rainy season (LRS) occurs from March to June and the short one (SRS) from September to October.

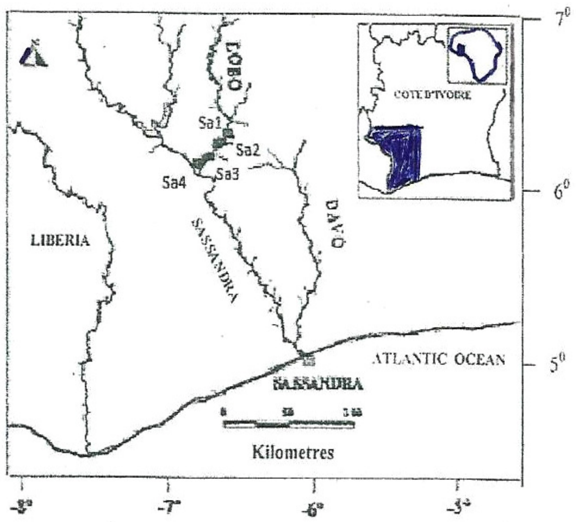

Figure 1. Map showing the localization of sampling stations (Sa) in the Lobo River (Côte d'Ivoire, West Africa).

3.2 Data collection: Fishes were collected monthly with a fleet of 17 weighted monofilament gill nets (8 to 90 mm mesh sizes); 30 m in length and 1.5 m in height were employed to capture fish. Nets were set overnight (17 to 07 h) and during the following day (07 to 12 h). In the field, the fish caught were identified following Teugels and Thys van den Audernaerde (2003), and standard length (mm) and body weight (g) were recorded for each specimen. The fish sampled were divided into four different length classes of 50 mm amplitude (class I: SL ranged between 50 - 100 mm; class II: SL ranged between 100 - 150 mm; class III: SL ranged between 150 - 200 mm and class IV: SL ranged between 200 - 250 mm). The effect of the parasites on the health status of the fish host was investigated from Fulton's condition factor (K-factor) with the following formula: $Kc = W \times 10^5/SL^3$, where W is the weight (grams) and SL the standard length of fish (millimeters) (Klemm *et al.*, 1992). Fishes were decerebrated without bloodshed and dissected to determine their sex by visual inspection of urinogenital papilla and gonads. After being determined the sex, the operculum was removed to expose the gills, which were carefully removed fresh, separated into left and right, and stored in ice (0 °C). Upon arrival at the laboratory, the left and right gill arches excised were separated, and placed in a Petri dish containing water. Gill arches were examined using a binocular microscope (Olympus SZ 60). Left and right arches were numbered 1 to 4, gill arch 1 nearest the operculum and gill arch 4 nearest the midline. Monogeneans were removed, fixed and mounted in a drop of ammonium picrate-glycerine mixture, following the method of Malmberg (1957). Observed parasites were identified based on available taxonomic characters as described by Pariselle and Euzet (2009).

3.3 Data analysis: Classical epidemiological variables (prevalence and intensity) were calculated according to Bush *et al.* (1997). The classification of the species based on prevalence (P) was made according to Valtonen *et al.* (1997). Thus, parasite species were considered as frequent if $P > 50\%$, as less frequent if $10 \leq P \leq 50\%$ and rare if $P < 10\%$. These categories may correspond to what other authors such as Koskivaara and Valtonen (1992) termed respectively as core, secondary or satellite species. The mean intensity (MI) was considered as high if $MI > 100$, average if $50 < MI \leq 100$, low if 10

< MI ≤ 50 and very low if MI <10 (Bilong Bilong and Njiné, 1998). The dispersion index (S^2/X) was used to examine the pattern of aggregation of the species of ectoparasites (Shaw and Dobson, 1995). Parasite diversity of the sample was calculated using Shannon's (Shannon and Weaver, 1963) index of diversity (H'). For evenness, Shannon-based evenness was calculated. Standard statistical computation (standard deviation) was carried out using Microsoft Excel. Sperman's rank correlation coefficient "rs" was calculated to determine the existence of any meaningful association between abundances of monogenean species and relative condition factor of the hosts (Zar, 1996). Statistical significance differences observed in the prevalence values were assessed using the Chi-square (x^2) test, according to Rosza *et al.* (2000). Analysis of variance and Student U test were respectively used to compare two and several averages. The statistical significance level was evaluated at $p \leq 0.05$. The various statistical analyses were performed using the STATISTICA program version 7.1.

4 RESULTS

4.1 Species richness and status of monogenean parasites species: Three monogenean species were found to have infested the gills of *Tilapia zillii* collected at Lobo River. The core species of this component infracommunity was *Cichlidogyrus digitatus*. Its mean intensity was low and this monogenean adopted a regular distribution. *Cichlidogyrus aegypticus* and *C. vexus* were secondary species. The mean intensity was very low for *C. vexus* and it was low for *C. aegypticus*. These two species adopted an aggregated distribution (Table 1). A significant association was observed between fish condition factor and the presence of monogeneans *Cichlidogyrus vexus*, *C. aegypticus* and *C. digitatus* (rs = 0.41, 0.62 and 0.83 respectively, p = 0.00 < 0.05).

Table 1. Prevalence, mean intensity, variance, dispersion index and distribution of gill monogenean parasites of *Tilapia zillii*

Monogenean species	Prevalence (%)	Mean intensity ± SD	Variance	Dispersion Index (S^2/X)	Distribution
Cichlidogyrus digitatus	70.99	24.43±25.64	560.5	22.94	Aggregated
Cichlidogyrus aegypticus	44.59	11.13±11.26	206.24	18.53	Aggregated
Cichlidogyrus vexus	38.96	7.09±6.38	92.05	13	Aggregated

SD: Standard Deviation

4.2 Seasonality and distribution of monogenean species: Three monogenean gill parasite species were recorded during the sampling period from the redbelly tilapia, *Tilapia zillii*. There were *Cichlidogyrus vexus* (overall prevalence 71 %), *C. aegypticus* (overall prevalence 44.6%) and *C. digitatus* (overall prevalence 39%). As for *Cichlidogyrus digitatus*, the prevalence levels of infestation were highest (100%) in long rainy season, followed by 78.9% in small rainy season, 51.8% in small dry season and 49.3% in long dry season. The highest mean intensity (30.8 parasites/fish) (range: 1-135) was recorded in long rainy season and the lowest mean intensity (10.3 parasites/fish) (range: 1-64) in long dry season (Table 2). Globally, seasonal changes in the prevalence and mean intensity of this parasite species also showed variation ($X^2 = 51.59$, df = 3, p = 0.00 < 0.05; Analysis of variance F = 21.75, dl = 3, p = 0.00 < 0.05, respectively). A

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significantly difference was also found between small dry and rainy seasons (Student t = 4.89, p = 0.039), small dry season and long rainy season (Student t = 6.18, p = 0.0046 < 0.05), small rainy season and long dry season (Student t = 8.28, p = 0.008 < 0.05), and between long dry and rainy seasons (Student t = 3.93, p = 0.007 < 0.05). However, there were no significant differences in the intensity of infection between small and long dry seasons (Student t = 3.61, p = 0.32 > 0.05) and between small and long rainy seasons (Student t = 4.12, p = 0.06 > 0.05). The rate of infestation of *Cichlidogyrus aegypticus* was maximum (62.4%) in long rainy season, followed by 58.1% in small rainy season, 34.5% in small dry season and 21.2% in long dry season. The maximum intensity level was found in long rainy season as 14.2 parasites/fish (range: 1-71), decreasing gradually to 11.9 parasites/fish (range: 1-63) in small rainy season, and 6.1 parasites/fish (range: 1-42) in small dry season; the minimum mean intensity was detected in long dry season at 4.6 parasites/fish (range: 1- 32) (Table 2). There was a significant difference in prevalence between seasons (X^2 = 28.61, df = 3, p = 0.00 < 0.05). A seasonal effect was noted for this species between small dry and rainy seasons (Student t = 4.62, p = 0.04), small dry season and long rainy season (Student t = 4.06 p = 0.01539 < 0.05), small rainy season and long dry season (Student t= 7.38, p= 0.00179 < 0.05) and long dry and rainy seasons (Student t = 6.87, p = 0.0005 < 0.05). In contrast, no significant difference in the number of parasites was found between small and long dry seasons (Student t = 8.21, p = 0.09 > 0.05) and between small and long rainy seasons (Student t = 6.2, p = 0.7 > 0.05). The prevalence of infestation of *Cichlidogyrus vexus* ranged from 19.6% in long dry season to 56.1% in long rainy season throughout the seasons. The mean intensity levels recorded during the sampling period showed that the minimum level of mean intensity (3.2 parasites/fish) (range: 1-14) was found in long dry season and the maximum level (8.6 parasites/fish) (range: 1-61) in long rainy season (Table 2). The rates of infestation of this species varied significantly among seasons (X^2 = 22.87, df = 3, p = 0.00 < 0.05; Analysis of variance F =14.69, dl = 3, p = 0.02 < 0.05).

Table 2. Seasonal changes of Prevalence (%) and Mean intensity (MI) of gill monogenean parasites of *Tilapia zillii*

	small dry season (n=52)			small rainy season (n=53)			long dry season (n=61)			long rainy season (n=64)		
Monogenean species	P (%)	MI±SD	Range	P (%)	MI±SD	Range	P (%)	MI±SD	Range	P (%)	MI±SD	Range
C. digitatus	51.8	11.2±0.3	1-95	78.9	28.9±4.2	1-126	49.3	10.3±3.2	1-64	100	30.8±11.6	1-135
C. aegypticus	34.5	6.1±4.3	1-42	58.1	11.9±2.8	1-63	21.2	4.6±4.1	1-32	62.4	14.2±8.4	1-71
C. vexus	28.87	4.2±2.3	1-30	48.8	7.4±1.9	1-55	19.6	3.2±0.7	1-14	56.1	8.6±7.3	1-61

SD: Standard Deviation

A significantly difference was found between small dry and rainy seasons (Student t = 2.14, p = 0.016 < 0.05), small and long dry seasons (Student t = 3.2, p = 0.04), small dry season and long rainy season (Student t = 5.12, p = 0.037 < 0.05) and small rainy season and long dry season (Student t = 1.98, p = 0.00 < 0.05) and long dry and rainy seasons (Student t = 3.68, p = 0.034 < 0.05). However, there were no significant differences in the intensity of infection between small and long rainy seasons (Student t = 3.51, p = 0.07 > 0.05). In the present study, Shannon-Wiener index varied from a lowest of 0.701 bit.ind^{-1} during the long dry season to a highest of 0.86 during the long rainy season. Evenness index ranged from a minimum of 0.64 in the long dry season to a maximum of 0.78 in the long rainy season. The three monogeneans were more organized in the rainy season than those in the dry season. For the monogenean component infracommunities on the redbelly tilapia from different sampling period, none of these parameters exhibited significant seasonal difference (Analysis of variance F = 4.41 and 1.98, dl = 3, p = 0.63 and 0.71 > 0.05, respectively).

4.3 Monogenean species according to host size: Prevalence and mean intensity of parasitic monogenean infection varied with host size (Figures 2 and 3). The prevalence of *Cichlidogyrus digitatus* varied from 35.3% in the size group I to 100% in the size group IV, and the intensity of infection varied from 9.2 parasites/fish to 31.3 parasites/fish in these size groups, respectively. There was a significant difference between the rates of infestation (prevalence and intensity of infection) of *C. digitatus* and the host size groups (X^2= 68.7, df = 3, p = 0.00 < 0.05; Analysis of variance F = 7.28, dl = 3, p = 0.00 < 0.05, respectively). There was a significant difference between the number of this monogenean and the size groups I and III (Student t = 3.02, p = 0.00 < 0.05), the size groups I and IV (Student t = 2.55, p = 0.01 < 0.05), size groups II and III (Student t = 2.01, p = 0.02 < 0.05) then between the size groups II and IV (Student, t = 3.57, p = 0.00 < 0.05). *Cichlidogyrus aegypticus* was occurred in the fish with a varying prevalence from 20.6% in the size group I to 56.5% in the size group IV. The mean intensity ranged from 5 parasites/fish in size group I to 12.71 parasites/fish in the size group IV. The difference in the prevalence and the intensity of infection of this species among the 4 size groups was significant (X^2= 21.37, df = 3, p = 0.00 < 0.05; Analysis of variance F = 6.84, dl = 3, p = 0.00 < 0.05, respectively). Statistically difference was recorded between the intensity of infection of this species and the size groups I and III (Student t = 0.66, p = 0.02 < 0.05), the size groups I and IV (Student t = 1.97, p = 0.04 < 0.05), the size groups II and III (Student t = 1.71, p = 0.04 < 0.05) then between the size groups II and IV (Student t = 5.24, p = 0.00 < 0.05). *Cichlidogyrus vexus* was found in the fish of all size groups, with a varying prevalence from 11.7% in the size group I to 52.9% in the size group IV, and the intensity of infection varied from 2.5 parasites/fish to 8.9 parasites/fish in these size groups, respectively. A significant difference in prevalence and mean intensity according to size group was observed (X^2 = 20.63, df = 3, p = 0.00 < 0.05; Analysis of variance F = 3.30, dl = 3, p = 0.02 < 0.05). A significant difference was observed between the number of this parasite and the size groups I and III (Student t = 0.42, p = 0.00 < 0.05), the size groups I and IV (Student t = 1.34, p = 0.00 < 0.05) then between the size groups II and IV (Student t = 3.57, p = 0.00 < 0.050).

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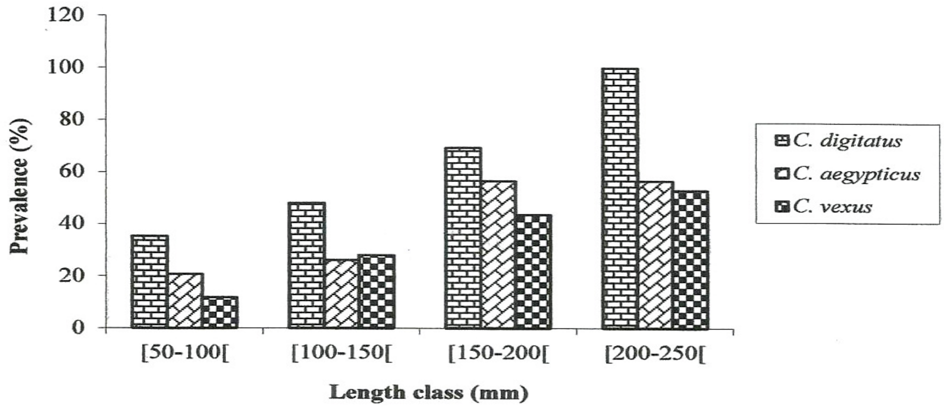

Figure 2. Prevalence (%) of *Cichlidogyrus digitatus* (*C. digitatus*), *Cichlidogyrus aegypticus* (*C. aegypticus*) and *Cichlidogyrus vexus* (*C. vexus*) according to the host length class.

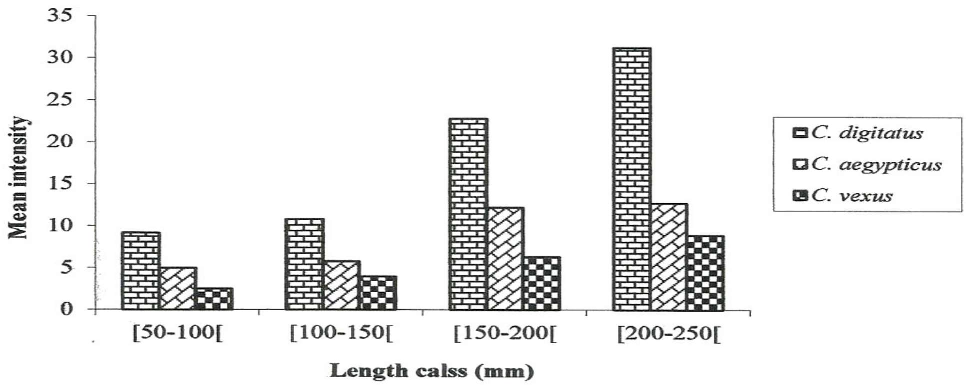

Figure 3. Mean intensity of *Cichlidogyrus digitatus* (*C. digitatus*), *Cichlidogyrus aegypticus* (*C. aegypticus*) and *Cichlidogyrus vexus* (*C. vexus*) according to the host length class.

4.4 Monogenean species according to host sex: A total of 231 specimens of *Tilapia zillii* (125 males and 106 females) were examined for monogenean parasites. The prevalence of infestation was slightly higher in females than males. Of the 106 females, 77 females were found to be infested by one or more parasites species. Overall prevalence of parasitic infestation was found to be 77.6% and 70.4% in females and males, respectively (Figures 4 and 5). The prevalence and mean intensity levels of *Cichlidogyrus digitatus* were higher in females (respectively 72.6% and 24.4 parasites/fish) than in males (respectively 70.4% and 23.4 parasites/fish). The rates of infestation (prevalence and intensity of infection) did not differ between males and females ($X^2 = 0.14$, df = 1, p = 0.707; Analysis of variance F = 0.11, dl = 1, p = 0.73 > 0.05, respectively). The monogenean *Cichlidogyrus aegypticus* was found in 56 of 125 male fish examined (44.8%) and in 47 of 106 female fish (44.3%), with a mean intensity of 10.8 parasites/fish and 11.6 parasites/fish, respectively. The Chi square test (X^2) test applied showed that this species was partitioned equally between males and females ($X^2 = 0.0$, df = 1, p = 0.944 > 0.05). Analysis of variance also indicated that host sex did not affect significantly the

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intensity of infection of *C. aegypticus* (Analyse of variance F = 0.21, dl = 1, p = 0.65 > 0.05). *Cichlidogyrus vexus* occurred in male and female fish. This species was recorded in 40 out of 106 females (37.7%) and in 50 out of 125 males (40%). In contrast, the intensity of infection was slightly higher in females (7.2 parasites/fish) than in males (6.9 parasites/fish). No significant differences were noted among prevalence and intensity of infection of this monogenean in male and female hosts (X^2= 0.12, df = 1, p = 0.725 > 0.05, Analysis of variance F = 0.54, p = 0.46 > 0.05, respectively).

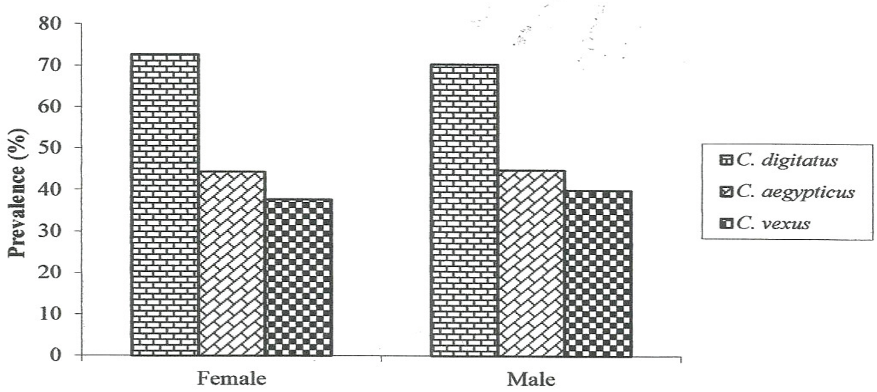

Figure 4. Prevalence (%) of *Cichlidogyrus digitatus* (*C. digitatus*), *Cichlidogyrus aegypticus* (*C. aegypticus*) and *Cichlidogyrus vexus* (*C. vexus*) according to the host sex.

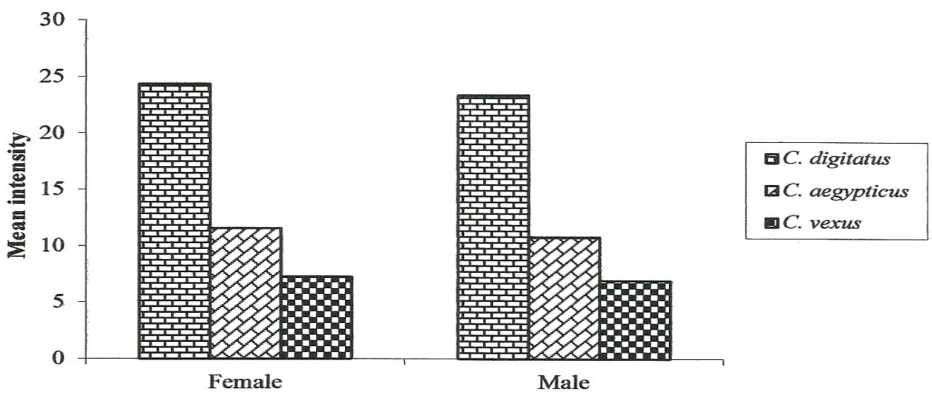

Figure 5. Mean intensity of *Cichlidogyrus digitatus* (*C. digitatus*), *Cichlidogyrus aegypticus* (*C. aegypticus*) and *Cichlidogyrus vexus* (*C. vexus*) according to the host sex.

4.5 Branchial repartition of monogenean species: As for Cichlidogyrus *digitatus*, the prevalence was 96.7% on the left and 90% on the right sides. Its mean intensity value was 20.2 parasites/fish and 18.56 parasites/fish on the left and right sides, respectively. Host side did not affect significantly the infection (X^2 = 1.07, df = 1; p = 0.301 > 0.05; Analysis of variance F = 0.21, dl = 1, p = 0.45 > 0.05, respectively) (Figures 6 and 7). Most parasites occurred on the second and the third gill arches of the branchial chamber (X^2 = 26.02, df = 3, p = 0.000 < 0.05;

Analysis of variance F = 7.28, dl = 3, p = 0.00 < 0.05, respectively) (Figures 8 and 9). The prevalence and mean intensity values of *Cichlidogyrus aegypticus* was respectively 73.3% and 18.1 parasites/fish on the left and 70% and 16.7 parasites/fish on the right side. This species was partitioned equally between left and right host sides (X^2 = 0.08, df = 1, p = 0.3006 > 0.05; Analysis of variance F = 0.37, dl = 1, p = 0.22 > 0.05) (Figures 6 and 7). Statistical tests revealed that the infection level of this monogenean species varied significantly from the first gill arch to the fourth one, indicating a pattern of gill-arch preferences (X^2 = 10.837, df = 3, p = 0.01264 < 0.05; Analysis of variance F = 6.84, p = 0.00 < 0.05) (Figures 8 and 9). *Cichlidogyrus vexus* was present in 60% on the left side and 63.3% on the right side. The prevalence did not differ between left and right sides (X^2= 0.07, df = 1, p = 0.774 > 0.05). The mean intensity value was 14.3 parasites/fish on the left side whereas it was 14.9 parasites/fish on the right side (Figures 6 and 7). In addition, there was no significant difference in the intensity of infection between host sides (Analysis of variance F = 0.03, dl = 1, p = 0.1 > 0.05). Most parasites were mainly isolated from the second and third gill arch filaments (X^2 = 11.383, df = 3, p = 0.00983 < 0.05; Analysis of variance F = 3.30, p = 0.02 < 0.05) (Figures 8 and 9).

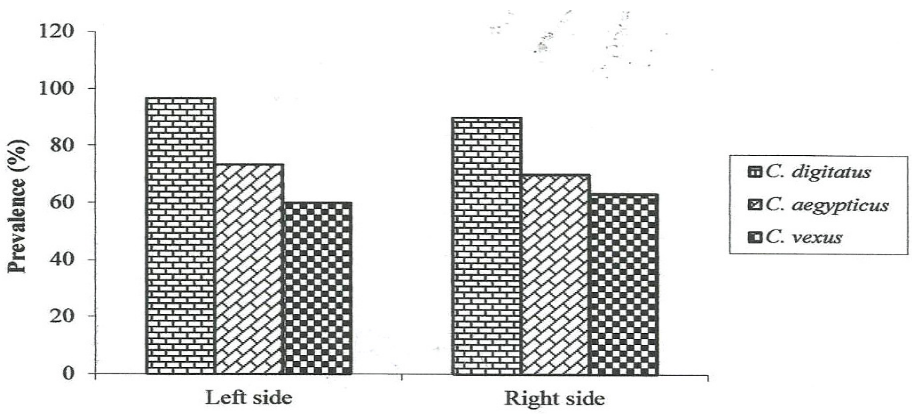

Figure 6. Prevalence (%) of *Cichlidogyrus digitatus* (*C. digitatus*), *Cichlidogyrus aegypticus* (*C. aegypticus*) and *Cichlidogyrus vexus* (*C. vexus*) according to the host side.

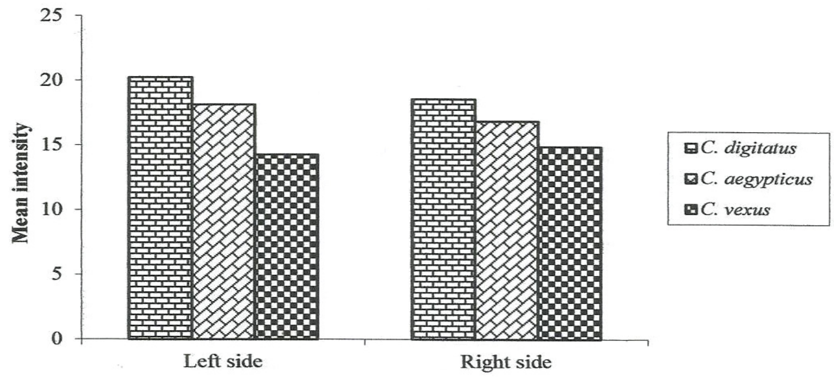

Figure 7. Mean intensity of *Cichlidogyrus digitatus* (*C. digitatus*), *Cichlidogyrus aegypticus* (*C. aegypticus*) and *Cichlidogyrus vexus* (*C. vexus*) according to the host side.

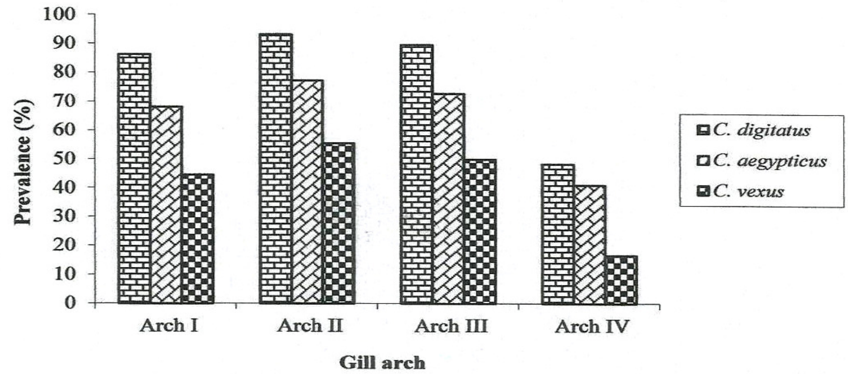

Figure 8. Prevalence (%) of *Cichlidogyrus digitatus* (*C. digitatus*), *Cichlidogyrus aegypticus* (*C. aegypticus*) and *Cichlidogyrus vexus* (*C. vexus*) according to the gill arch.

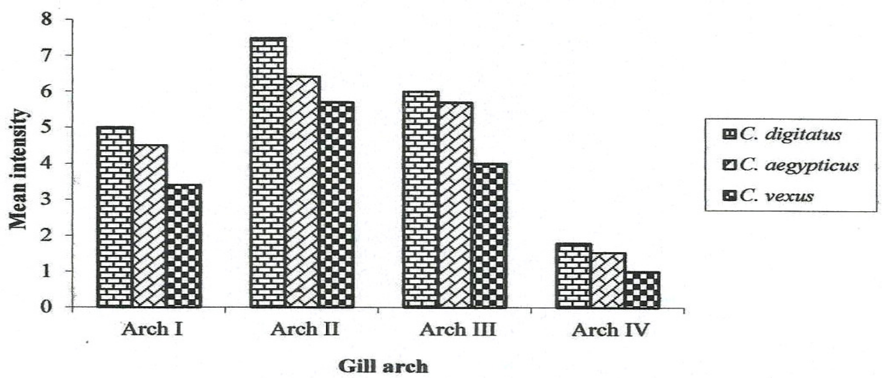

Figure 9. Mean intensity of *Cichlidogyrus digitatus* (*C. digitatus*), *Cichlidogyrus aegypticus* (*C. aegypticus*) and *Cichlidogyrus vexus* (*C. vexus*) according to the gill arch.

5 DISCUSSION

Previously studies on the monogenean species-richness of Cichlid host have been conducted. Euzet and Pariselle (2009) reported that in Africa, eleven monogenean species infested *Tilapia zillii* gill system namely: *Cichlidogyrus aegypticus*, *C. anthemocolpos*, *C. arthracanthus*, *C. cubitus*, *C. digitatus*, *C. ergensi*, *C. ornatus*, *C. tiberianus*, *C. vexus*, *C. yanni* and *Scutogyrus longicornis*. In this study, the gill parasite community of *T. zillii* collected at Lobo River consisted of three of the eleven monogeneans species described in Africa and also presents a low species-richness compared to *T. zillii* from the man-made Lake Ayamé I (Côte d'Ivoire) in which a total of eight species have been recorded (N'Douba, 2000). This variability of parasite richness has been associated to various factors among them experimentation factors (effort of individuals examined hosts) (Walther *et al.*, 1995), factors related to the host and with its social behavior (trait of life, size, habitat and behavior) (Morand *et al.*, 1999; Zharikova, 2000) and factors related to the phylogeny of hosts and parasites (Guégan and Morand, 1996; Sasal *et al.*, 1997). Factors linked to habitat environmental and biological aspects can also affect structure and species composition (Vidal-Martinez and Poulin, 2003, Tavares and Luque, 2008; Violante-Gonzalez *et al.*, 2010). Thus, the lack of the Monogeneans *Cichlidogyrus anthemocolpos*, *C. arthracanthus*, *C. cubitus*, *C. yanni* and *C. tiberianus* in Lobo River could be due to the water current velocity. Indeed, the current is often evoked as a factor limiting the recruitment of infective larva stages, thus reducing the intensity of parasitism (Silan and Maillard, 1990). Moreover, this study has underlined a polyparasitism with predominance of *Cichlidogyrus* species on the gills of *Tilapia zillii* collected at Lobo River. Some cases in which more than one *Cichlidogyrus* species is present on a single host fish species have also been already reported. Ibrahim (2012) collected seven monogenean species of *Cichlidogyrus* from *Tilapia zillii* gill system. Lim *et al.* (2016) also found that, the gill system of Nile tilapia (*Oreochromis niloticus*) and red hybrid tilapia (*Oreochromis* spp.) is parasitized by six monogenean species. The great diversity of monogenean gill parasites in African Cichlids mentioned by Pariselle (1996) was hereby confirmed. This multi-specific parasitism of *T. zillii* could be explained by the permanent presence of vacant niches on its gill biotope (Simkova *et al.*, 2006). The studied monogenean was composed of one core species (*Cichlidogyrus digitatus*) and two secondary species (*C. aegypticus* and *C. vexus*), with very low intensities except for *C. digitatus* and *C. aegypticus* that were low. These findings are similar to those of Koyun (2011), who reported very low intensities of *Dactylogyrus minutus* and *D. anchoratus*, gill parasites of *Carassius carassius*. These results corroborate the observation in the natural environment where the parasitic load is generally limited due to the low density of hosts (Buchmann and LindenstrØm, 2002). They could also show the low inflow of infective larvae. Indeed, under such conditions, the infrapopulation cannot easily reach a high-level due to own natural mortality of individuals (Combes, 1995). In the present study, all of the parasites presented an aggregated distribution pattern, which, according to Krasnov and Poulin (2010) is characteristic of parasite systems. The main cause of such distribution in host populations relates to environmental stochastic factors. Among these factors are the environmental changes to physical parameters in time and space, especially differences in host susceptibility to infection, which can occur due to immunological and behavioural differences, as well as genetic factors (Zuben, 1997). Parasite population aggregation in a small host population increases the relationship stability, due to regulatory mechanisms such as host mortality, which depends on the parasite density and the decrease in survival and fecundity of parasites caused by intraspecific competition between parasites or immunological reactions of hosts (Dobson, 1990). According to Zuben (1997), the aggregated distribution pattern acts to increase the density dependent regulation, the abundance of both host and parasite, and reduce the level of competition among parasite species. In several studies, there has been a growing interest on the influence of the abundance of parasitic species on the condition factor of host fish. Thus, Yamada *et al.* (2008) reported a significant and positive correlation of the condition factor of Cichlids with the abundance of a species of monogeneans. In contrast to these results, Tozato (2011) found no differences in condition factor of *Corydoras aeneus* (Gill, 1858) parasitized and not parasitized by monogeneans and concluded that these parasites did not affect the welfare of the host. The increase of number of parasites per host fish with the condition factor of the fish can be attributed to the fact that, the monogenean community studied has low pathogenicity to the host fish in this River. This study also agrees with Cone (1995), that larger fish and a better condition factor can withstand higher intensities of infection by monogeneans parasites despite being pathogenic. Regarding temporal variation of the occurrence of parasites, all species of monogeneans (*Cichlidogyrus digitatus*, *C. aegypticus* and *C. vexus*) identified have been present throughout the year in the host fish. The same trend was also reported by Bilong Bilong and Tombi (2005) who noticed that, except for *Dactylogyrus maillardi* absent in July 1999, there was temporary disappearance of *Barbus martorelli* gill monogenean parasites in Foulou stream. The presence of *Tilapia zillii* gill parasites suggested that physical and chemical conditions in Lobo River still allowed these organisms' growth. In this study, seasonal variations in the prevalence and the intensity of infection of *Cichlidogyrus digitatus*, *C. aegypticus* and *C. vexus* were obtained. Highest infection levels were was observed in the rainy seasons (small and long rainy seasons). These observations in lotic environment concur with findings of those of Blahoua *et al.* (2015) in lentic environment. The latter showed that the highest intensities of *Tilapia zillii* monogenean gill parasites occurred during the rainy seasons, whereas dry seasons are characterized by the mortality of adult worms as a result of higher water temperature (32.7 °C). Temperature is generally considered to be the most important factor associated with seasonal variation in monogenean infections, because all stages of the monogenean life cycle are temperature-dependent (Tubbs *et al.*, 2005; Hirazawa *et al.*, 2010). For *Cichlidogyrus digitatus*, *C. aegypticus* and *C. vexus* (usually few in dry seasons), water high temperature (e.g. 27 °C) must have been harmful on the adult worms. Specific diversity calculated by Shannon-Weaver index is a measure of the degree of the community organization; low diversity is synonymous to good organization while high diversity reveals poor organization (Caltra and Silan, 1996). It appears therefore that, the lower values of Shannon's (H) index specifies less diversification of parasitic community. The higher value of Shannon based evenness suggests that community structures show consistent distribution of all parasite species during the rainy and dry seasons. As regards the relationship between the level of *Cichlidogyrus* infection and the size of host fish, there have been several researches indicating that the abundance of *Cichlidogyrus* is often higher on older fish than younger ones. For example, Ibrahim (2012) reported the positive significant correlation of prevalence and mean intensity of seven monogenean species of *Cichlidogyrus* (*Cichlidogyrus arthracanthus, C. aegypticus, C. sclerosus, C. halli typicus, C. tilapiae, C. ergensi, C. tiberianus*) with the total length of *Tilapia zillii.* The increase in the parasite infection rate as a function of the size of the host specimen can be explained by the increase in gill surface area with body length (Cable *et al.*, 2002; Bilong Bilong and Tombi, 2004). According to these authors, larger-sized fish provide a larger gill surface area that can hence accommodate greater numbers of parasites. Furthermore, the large volume of water flows over the gills of large fish would increase the possibility of their invasion by oncomiricidium (Simkova *et al.*, 2006). Monogenean species showed no preference for host sex. This concurs with Le Roux *et al.* (2011) who found no difference in infection of *Cichlidogyrus philander* attributable to the sex of *Pseudocrenilabrus philander philander*. Blahoua *et al.* (2016) also found the same result with all monogeneans of *Oreochromis niloticus*. Our result holds true with the views of Rohde (1993) who suggested that few parasite species show a preference for host sex. The present study indicates that there was no statistical difference in the distribution of monogeneans between the left and the right gills of *T. zillii*. Similarly, Blahoua *et al.* (2016) and Lim *et al.* (2016) also reported that there is no significant difference in the preferences of monogeneans on both the gill sides of *Oreochromis niloticus* and *Oreochromis spp.*, respectively. According to Rohde (1993), the preferences of a parasite to specific site of the host may be associated with the body symmetry of the parasites. Since *Cichlidogyrus* is bilateral symmetry, it is very likely that the monogeneans can have equitable distribution on both sides of the gills, which have similar morphology and exposure to ventilation current. The study of the occupation of the four pairs of gill arches revealed that the number of each parasite decreases in the anterio-posterior direction. The first two to three gills were mostly infected by all the species of monogeneans. The gill arch IV has been least parasitized. These results are similar to those of Tombi *et al.* (2014) who showed that the number of *Cichlidogyrus thurstonae, C. halli, C. tilapiae* and *Scutogyrus longicornis* on the four-gill arches of *Oreochromis niloticus* decreased from arch I to arch IV. Based on parasite loads, this study reveals that *C. digitatus*, *C. aegypticus* and *C. vexus* occurred commonly on the gill arches II and III of *Tilapia zillii*. Similarly, Özer and Öztürk (2005) had found greater and statistically significantly numbers of *Dactylogyrus cornu* on the second gill arches of *Vimba tenella*. Le Roux *et al.* (2011) also reported that, in *Pseudocrenilabrus philander philander*, *Cichlidogyrus philander* was preferentially attached to the arches II and III. The median preference arches II and III could be explained by two main factors: respiratory water currents and gill surface area as suggested by Gutiérrez and Martorelli (1999) and Lo and Morand (2001). According to these authors, greater respiratory water current flowing through the gills will facilitate the settlement of these parasites. Thus, the gill arch IV was less infested because it has the smallest colonized surfaces area and the lowest number of gill filaments as compared to the first three gill arches (El-Naggar and Reda, 2003; Madanire-Moyo *et al.*, 2011).

6 CONCLUSION

The study of the occurrence of the gill monogenean parasites in *Tilapia zillii* has identified the most vulnerable hosts. In fact, these organisms appeared throughout the year with an increase in the intensity of infection during the rainy season. Parasites adopted a regular distribution and a significant positive correlation between the intensity of infection and the relative condition factor was found. Moreover, host trait such as body size affects monogenean structure. Monogeneans prefer to harbour on the gill arches II and III but have no preference for the left or right side of the gills. The information obtained may provide strategies in aquaculture management to reduce potential economic losses of tilapia caused by parasitic infection.

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