

Host Sexual Dimorphism and Size Polymorphism in Susceptibility of the Nest-Breeding, Nile Green Tilapia (*Tilapia zilli*) Gervais, 1848 to the Monogenean Gill Parasites

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Keywords: Mansouria Canal, *Tilapia zilli*, Breeding Season, Sexual imorphism, Size Polymorphism, Monogenea, *Cichlidogyrus*.

Abstract

A detailed account has been made of the sexual dimorphism and size polymorphism in susceptibility of the nest-breeding, Nile green tilapia (*Tilapia zilli*) Gervais, 1848 to cichlidogyrin monogeneans at Mansouria Canal, Nile Delta, Egypt. The spawning period extended from early April to late August in 2016. Only four gill monogenean species, namely *Cichlidogyrus arthracanthus*, *C. aegypticus*, *C. tilapiae* and *C. halli typicus* were encountered on the gills of the green tilapia. The two genders of the breeding tilapia acquired significantly higher numbers of monogenean worms than their conspecifics of the non-breeding tilapia. However, the infection variables (prevalence, mean intensity and abundance) showed no significant variation between the two genders in the breeding or non-breeding forms of tilapia. Extensive field observations revealed that the breeding forms of the green tilapia were resident, mostly quiescent during the spawning time, indicating increased opportunities for monogenean populations to proliferate on the likely captive host individuals. The prevalence of the most dominant monogenean, *Cichlidogyrus arthracanthus* varied significantly among different classes of the host condition factor in the breeding males, non-breeding males and non-breeding females.

However, the infection variables of other monogeneans attained no significant variation among different classes of the host condition factor. The condition (class I) acquired greater number of the monogenean *Cichlidogyrus arthracanthus*, followed by class II and class III. Factors contributing to the sexual dimorphism and size polymorphism in monogenean infestation on the breeding forms of the green tilapia are discussed.

Introduction

Host factors such as host sex, length and weight are considered among the most important biotic elements shaping the life history of the fish monogenean parasites (Buchmann 1989; Hayward *et al.*, 1998; Hagrais *et al.*, 1995, 2001). El-Naggar and Reda (2003) found that the infestation levels of the monogeneans *Pseudodactylogyrus anguillae* and *Pseudodactylogyrus bini* increase as the fish host, the European eel, *Anguilla anguilla* grows. Similar relationship was demonstrated for the parasite assemblage of the yellow perch, *Perca flavescens* (Zelmer and Arai, 1998), for the monogenean *Enterogyrus cichlidarum* in the white tilapia, *Oreochromis niloticus* (Khidr, 1990) and for the monogenean *Protoancylodiscoides mansourensis* on the longfin catfish, *Chrysichthys auratus* (El-Naggar and Reda, 2003). However, an inverse relationship between monogenean infestation and host size was reported by Shotter (1973), Khidr (1990) and Mashaly (2014). (Hagrais *et al.* 1995 and 2001) reported that medium-sized fish are preferred by monogeneans over immature and aging fish, and correlated this distribution to the marked activity of medium-sized fish, which seems likely to increase the host-parasite contact.

To the best of our knowledge, no previous studies were carried out to compare the monogenean microfauna either between nesting and non-nesting forms or between mating partners of the nesting forms of the Nile green tilapia, *Tilapia zilli*. Hagraš *et al.* (2001) studied the relationship of the host sex and length with the infestation level of nine monogenean species from the gills of two cichlid fish, namely *Oreochromis niloticus* and *T. zilli* from the River Nile and Manzala Lake. However, the authors paid no attention to the ecological and ethological aspects of *T. zilli* during the breeding season as a possible determinant of the monogenean community structure. To fill in this gap, the present investigation was conducted to analyze the monogenean microfauna on the gill of nesting and non-nesting forms of the green tilapia inhabiting Mansouria Canal, Nile Delta, Egypt. The breeding season of the green tilapia commences earlier in April and extends to late August.

The green tilapia, *T. zilli* was chosen because the inspection of the reproductive behaviour and mating tactics, oviposition and nest-guarding duties during the breeding season is simple and direct; the green tilapia spends the spawning period in shallow water, close to the shoreline of Mansouria Canal (i.e. inshore or pelagic fish). Moreover, the monogenean assemblage of the green tilapia is well known (Ergens, 1981; Pariselle and Euzet, 1995; El-Naggar, 1999). Furthermore, the green tilapia is easily caught with rod and line during the breeding season; they seldom leave their nests and furiously defend their eggs/juveniles against intruders.

Monogeneans of the cichlid hosts provide an ideal model to clarify the relationship between the host factors and the parasite load. First, cichlidogyrid and scutogyrid monogeneans attain direct and simple life cycle

and can build up regular populations within a brief time (El-Naggar and Khidr, 1985, 1995; Flores-Crespo and Flores, 2003). Second, cichlidogryid and scutogryid monogeneans have been regarded as bioindicators of water pollution (for example, Sanchez-Ramirez *et al.*, 2007). The null hypothesis to be tested assumes that: (1) nesting and non-nesting forms of the green tilapia are opened unequally to the monogenean infestation, where the nesting forms undergo an immunosuppression and marked fatigue due to the nesting activities (Pickering, 1977), (2) males and females of the green tilapia accommodate an identical monogenean load, where both sexes share an identical environment, and (3) small-sized, and perhaps younger, hosts have fewer monogenean worms than large-sized ones, which possess more attachment sites and food items (Khidr, 1990; El-Naggar and El-Tantawy, 2001).

Materials and Methods

1. Study Area:

Mansouria Canal is a freshwater stream originating from the River Nile, 100 km south of Cairo (Figure 1A). The canal flows parallel to the Damietta Branch of the River Nile and has a rough length of 200 km, an average width of 50 m and a depth changing from 10 to 15 m. The banks of the canal are rich in vegetation cover (Figures 1B and 1D). Many trees growing on the banks of the canal are occupied by the resident Cattle Egret, *Bubulcus ibis* (Figure 1C) that deteriorates the underlying aquatic habitat patches through its characteristic whitish, repellent feces. The study area is the sector of Mansouria Canal nearby Salaka Village, Mansoura City, Nile Delta, Egypt (Figure 1A). The length of the investigated shoreline measures about 2 km. The macrofauna of Mansouria Canal is dominated by a variety

of freshwater fish and native birds. The common fish species includes the Nile green tilapia (*Tilapia zilli*) Gervais 1848 (Figures 2A, 2B, 3A and 3B).

2. Biotic (host) parameters:

Host total length from nose to end of the tail fin, was recorded for each host individual. Fish were discriminated into males and females according to the external genitalia and internal sex organs (testis in male and ovary in female). The condition factor (CF) is a measurement of the general health condition of fish and an indicative of environmental quality. CF is used to compare the growth parameters of fish and is calculated as the ratio of the body weight to body length. According to Fulton (1904), the standard weight of a fish is proportional to the cube of its length. As fish grow in length, they increase in weight. The relationship between length (L) and weight (W) is not linear, and is expressed by the following equation: $K = 100 (W \text{ in grams} / L^3 \text{ in centimeters})$ (Richter *et al.*, 2000). Three classes of the condition factor were designed, namely condition factor - I (from 0.5 to 1.9), condition factor - II (from 2 to 3.4) and condition factor- III (from 3.5 to 4.7). The breeding forms of the green tilapia displayed marked colouration than their conspecifics (Figures 2A and 2B). The breeding forms exhibited pronounced nesting activities, for example digging spawning pits (Figure 3A) and parental care (Figure 3B).

3. Collection of the monogenean parasites

Records were made of the number of monogenean worms on male and female host individuals, length and weight classes and categories of the condition factor of the breeding and non-breeding forms of the green tilapia. The gills were removed and placed in 1:4000 formalin/water (Kritsky *et al.*, 1986). Cichlidogyrid monogeneans were brushed from the gills and

identification was based on comparison of the copulatory structures and measurements of sclerotized hamuli, hooks, and connective bars of the haptor. Identification of the monogenean fauna was performed according to Ergens (1981). To remove monogenean worm off their microhabitats on the gills of the fish host, a sharp needle was inserted gently underneath the firmly anchoring haptor; then, the worms were dislodged individually and directed to the glass bottom of the dish. Monogenean worms were then transferred into a drop of water on a clean glass slide, and pressed and flattened gently under a coverslip to clarify the characteristic features of the monogenean species. The latter comprise the haptoral sclerites (massive hamuli and tiny marginal hookets), copulatory apparatus and sclerotized vaginal tube. Draws were made of these species-specific sclerites with the aid of Camera Lucida and high-power Leitz-Labroux Light microscope.

4. Morphological and morphometric variations in monogenean species:

Monogene identification was based on comparison of copulatory structures and measurements of sclerotized hamuli, hooks, and connective bars of the haptor. Cichlidogyrid monogeneans were identified according to Ergens (1981). The methods of measurement followed the dimensions suggested by El-Naggar (1999). As shown in Figures 4, 5, 6 and 7, each monogenean species attains a characteristic design of the copulatory organ and supporting accessory sclerites, in addition to the distinctive measurements of the haptoral sclerites.

Cichlidogyrus halli typicus recorded the largest size among the studied monogeneans: total length = 860 (850-910) μm , maximum breadth = 240 (230-270) μm , while *Cichlidogyrus tilapiae* attained the smallest size:

total length = 400 (380-460) μm , maximum breadth = 100 (90-120) μm . The dorsal hamuli of the monogeneans *C. arthracanthus*, *C. halli typicus*, *C. aegypticus* and *C. tilapiae* measured 34, 52, 23 and 38 μm , respectively. However, the ventral hamuli of the above mentioned monogeneans measure 30, 60, 25 and 30 μm , respectively. The copulatory complexes of *C. tilapiae* and *C. halli typicus* are obviously simple than those of *C. arthracanthus* and *C. aegypticus* (Figures 4A, 5A, 6A and 7A). In *C. aegypticus*, the additional accessory sclerite comprises relatively thin and flattened piece provided with serrated distal area (Figure 6A). However, the main (primary) accessory sclerite is massive and irregular in shape (total length = 25 μm). Unlike *C. halli typicus* and *C. aegypticus*, *C. arthracanthus* possesses obviously long and coiled, thin copulatory tube (Figures 4A, 6A and 7A).

The orientation and morphology of the hamuli and hooklets of the monogenean *C. tilapiae* resemble the corresponding features of the congeneric *C. halli typicus* and *C. aegypticus*, however the core monogenean *C. arthracanthus* is characterized by two large, first marginal hooklets. Unlike *C. aegypticus* that possesses well sclerotized and widened vaginal tube (Figure 6B), and *C. arthracanthus* that have lightly sclerotized vaginal tube, the monogeneans *C. halli typicus* and *C. tilapiae* have no sclerotized vaginal tube. Moreover, the marginal hooklets of *C. aegypticus* are larger than those of *C. tilapiae*, *C. halli typicus* and *C. arthracanthus*. Another distinctive feature of *C. tilapiae* is the U-shaped ventral bar (60 μm in total length) (Figure 5B).

5. Calculation of the infection variables

Ecological terms (prevalence, mean intensity and abundance) used in the present study are in accordance with Margolis *et al.* (1982). The authors described the prevalence as the percentage of infection: $P = (\text{the number of fish infected by a monogenean species} / \text{the number of fish examined}) \times 100$. Mean Intensity (MI) = the number of worms of a monogenean species divided by the number of fish infected by this species. Abundance (A) = the number of worms of a monogenean species divided by the number of fish examined. The prevalence (percentage of infection) was employed to determine the core, common, secondary and satellite monogenean species. The following division was proposed: core species (more than 60%), common species (between 40 % and 60%), secondary species (between 15% and 40%) and satellite species (less than 15%).

6. Statistical analysis

All data were tabulated as (Mean \pm SD). Variations of the prevalences, mean intensities and abundances of the monogenean species on different categories of the condition factor of the green tilapia were tested using the parametric Analysis of Variance: One-way ANOVA test on SPSS package (version: 20). Informative output of the One-way ANOVA test was followed by further statistical analysis, namely Tukey Honestly test localize the significance among analyzed categories of the condition factor. Probability values ≤ 0.05 were designed as significant, those ≤ 0.01 as highly significant, ≤ 0.001 as very highly significant, while > 0.05 as non-significant.

Results

1- Host sex and monogenean infestation:

As shown in Table (1), the prevalence, mean intensity and abundance of *C. arthracanthus* are higher on males and females of the breeding forms than those on their conspecifics of the non-breeding forms. Regarding the non-breeding forms, *C. arthracanthus* was completely absent during May and June from the male and female fish host (Table 1). The parasite showed the same mean prevalence on the breeding males (60.00 ± 21.21) and females (60.00 ± 18.71) of *T. zillii*. On the other hand, the mean prevalence of the parasite was slightly higher on the non-breeding males (20.00 ± 18.71) than females (13.50 ± 13.87). However, the mean intensity values of *C. arthracanthus* were higher on the breeding females than their conspecifics of the breeding males (Table 1). A similar sexual dimorphism was recorded for the abundance of *C. arthracanthus* on the breeding forms of tilapia. However, an opposite trend was recorded for the mean intensity and mean abundance of the parasite between the non-breeding males and females (Table 1).

The mean prevalence, mean intensity and mean abundance values of *C. aegypticus* were higher on the breeding forms than non-breeding ones (Table 2). From Table 2, it is clear that these infection variables attain higher values on males than females in either forms, except for the mean intensity of this monogenean on the breeding forms that exhibits an opposite distribution between the two genders of tilapia. This monogenean was not recorded on the non-breeding female during April, May, June and August; on non-breeding male during May, June and August; and on breeding male tilapia during May (Table 2). The monogenean *C. aegypticus* was not encountered on the gills of the non-breeding females during May, June, July and August; on non-breeding males during May, June and August; on

breeding females during June and August; and on breeding males during May and August (Table 2).

The mean prevalence, mean intensity and mean abundance values of *C. tilapiae* were higher on the breeding forms than non-breeding ones. From Table 3, it is clear that these infection variables attain mostly higher values on males than females in either forms. This monogenean was not recorded on the non-breeding female during April, May, June and August; on non-breeding male during May, June and August; and on breeding female during May (Table 3).

The mean prevalence, mean intensity and mean abundance values of *C. halli typicus* are markedly low as recorded in Table (4). It can be noticed that this monogenean attained low infestation level and was completely absent from the gills the non-breeding males (Table 4). This monogenean was not encountered on the non-breeding female during May, June, July and August; and on breeding female during the same period. The parasite was also absent from the gills of the breeding males during June, July and August (Table 4).

One-way ANOVA test showed very high significant difference in the prevalence of *C. arthracanthus* among the studied groups ($F= 9.394$, $P \leq 0.001$). Further statistical analysis (PostHoc test: Tukey HSD) indicated significant difference between the breeding males and non-breeding males, breeding males and non-breeding females. Similar significant differences were detected by Tukey HSD between the breeding females and non-breeding males as well as non-breeding females. One-way ANOVA test indicated high significant difference of the abundance of *C. arthracanthus* among different forms of the green tilapia ($F= 5.072$, $P \leq 0.01$). Tukey HSD

revealed significant differences in the abundance of *C. arthracanthus* between the breeding females and non-breeding males as well as non-breeding females. A significant difference of the mean intensity of *C. arthracanthus* was also detected among the studied forms of the fish host (One-way ANOVA test: $F= 3.280$, $P \leq 0.05$). Tukey HSD indicated significant difference in the mean intensity of *C. arthracanthus* between the breeding females and non-breeding males as well as non-breeding females of the cichlid host.

The prevalence of *C. aegypticus* showed highly significant difference among different forms of the cichlid host (One-way ANOVA: $F= 7.550$, $P \leq 0.01$). Tukey HSD revealed significant difference in the prevalence of *C. aegypticus* between the breeding females and non-breeding males as well as non-breeding females. Similar significant differences were recorded for the abundance ($F= 4.268$, $P \leq 0.05$) and mean intensity ($F= 3.684$, $P \leq 0.05$) of *C. aegypticus* among the four groups of the fish host. Tukey HSD showed significant difference of the mean intensity and abundance of *C. aegypticus* between the breeding females and non-breeding males as well as the non-breeding females of *T. zilli*. However, the infestation parameters (prevalence, mean intensity and abundance) of the monogeneans *C. tilapia* and *C. halli typicus* did not change significantly among males and females of the breeding and non-breeding forms of the green tilapia inhabiting Mansouria Canal ($p > 0.05$ in all cases).

2- Host condition factor and monogenean infestation:

The prevalence, mean intensity and abundance of different monogenean species on various length and weight (condition factor) classes of the breeding and non-breeding forms of *T. zilli* are shown in Tables 5, 6, 7 and

8. There is a marked difference in the distribution of *Cichlidogyrus arthracanthus* among various classes of the condition factor between the breeding and non-breeding forms of the green tilapia (Table 5). In the breeding forms, *C. arthracanthus* attained the highest prevalence and mean intensity on the condition factor (class II), however the parasite attained peak values on the condition factor (class I) in the non-breeding forms (Table 5). It can be also noticed that this monogenean was not recorded on the condition factor (class III) of the non-breeding forms. As shown in Table 5, the lowest levels of the infection variables of *C. arthracanthus* are found on the condition factor (class III) in the breeding forms of *T. zilli*. This monogenean was completely absent from the condition factor (class I and class II) of the non-breeding forms during May and June, from the condition factor (class I) during June, and from the condition factor (class III) of the breeding forms during April, May, July and August (Table 5).

According to the data presented in Table 6, the monogenean *C. aegypticus* recorded no marked variation in the mean prevalence and mean abundance values between the condition factor (class I and class II) of the breeding forms, however, an obviously higher mean intensity value was recorded on the condition factor (class I). It can be also noticed from Table 6 that this monogenean was not recorded on the condition factor (class III) of the breeding and non-breeding forms of the green tilapia. As shown in Table (6), similar disappearance was recorded for *C. aegypticus* from the condition factor (class I) in the non-breeding forms of tilapia. The infection variables of *C. aegypticus* on the condition factor (class II) of the non-breeding forms are markedly low (Table 6).

According to the data presented in Table 7, the monogenean *C. tilapiae* recorded no marked variation in the mean prevalence, mean intensity and mean abundance values between the condition factor (class I and class II) of the breeding forms. It can be also seen that this monogenean was completely absent from the gills of the host individuals belonging to the condition factor (class III) of the breeding and non-breeding forms of the green tilapia, and from the condition factor (class I) of the non-breeding forms (Table 7).

The infection variables shown in Table 8 indicate that *C. halli typicus* was completely absent from the gills of the host individuals belonging to the condition factor (class III) of the breeding and non-breeding forms, and from the condition factor (class I) of the non-breeding forms of the green tilapia. The mean prevalence, mean intensity and mean abundance values of this monogenean are higher on the condition factor (class I) than that on the condition factor (class II) of the breeding forms (Table 8).

Statistical analysis (One-way ANOVA test) revealed high significant difference in the prevalence of the core monogenean, *Cichlidogyrus arthracanthus* among different categories of the condition factor of the breeding males of *T. zilli* ($F= 7.010$, $P \leq 0.01$). Further statistical analysis (PostHoc Tests: Tukey HSD) indicated significant difference in the prevalence of *C. arthracanthus* between host individuals attaining the condition factors class I and class III as well as class II and class III. One-way ANOVA test also indicated significant difference in the prevalence of *C. arthracanthus* among different categories of the condition factor of non-breeding males of *T. zilli* ($F= 3.728$, $P \leq 0.05$). Tukey HSD Test showed

significant differences in the prevalence of *C. arthracanthus* between host individuals belonging to the condition factors class I and class III.

Unlike the breeding females, the monogenean infestation level varied obviously among different condition factor categories of the non-breeding females. One way ANOVA test showed high significant difference in the prevalence ($F= 5.963$, $P \leq 0.01$), and significant differences in the mean intensity ($F= 5.365$, $P \leq 0.05$) and abundance ($F= 5.063$, $P \leq 0.05$) of *C. arthracanthus* among different categories of the condition factor of *T. zilli*. Further statistical analysis indicated significant differences in the prevalence, mean intensity and abundance of *C. arthracanthus* between host individuals belonging to the condition factors class I and class II as well as class II and class III. Other differences in the infestation level of *C. arthracanthus* on *T. zilli* were non-significant statistically ($p > 0.05$ in all cases). One-way ANOVA test revealed that differences in the infestation levels of the monogeneans *C. aegypticus*, *C. tilapiae* and *C. halli typicus* on different categories of the condition factor of the breeding and non-breeding forms of the green tilapia were non-significant statistically ($P > 0.05$).

Discussion

A survey has been done and a detailed account has been given of the monogenean burden on the breeding and non-breeding forms of the Nile green tilapia (*Tilapia zilli*) from Mansouria Canal during the breeding season which lasts from early April to late August. Two host factors were involved, namely host sex and host size (expressed by the condition factor). Four forms of the green tilapia were studied, namely the breeding males, breeding females, non-breeding males and non-breeding females. The present findings accepted the assumptions of the null hypothesis that nesting and

non-nesting forms of the green tilapia are opened unequally to monogenean infestation, and that males and females of either form acquire similar monogenean load. On the other hand, our data rejected the assumption of the null hypothesis that smaller, and perhaps younger host individuals accommodate lower number of monogenean worms than larger, and perhaps older ones. Both host gender and size showed pronounced effects on the infection variables of the studied monogeneans, particularly the most dominant *Cichlidogyrus arthracanthus*. Moreover, the behavioural aspects of the breeding tilapia seem likely to play a critical role in host susceptibility to parasitic infection.

During the spawning time, the non-breeding males and females of the green tilapia were located in relatively distant, offshore water layers. On the other hand, other forms of *T. zilli*, namely the breeding males and females were resident in the close proximity of the shoreline at Mansouria Canal. The non-breeding forms of the green tilapia prefer deeper, offshore water, characterized by lower temperature, comparatively higher oxygen level and more lotic water currents. Unlike the nesting forms, the non-nesting forms seem likely more protected from the predation and disturbance created by the aggressive organisms dwelling the shoreline. Such habitat variability and associated behavioral patterns could play an important role in determining the infestation level and structuring the monogenean community of *T. zilli*.

Regarding the monogenean infestation level on *T. zilli*, One-way ANOVA test revealed significant differences in the prevalence, mean intensity and abundance of the most dominant monogenean, *Cichlidogyrus arthracanthus* and the secondary monogenean, *C. aegypticus* among

different forms of the green tilapia during the breeding season, with the breeding females being the favorable target and received higher parasite load than other forms. There was significant variation in the monogenean infestation on males of the breeding tilapia than non-breeding males and females, particularly the core monogenean *C. arthracanthus*. Theoretically, different forms of the green tilapia are opened equally to the invading monogenean parasites. However, many abiotic and biotic factors can structure the monogenean populations on different forms of the cichlid host. Among these factors, the behavioral aspects of the host and parasite seem likely to play a critical role in the commencement and propagation of the infestation pattern.

On the one hand, the breeding forms of the green tilapia prefer the shallow, inshore water, characterized by higher temperature, greater light intensity (illumination), lower oxygen level and more lentic water. Moreover, these forms are vulnerable to predation and exploitation by cohabitant organisms that attack the spawning sites at regular intervals, searching for food and/ or nesting site. Concerning the monogenean populations on the breeding (nesting) forms of the green tilapia, the transmission and dispersal of the parasites seem likely to be facilitated by the physical and chemical cues shaping the inshore water. Moreover, there is a closer contact between host mating partners and different stages of the life cycle of monogenean parasites (egg/ oncomiracidium/ immature worm/ mature or adult worm). Such habitat features may facilitate and accelerate egg deposition, egg hatching, and emergence of the oncomiracidium, and ease the host-parasite contact. Chemical cues created in the vicinity of the mating partners are likely enriched by host secretions and waste products of

the relatively quiescent host mates seem likely to promote monogenean egg hatching and host-finding trials of the emerging oncomiracidium that swims passively in more lentic water for a short distance to settle on its preferred microhabitat on the host gills.

Regarding the monogenean populations on the non-breeding (non-nesting) forms of the green tilapia, two different scenarios may be proposed. First, the transmission and dispersal of parasites may be delayed or impeded through the likely insufficient chemical and physical cues created in the vicinity of the offshore habitat which accommodates the non-breeding forms. The dilution effect of deeper, offshore water on the host secretions and waste products may inhibit or delay egg deposition and emergence of the oncomiracidium. Moreover, the free swimming oncomiracidium appears to struggle and actively swims against the full force of the powerful water currents and may be lost before recognizing an appropriate host and establishing on a hospitable microhabitat patch.

Second, the transmission and dispersal of cichildogyrid monogeneans may be promoted in response to the aggregation (shoaling) of the non-nesting males that translocate between the lentic and lotic habitats to compete for mates with resident males. Moreover, the inshore water sectors are fully occupied by adjacent nesting excavations. This crowding over limited vacant niches may facilitate or offer an opportunity for the transmission and dispersal of monogeneans between the two forms of the fish host. It is worth noting that readily infested fish that enter the nesting sites seem likely to spread the infection in its own spawning ground as well as in the neighbouring nesting areas. Another factor which may account for

the difference in the monogenean load between non-nesting forms of *T. zilli* is the fasting habit of the breeding tilapia which may reduce the energetics and weaken the defense mechanisms of the spawning fish and prone them more susceptible to monogenean infestation.

Tombi *et al.* (2014) found that members of the genus *Cichildogyrus* showed no preference for host sex. Similar findings were recorded by Tombi and Bilong Bilong (2004) in the monogeneans *Dactylogyrus simplex* and *D. maillardi* between the males and females of *Barbus martorelli*, and by Le Roux *et al.* (2011) in the monogenean *Cichildogyrus philander* between males and females of *Pseudocrenilabrus philander philander*. However, Tombi *et al.* (2014) found that *Scutogyrus longicornis* is more abundant in males than females. Similar preference of one sex over the other was reported for the monogenean fauna of *Sarotherodon melanotheron* (Blahoua *et al.*, 2009) and for the monogenean fauna of *Tilapia zilli* (Ibrahim, 2012). Akoll *et al.* (2011) reported that more female *Oreochromis niloticus* were infested and harbored comparatively higher numbers of *Cichildogyrus* monogeneans than males. Pickering (1977) showed that the mucous production in mature male brown trout decreases markedly during the breeding season.

Factors or mechanisms contributing to the differences between male and female host individuals in the intense and dynamics of infection pattern and disease propagation are overlapping and complicated. First, male host individuals may be immunosuppressed as a consequence of negative impacts of the hormones androgen (Folstad and Karter, 1992) and testosterone (Zuk and Mckean, 1996) on the host immune functions. Second, male host

individuals may be more susceptible to infection and therefore acquiring more intense levels of parasitism (Moller *et al.*, 1998). Third, male host individuals attain larger body size than conspecific females (Poulin, 1996). More interestingly, male host individuals may harbour larger worms than their female counter parts (Poulin, 1996; Zuk and Mckean, 1996). According to Yoon (1998), the monogenean *Entobdella hippoglossi* attained higher infestation level on females of the Atlantic halibut, *Hippoglossus hippoglossus*. They attributed this finding to the fact that male halibut exhibits active spawning behaviour that minimizes the chance of oncomiracidium host contact or dislodge the parasites off their microhabitats. In the present investigation, male host individuals were lightly infected than females, particularly in the breeding forms of *T. zilli*.

Higher monogenean infestation levels on the breeding female host individuals could be attributed to a composite of fish behavioral aspects, which include relatively immovable body, obvious adherence to the muddy substrate, prolonged fasting, stress-induced conflict against intruders, egg laying and intensive care of the egg clusters and body weight loss over the spawning course. Comparatively, the breeding males seem likely less stressed than females where they defend the marginal area of the nest and paid little attention to the aggressiveness displayed by intruders. Apart from their larger body sizes, breeding males received fewer, but non-significant number of monogenean worms indicating that their behavioural aspects and spawning-related duties may be the key factor regulating the structure of their monogenean populations. However, some physicochemical environmental parameters such as light intensity, water depth, pollution and level of eutrophication can shape the monogenean populations on the nesting

tilapia. Host fecundity and shoaling can shape the life history and dynamics of the parasite population (Granovitch *et al.*, 2009; Hanson and Stallsmith, 2013).

Bartoli *et al.* (2000) investigated the relationship between the acquisition of the helminth parasites *Genitocotyle mediterranea*, *Lecithaster stellatus* and *Macvicaria alacris* and behavioural aspects of the labrid fish, *Symphodus ocellatus* and demonstrated that these helminthes exhibit similar physiological and nutritional needs and motivated similar pathological impacts. Out of 176 worms belonging to *G. mediterranea*, 141 (80.1%) were collected from terminal males that represented only 14% of the studied host population (Bartoli *et al.*, 2000). The authors attributed the higher infection level on male host individuals to the design and infrastructure of the spawning nest, which was designed with vegetation collected by terminal males, in order to build a new niche in the environment. Additional nests designed by males were colonized by some invertebrates that contributed to the transmission of *G. mediterranea* in the vicinity of the nest.

Attir *et al.* (2017), working on the cichlidogyrid monogenean *Cichlidogyrus cubitus* from *Tilapia zilli* in North West Africa, showed that male fish were more parasitized than females. Ejere *et al.* (2014) encountered more monogenean worms on cichlid females than males in the tropical river Warri (Nigeria). Simkova *et al.* (2005) attributed the high infestation in female fish hosts to the spawning tactics of this gender; they estimated a positive relationship between abundance of the monogenean *Gyrodactylus* and either the gonad mass or gonadosomatic index in female hosts. Definitely, these findings indicate that female fish are more vulnerable to monogenean

infestation at times of higher reproductive venture. This supports the hypothesis that the life cycle of a monogenean might be harmonized with the commencement of the reproductive cycle of the host. According to Attir *et al.* (2017), increased susceptibility of male fish to parasites may be contributed to the suppression of their immune response by the male sex hormone, namely testosterone.

Rohlenova and Simkova (2010) showed that spawning males of the cyprinid fish *Leuciscus cephalus* were more susceptible to helminth parasites and attained minor spleen scope as a result of a reduction in the efficacy of immune responses induced by some steroids. These indications are verified by many investigations (e.g. Gbankoto *et al.*, 2001; Goselle *et al.*, 2008; Ibrahim *et al.*, 2010; Uhuo *et al.*, 2014). Rohlenova and Simkova (2010) concluded that the abundance of monogenean parasites in *L. cephalus* exhibited relatively high levels in the pre-breeding time, thereafter declined over the breeding period, and terminally modified to highest burden during post-breeding time.

The digging activity, primarily practiced by female tilapia to excavate the muddy ground during nest construction, may play a role in shaping the monogenean community of *T. zilli*. By withdrawing and releasing sediment particles, mating partners make their monogenean assemblage in direct contact with abiotic and biotic components of the muddy substrate. The latter may be contaminated with heavy metals, organic compounds and/or stages of the parasite life cycle. Monogenean eggs deposited on, or swept to, the muddy substrate may be engulfed to settle on the gill microhabitats of the nesting forms of *T. zilli*. Larval stages of the oviparous monogenean,

namely oncomiracidia that swim freely nearby the bottom of the stream may have a greater opportunity to invade the gills during mouth-sediment contact. Moreover, abundant host chemical cues in the vicinity of newly established nests may promote the oncomiracidial swimming activity to find its specific host. However, nest construction may pose deleterious impacts on previously implanted worms on the gills; the coarse particles of the sediment may exert relative friction and sweep monogenean worms off their attachment loci. Also, sediment microfauna may alter the environment shaping the host-parasite system.

Morales-Montor *et al.* (2004) reviewed the relationship between host gender and parasitic invasions and correlated this association to molecular and cellular mechanisms of the host and parasite. The authors added that the host exerts direct impacts on the physiological processes of the parasite. They highlighted the gap of knowledge about the immune profiles of the host under different circumstances. Million *et al.* (2017) studied the possible effects of the monogenean gill parasite *Aethycteron moorei* on the reproductive ecology of *Etheostoma flabellare* and found no marked correlation between the parasite burden and size of the host. They also found that male hosts acquired higher number of worms than females.

According to Barber *et al.* (2000) and Lafferty (2008), fish parasites have the potential to alter the host occurrence, physiology, behavioural responses and physical condition. Jones *et al.* (1999) suggested that length and mass relation acts as an indicator of the general fish health and assumed that heavier individuals of a particular length class are ranked in a higher physical condition. Lagrue and Poulin (2015) calculated the body condition of the common bully, *Gobiomorphus cotidianus* inhabiting some New

Zealand lakes. The authors compared two data sets: body condition of the common bully loaded with helminth parasites and body condition of host conspecifics free of the helminth fauna and found positive correlation between the parasite load and fish body condition indices when the mass of parasites was included. However, no correlation was evident between the parasite load and fish body condition when the mass of parasites was omitted (Lagrue and Poulin, 2015). The authors recommended that parasite mass should not be involved in fish mass when estimating body condition indices. Lemly and Esch (1984) and Santoro *et al.* (2013) assumed that heavily parasitized host individuals become thinner than lightly or non-infected conspecifics, considering that the histopathological impacts, physiological alterations and behavioural changes increase when the infection becomes more intense. At the level of individual fish, the parasite mass becomes significant only in the host-parasite systems where large-sized parasites exploit small-sized fish (Lagrue and Poulin, 2015).

It is worth noting that a broad spectrum of parasites have smaller and weaker bodies than their preferred hosts (Kearn, 1998; El-Naggar, 1999). Monogenean parasites on fish hosts represent an ideal example of tiny worms grazing over plentiful and renewable host resources. For example, the total length of a cichlidogryid monogenean on tilapia does not exceed few hundred microns, however their gill microhabitats largely overestimate their requirements for food, shelter and reproduction.

In the present study, higher monogenean infestation levels were recorded on host individuals acquiring lower condition factor. In contrast, host individuals belonging to the condition factor-III were free or almost free of monogenean worms. These findings indicate a possible effect of

monogenean infestation on the physical condition and general health status of fish. However, the lifestyle and behavioural aspects of the monogeneans parasites should be considered. First, monogeneans of the genus: *Cichildogyrus* attain obviously small size (Ergens, 1981; El-Naggar, 1999). Second, the meals drawn by these tiny organisms are limited and may not seriously alter the body condition of the green tilapia. Third, the number of monogenean worms (337) encountered on the cichlid host (150 individuals) seems likely to reflect a light infestation pattern.

A positive correlation between the host length and weight of the piscine hosts and their monogenean microfauna has been reported by El-Naggar and Reda (2003) in *Protoancylodiscoides mansourensis* from the longfin catfish *Chrysichthys auratus*, by Buchmann (1989) in *Pseudodactylogyrus anguillae* and *Pseudodactylogyrus bini* from the European eel *Anguilla anguilla*, and by Khidr (1990) in *Enterogyrus cichlidarum* from the white tilapia *Oreochromis niloticus*. Khidr (1990) attributed the higher monogenean burden on the larger, and perhaps older, fish to the greater surface area available in these individuals. Long-term existence of older hosts and frequent exposure to the infective stages of the monogeneans may lead to the accumulation of more and more worms (Khidr, 1990). However, Hagraš *et al.* (1995 and 2001) reported that medium-sized host individuals were more heavily infested than small- and large-sized conspecifics. They contributed such distribution pattern to the marked activity of the medium-sized host individuals and higher breathing attitudes, which may drive more water and increase the opportunities of host-parasite contact. Finally, the physiological aspects associated with the

spawning period may affect the body conditions of the mating partners.

| Month (2016) | Breeding forms | | | | | | Non-breeding forms | | | | | |
|--------------|-----------------|---------------|---------------|-----------------|---------------|---------------|--------------------|---------------|---------------|-----------------|---------------|---------------|
| | Male | | | Female | | | Male | | | Female | | |
| | P (%) | MI | A | P (%) | MI | A | P (%) | MI | A | P (%) | MI | A |
| April | 80 | 3.60 | 3.10 | 90 | 3.10 | 2.80 | 40 | 1.60 | 0.70 | 30 | 1.50 | 0.50 |
| May | 50 | 1.50 | 0.75 | 50 | 10.00 | 5.00 | absent | | | absent | | |
| June | 30 | 2.00 | 0.75 | 60 | 1.30 | 0.80 | absent | | | absent | | |
| July | 60 | 2.20 | 1.40 | 40 | 2.00 | 0.80 | 30 | 2.50 | 0.90 | 25 | 2.00 | 0.50 |
| August | 80 | 4.00 | 3.40 | 60 | 5.50 | 3.60 | 30 | 1.75 | 0.50 | 12.5 | 1.00 | 0.13 |
| Mean ±SD | 60.00 ±21.21 | 2.66 ±1.08 | 1.88 ±1.28 | 60.00 ±18.71 | 4.38 ±3.52 | 2.60 ±1.82 | 20.00 ±18.71 | 1.17 ±1.12 | 0.42 ±0.41 | 13.50 ±13.87 | 0.90 ±0.89 | 0.23 ±0.26 |

Further investigations are required to clarify such relationship.

Table (1). Monthly values of the infestation level of *C. arthracanthus* on males and females of breeding and non-breeding forms of *Tilapia zilli* during the spawning period.

P: prevalence

MI: mean intensity

A: abundance

Table (2). Monthly values of the infestation level of *Cichidogyrus aegypticus* on males and females of breeding and non-breeding forms of *Tilapia zilli* during the spawning period.

P: prevalence

MI: mean intensity

A: abundance

| Month (2016) | Breeding forms | | | | | | Non-breeding forms | | | | | |
|--------------|----------------|------------|------------|--------------|------------|------------|--------------------|------------|------------|------------|------------|------------|
| | Male | | | Female | | | Male | | | Female | | |
| | P (%) | MI | A | P (%) | MI | A | P (%) | MI | A | P (%) | MI | A |
| April | 40 | 2.80 | 1.20 | 30 | 1.60 | 0.50 | 10 | 1.00 | 0.10 | 9 | 2.00 | 0.10 |
| May | absent | | | 50 | 2.00 | 1.00 | absent | | | absent | | |
| June | 37.5 | 1.00 | 0.38 | absent | | | absent | | | absent | | |
| July | 30 | 1.50 | 0.50 | 20 | 2.00 | 0.40 | 10 | 2.3 | 0.20 | absent | | |
| August | absent | | | absent | | | absent | | | absent | | |
| Mean ±SD | 21.50 ±19.97 | 1.06 ±1.17 | 0.42 ±0.49 | 20.00 ±21.21 | 1.12 ±1.04 | 0.38 ±0.41 | 4.00 ±5.48 | 0.66 ±1.01 | 0.06 ±0.09 | 1.80 ±4.02 | 0.40 ±0.89 | 0.02 ±0.04 |

| Month (2016) | Breeding forms | | | | | | Non-breeding forms | | | | | |
|--------------|----------------|------------|------------|--------------|------------|------------|--------------------|------------|------------|-------------|------------|------------|
| | Male | | | Female | | | Male | | | Female | | |
| | P (%) | MI | A | P (%) | MI | A | P (%) | MI | A | P (%) | MI | A |
| April | 40 | 2.50 | 1.07 | 50 | 1.80 | 0.90 | 20 | 1.50 | 0.40 | absent | | |
| May | absent | | | 50 | 2.00 | 1.00 | absent | | | absent | | |
| June | 12.5 | 1.00 | 0.13 | 40 | 2.00 | 0.80 | absent | | | absent | | |
| July | 9 | 2.00 | 0.18 | 20 | 2.00 | 0.40 | 7 | 1.00 | 0.07 | 25 | 2.00 | 0.50 |
| August | 30 | 1.40 | 0.50 | 30 | 1.00 | 0.30 | absent | | | absent | | |
| Mean ±SD | 18.30 ±16.30 | 1.38 ±0.96 | 0.38 ±0.43 | 38.00 ±13.04 | 1.76 ±0.43 | 0.68 ±0.31 | 5.40 ±8.71 | 0.50 ±0.70 | 0.10 ±0.17 | 5.00 ±11.18 | 0.40 ±0.90 | 0.10 ±0.30 |

Table (3). Monthly values of the infestation level of *Cichidogyrus tilapiae* on males and females of breeding and non-breeding forms of *Tilapia zilli* during the spawning period.

P: prevalence

MI: mean intensity

A: abundance

Table (4). Monthly values of the infestation level of *Cichidogyrus halli typicus* on males and females of breeding and non-breeding forms of *Tilapia zilli* during the spawning period.

P: prevalence

MI: mean intensity

A: abundance

Table (5). Monthly fluctuations of the prevalence mean intensity and abundance of *Cichlidogyrus arthracanthus* on different categories of the condition factor of breeding and non-breeding forms of *Tilapia zilli*.

| Month (2016) | Breeding forms | | | | | | Non-breeding forms | | | | | |
|--------------|----------------|---------------|---------------|---------------|---------------|---------------|--------------------|----|---|---------------|---------------|---------------|
| | Male | | | Female | | | Male | | | Female | | |
| | P (%) | MI | A | P (%) | MI | A | P (%) | MI | A | P (%) | MI | A |
| April | 10 | 1.00 | 0.10 | 10 | 1.00 | 0.10 | absent | | | 10 | 2.50 | 0.40 |
| May | 25 | 5.00 | 1.25 | absent | | | absent | | | absent | | |
| June | absent | | | absent | | | absent | | | absent | | |
| July | absent | | | absent | | | absent | | | absent | | |
| August | absent | | | absent | | | absent | | | absent | | |
| Mean ±SD | 7.00 ±10.95 | 1.20 ±2.17 | 0.27 ±0.55 | 2.00 ±4.47 | 0.20 ±0.45 | 0.02 ±0.04 | — | | | 2.00 ±4.47 | 0.50 ±1.12 | 0.08 ±0.18 |

P: prevalence

MI: mean intensity

A: abundance

| | Month (2016) | Condition factor I | | | Condition factor II | | | Condition factor III | | |
|--------------------|--------------|--------------------|------------|------------|---------------------|------------|------------|----------------------|------------|------------|
| | | P (%) | MI | A | P (%) | MI | A | P (%) | MI | A |
| Breeding forms | April | 80 | 3.82 | 3.38 | 80 | 2.40 | 2.00 | absent | | |
| | May | 50 | 1.00 | 0.50 | 50 | 5.50 | 2.75 | absent | | |
| | June | absent | | | 40 | 1.66 | 0.71 | 50 | 2.00 | 1.00 |
| | July | 70 | 2.20 | 1.57 | 50 | 2.20 | 0.50 | absent | | |
| | August | 80 | 6.16 | 5.28 | 90 | 3.33 | 2.10 | absent | | |
| | Mean ±SD | 56.00 ±33.62 | 2.64 ±2.43 | 2.15 ±2.18 | 62.00 ±21.68 | 3.02 ±1.50 | 1.61 ±0.97 | 10.00 ±22.36 | 0.40 ±0.89 | 0.20 ±0.45 |
| Non-breeding forms | April | 100 | 1.00 | 1.00 | 30 | 1.66 | 0.58 | absent | | |
| | May | absent | | | absent | | | absent | | |
| | June | absent | | | absent | | | absent | | |
| | July | 100 | 3.00 | 3.00 | 20 | 2.28 | 0.64 | absent | | |
| | August | 30 | 1.25 | 0.38 | 20 | 1.00 | 0.28 | absent | | |
| | Mean ±SD | 46.00 ±50.79 | 1.05 ±1.23 | 0.88 ±1.26 | 14.00 ±13.42 | 0.99 ±1.01 | 0.30 ±0.31 | — | | |

Table (6). Monthly fluctuations of the prevalence mean intensity and abundance of *Cichlidogyrus aegypticus* on different categories of the condition factor of breeding and non-breeding forms of *Tilapia zilli*.

| Breeding forms | Month (2016) | Condition factor I | | | Condition factor II | | | Condition factor III | | |
|--------------------|--------------|--------------------|------------|------------|---------------------|------------|------------|----------------------|--------|--------|
| | | P (%) | MI | A | P (%) | MI | A | P (%) | MI | A |
| | | April | 50 | 2.00 | 1.16 | 10 | 4.00 | 1.00 | absent | absent |
| May | 40 | absent | 1.16 | 25 | 2.00 | 0.33 | absent | absent | absent | |
| June | | absent | | | 40 | 1.66 | 0.71 | absent | | |
| July | | 20 | 2.00 | 0.57 | absent | | | absent | | |
| August | | 40 | 1.00 | 0.42 | 30 | 1.66 | 0.50 | absent | | |
| Mean ±SD | | 22.00 ±22.80 | 1.02 ±1.03 | 0.43 ±0.48 | 21.00 ±15.97 | 0.06 ±1.52 | 0.54 ±0.37 | | | |
| Non-breeding forms | Month (2016) | Condition factor I | | | Condition factor II | | | Condition factor III | | |
| | | P (%) | MI | A | P (%) | MI | A | P (%) | MI | A |
| | April | absent | | | 10 | 1.50 | 0.17 | absent | | |
| | May | absent | | | absent | | | absent | | |
| | June | absent | | | absent | | | absent | | |
| | July | absent | | | 12 | 1.33 | 0.16 | absent | | |
| | August | absent | | | | | | absent | | |
| Mean ±SD | | — | | | 4.40 ±6.07 | 0.57 ±0.78 | 0.07 ±0.09 | — | | |

P: prevalence

MI: mean intensity

A: abundance

| | | | | | | | | | | |
|---------------------------|-----------------|--------------------|---------------|---------------|---------------------|---------------|---------------|----------------------|----|---|
| | May | absent | | | 25 | 2.00 | 2.00 | absent | | |
| | June | absent | | | 40 | 1.00 | 0.42 | absent | | |
| | July | 40 | 1.00 | 0.42 | 30 | 1.66 | 0.55 | absent | | |
| | August | absent | | | absent | | | absent | | |
| Mean ±SD | | 16.00 ±21.9 | 0.72 ±1.14 | 0.32 ±0.51 | 21.00 ±15.97 | 1.33 ±0.85 | 0.66 ±0.78 | — | | |
| Non- breeding forms | Month (2016) | Condition factor I | | | Condition factor II | | | Condition factor III | | |
| | | P (%) | MI | A | P (%) | MI | A | P (%) | MI | A |
| | April | absent | | | 10 | 1.00 | 0.11 | absent | | |
| | May | absent | | | absent | | | absent | | |
| | June | absent | | | absent | | | absent | | |
| | July | absent | | | 12 | 2.33 | 0.28 | absent | | |
| | August | absent | | | absent | | | absent | | |
| Mean ±SD | | — | | | 4.40 ±6.07 | 0.67 ±1.03 | 0.10 ±1.32 | — | | |

Table (7). Monthly fluctuations of the prevalence mean intensity and abundance of *Cichlidogyrus tilapiae* on different categories of the condition factor of breeding and non-breeding forms of *Tilapia zilli*.

P: prevalence

MI: mean intensity

A: abundance

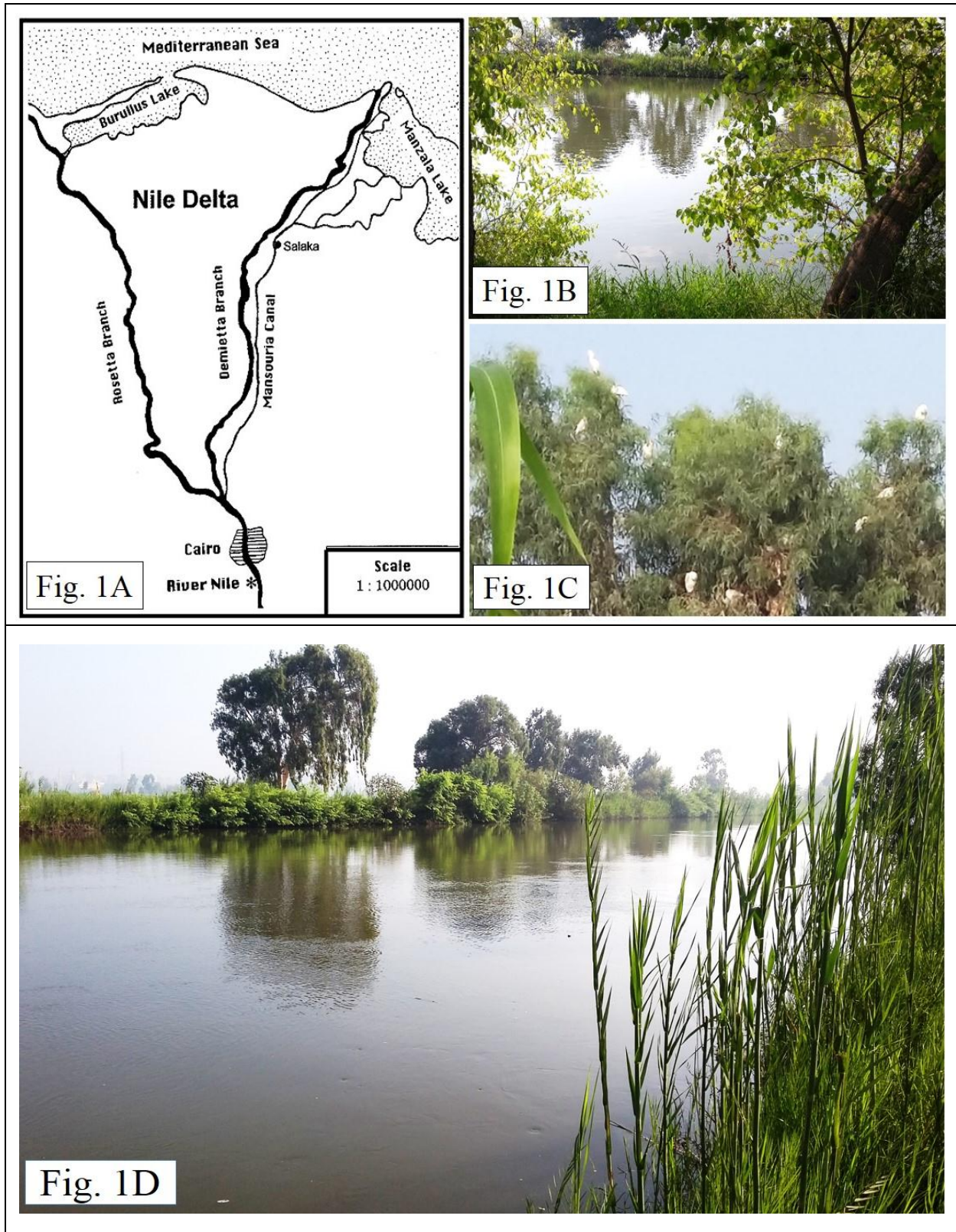
Table (8). Monthly fluctuations of the prevalence mean intensity and abundance of *Cichlidogyrus halli typicus* on different categories of the condition factor of breeding and non-breeding forms of *Tilapia zilli*.

| | Month (2016) | Condition factor I | | | Condition factor II | | | Condition factor III | | |
|--------------------|--------------|--------------------|------------|------------|---------------------|------------|------------|----------------------|----|---|
| | | P (%) | MI | A | P (%) | MI | A | P (%) | MI | A |
| Breeding forms | April | 10 | 1.00 | 0.16 | absent | | | absent | | |
| | May | 50 | 5.00 | 2.50 | absent | | | absent | | |
| | June | absent | | | 20 | 1.50 | 0.42 | absent | | |
| | July | absent | | | absent | | | absent | | |
| | August | absent | | | absent | | | absent | | |
| | Mean ±SD | 12.00 ±21.68 | 1.20 ±2.17 | 0.53 ±1.10 | 4.00 ±8.94 | 0.30 ±0.67 | 0.08 ±0.19 | — | | |
| Non-breeding forms | April | absent | | | 10 | 2.50 | 0.30 | absent | | |
| | May | absent | | | absent | | | absent | | |
| | June | absent | | | absent | | | absent | | |
| | July | absent | | | absent | | | absent | | |
| | August | absent | | | absent | | | absent | | |
| | Mean ±SD | — | | | 2.00 ±4.47 | 0.50 ±1.12 | 0.06 ±0.13 | — | | |

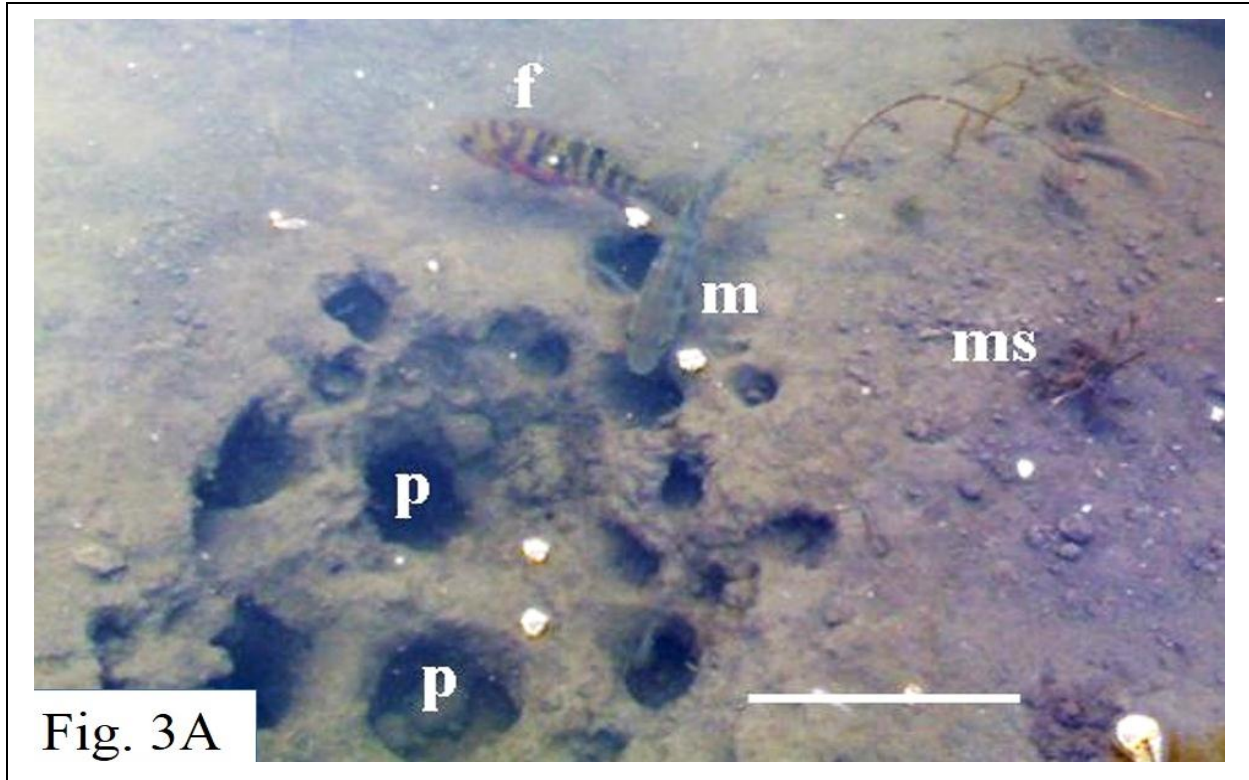
P: prevalence

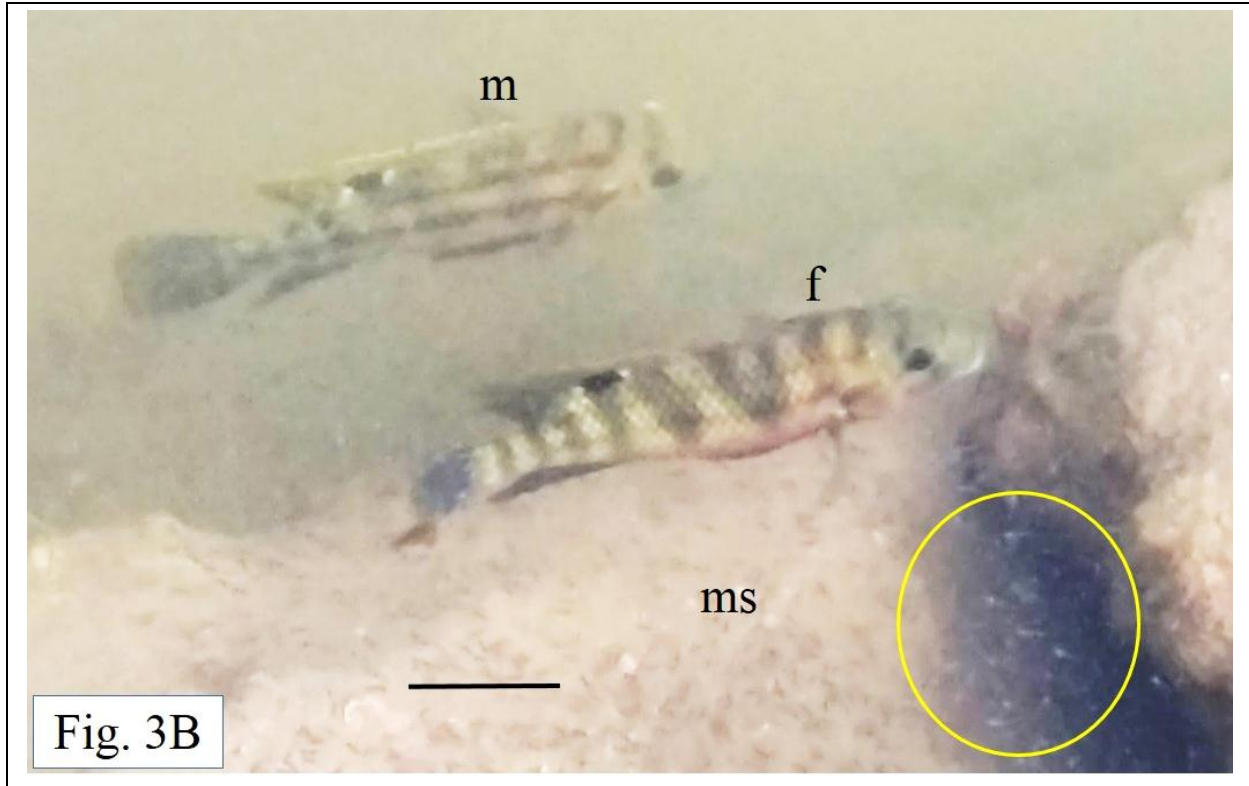
MI: mean intensity

A: abundance









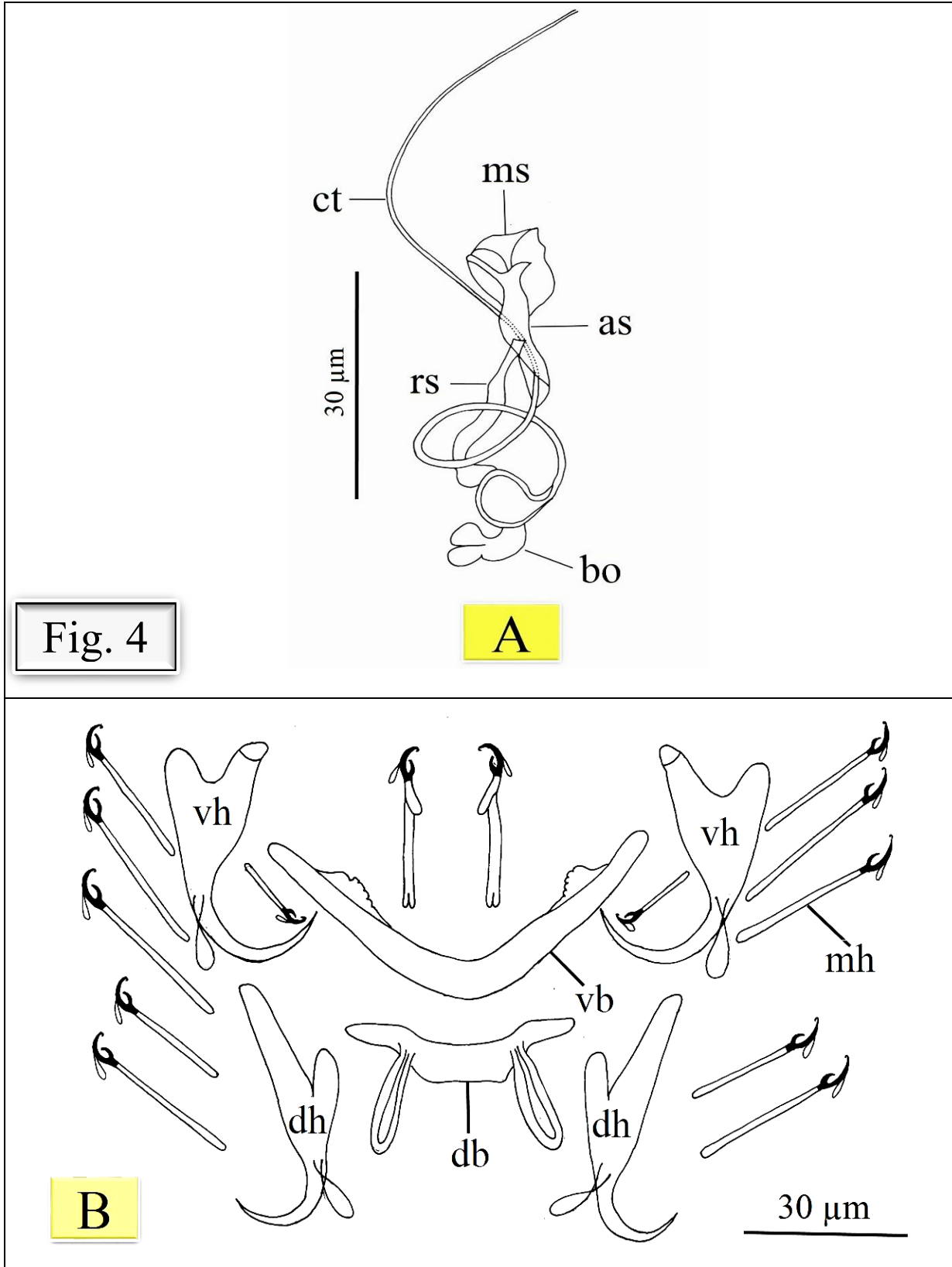
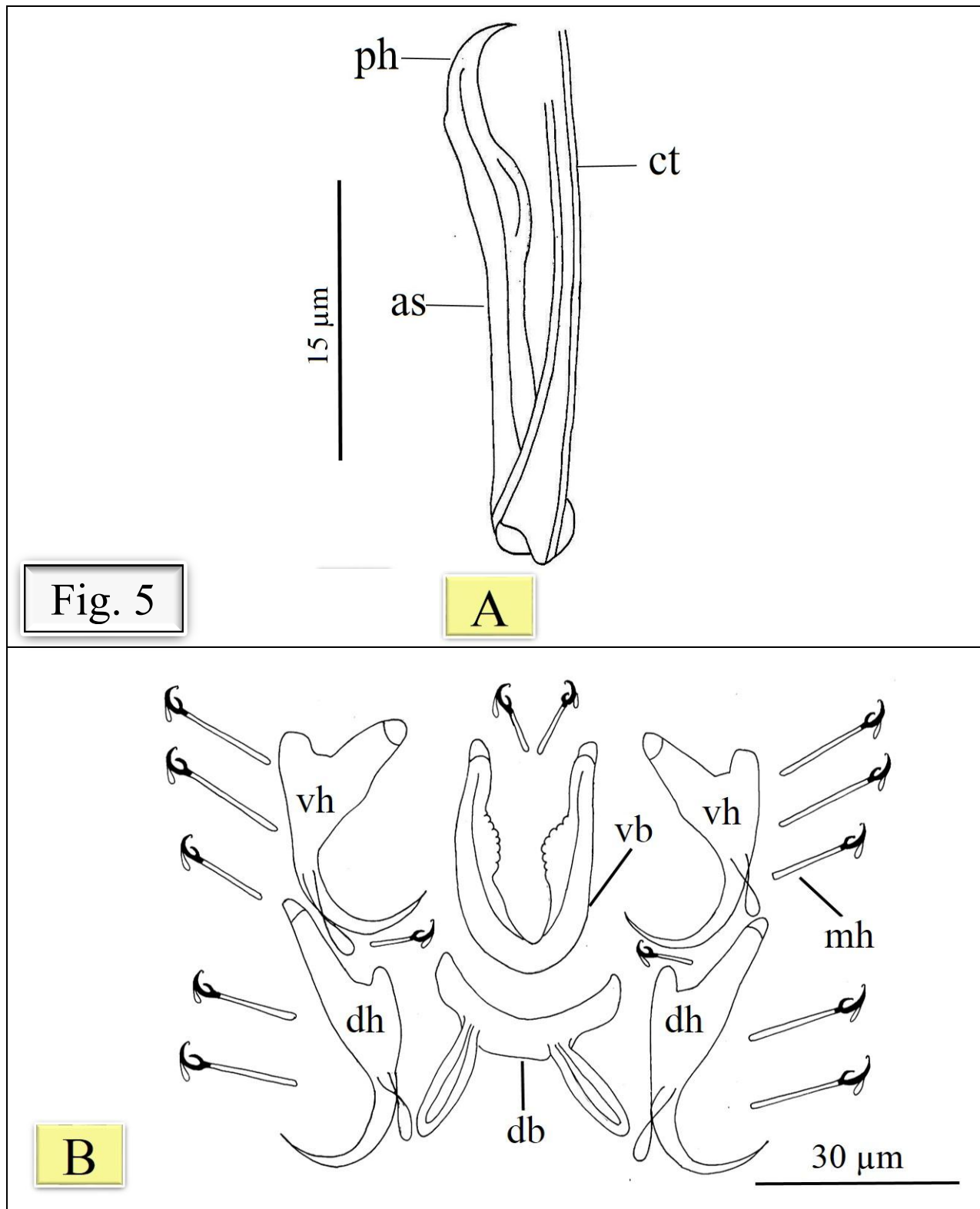
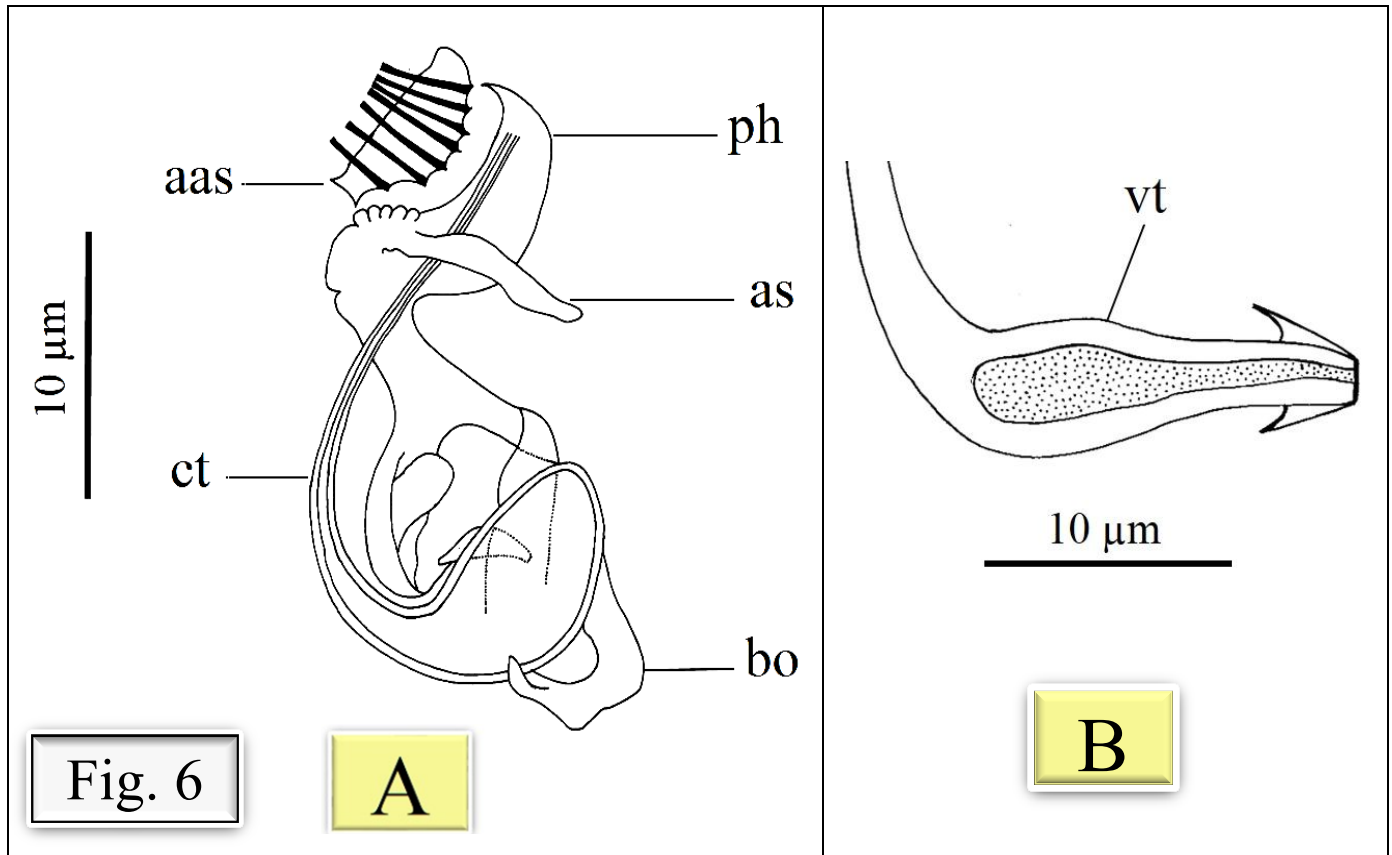


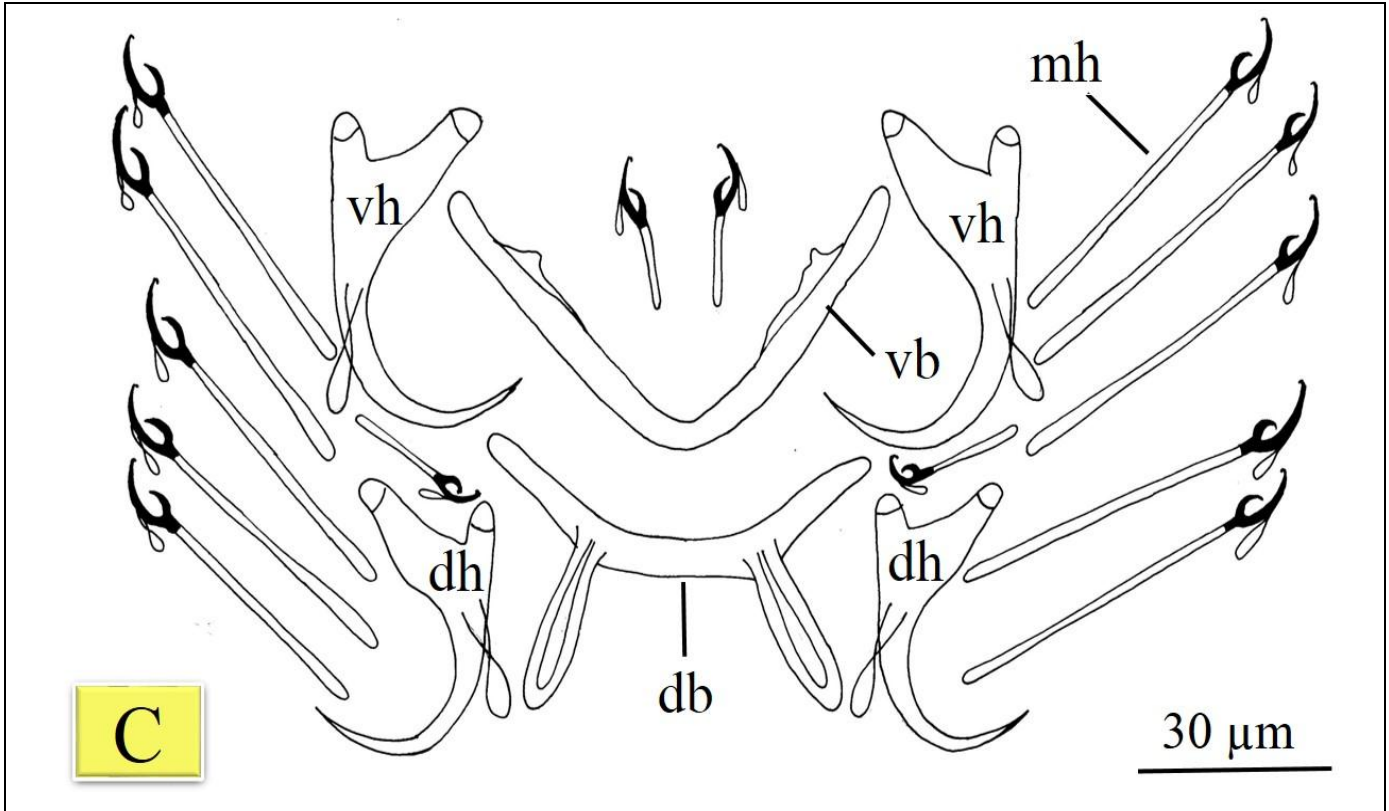
Fig. 4

A

B







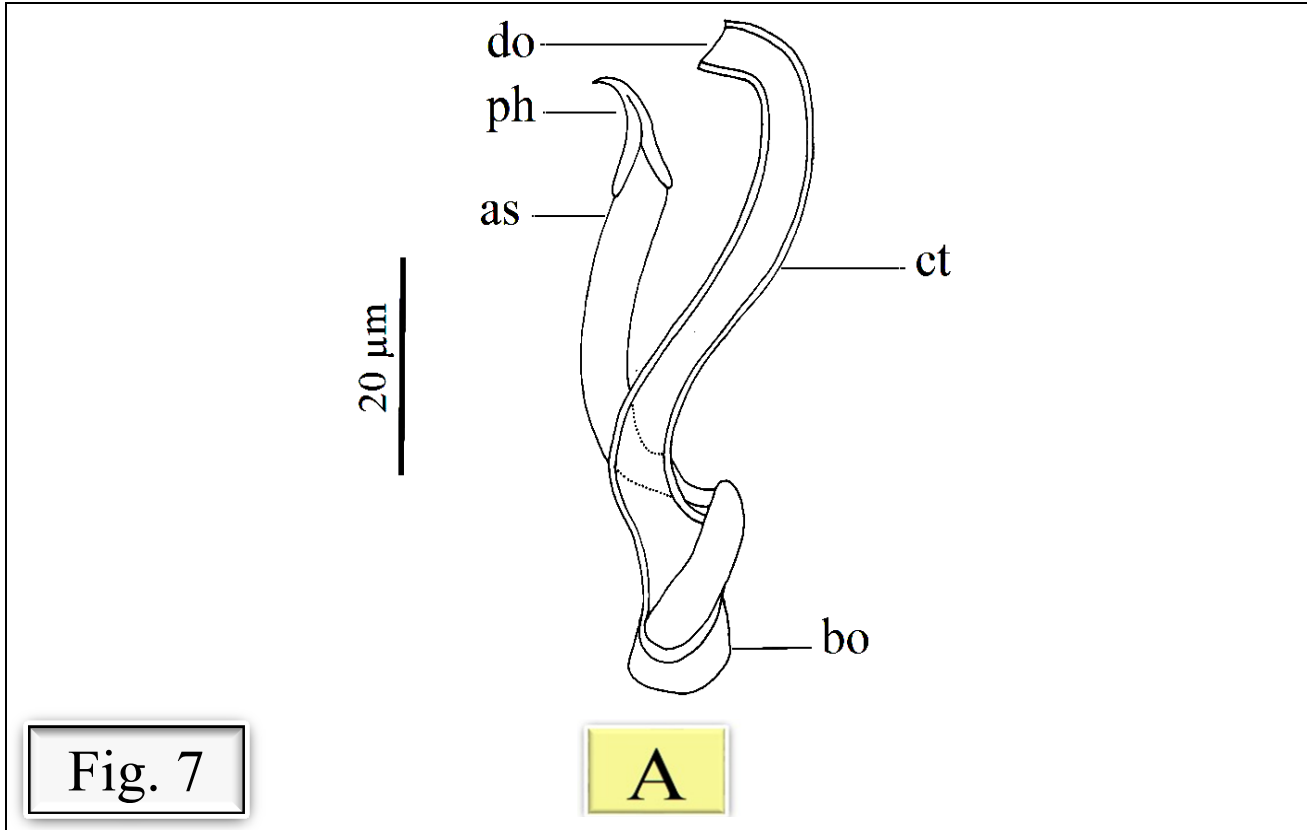
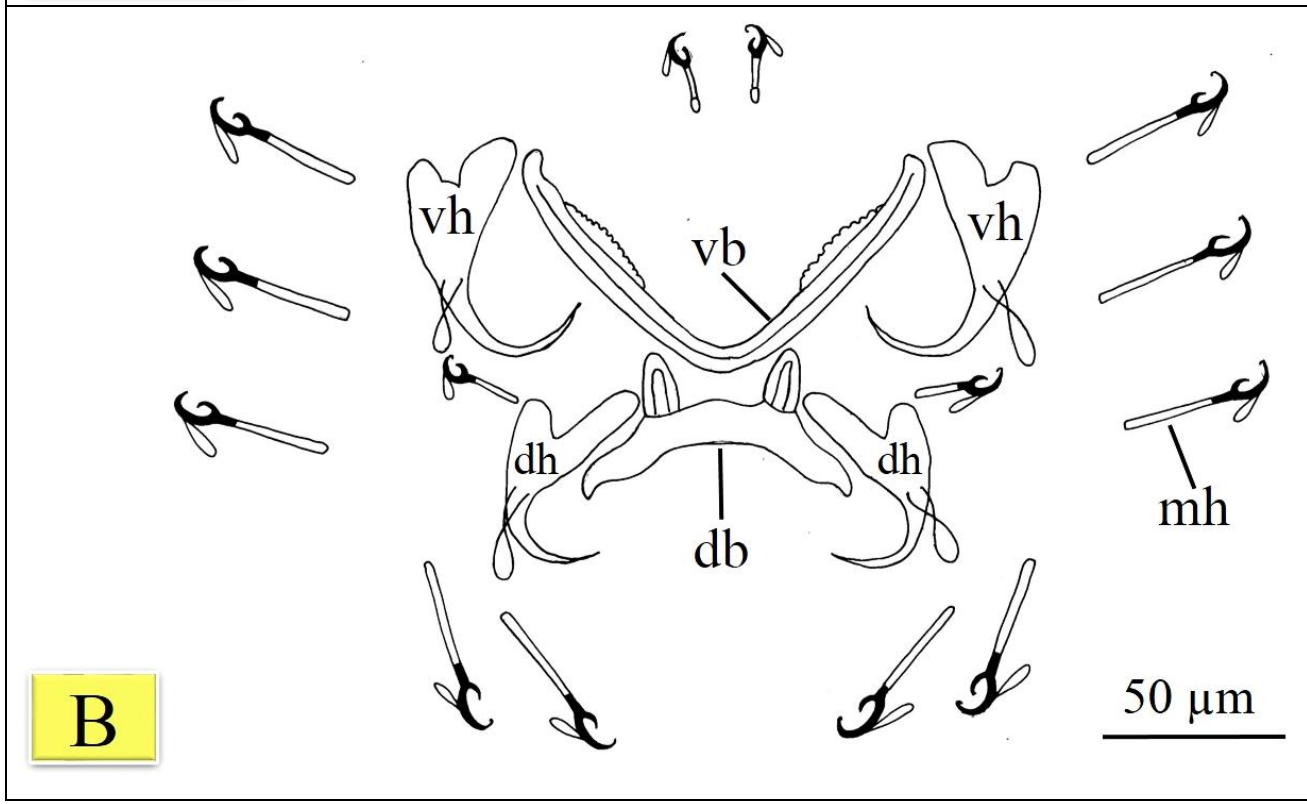


Fig. 7



Explanation of Figures

Fig. 1. Description of the investigation area. A) Map showing the location of Salaka Village at Mansouria Canal, Nile Delta, Egypt. B) Photograph showing the water of Mansouria Canal and the heavy vegetation on the banks. C) Photograph showing abundant vegetation on one of the banks of Mansouria Canal. Note the Cattle Egret nesting on the trees. D) Photograph showing some features (water and vegetation) of Mansouria Canal.

Fig. 2. Photomicrograph showing some morphological differences between non-breeding and breeding forms of *Tilapia zilli*. A) Non-breeding male. Note the light greenish colouration of the body. Scale bar = 35 mm. B) Breeding female. Note the bright red colouration of the throat (hence the name redbelly tilapia) and dark vertical bands on the body that gains yellowish colouration. Scale bar = 40 mm.

Fig. 3. Photomicrograph showing nesting forms of *Tilapia zilli*. A) Breeding male and female on muddy substrate. Note that the male sometimes defends the central area of the nest for a brief time. Note that this nest comprises 4 large-sized pits, 4 medium-sized pits and some small-sized and shallow pits. Scale bar = 150 mm. B) Breeding male and female securing their newly hatched larvae (yellow circle). Note that the female adheres to her offspring, whereas the comparatively larger male defends the periphery. Scale bar = 38 mm. f, female; m, male; ms, muddy substrate; p, spawning pit.

Fig. 4. Schematic drawing showing the hard sclerites of *Cichlidgyrus arthracanthus*. A) Copulatory organ. Scale bar = 30 μ m. B) Haptoral sclerites. Scale bar = 30 μ m. as, assessor sclerite; bo, basal outgrowth; ct, copulatory tube; db, dorsal bar; dh, dorsal hamulus; mh, marginal hooklet;

ms, membranous sclerite; rs, rod-like sclerite; vb, ventral bar; vh, ventral hamulus. Modified from Ergens, 1981.

Fig. 5. Schematic drawing showing the hard sclerites of *Cichlidgyrus tilapiae*. A) Copulatory organ. Scale bar = 15 μm . B) Haptoral sclerites. Scale bar = 30 μm . as, assessor sclerite; ct, copulatory tube; db, dorsal bar; dh, dorsal hamulus; mh, marginal hooklet; ph, pointed hook; vb, ventral bar; vh, ventral hamulus. Modified from Ergens, 1981.

Fig. 6. Schematic drawing showing the hard sclerites of *Cichlidgyrus aegypticys*. A) Copulatoregan. Scale bar = 10 μm . B) Vagina tube. Scale bar = 10 μm . C) Haptoral sclerites. Scale bar = 30 μm . aas, additional accessory sclerite; as, assessor sclerite; bo, basal outgrowth; ct, copulatory tube; db, dorsal bar; dh, dorsal hamulus; mh, marginal hooklet; ph, pointed hook; vb, ventral bar; vh, ventral hamulus; vt, vaginal tube. Modified from Ergens, 1981.

Fig. 7. Schematic drawing showing the hard sclerites of *Cichlidgyrus halli typicus*. A) Copulatory organ. Scale bar = 20 μm . B) Haptoral sclerites. Scale bar = 50 μm . as, assessor sclerite; bo, basal outgrowth; ct, copulatory tube; db, dorsal bar; dh, dorsal hamulus; do, distal opening; mh, marginal hooklet; vb, ventral bar; vh, ventral hamulus. Modified from Ergens, 1981.

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