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Microhabitat Selection of Ectoparasitic Monogenean Populations of the Nile Catfish, *Clarias gariepinus*

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Abstract

The spatial fluctuations in the monogenean populations of the Nile catfish, *Clarias gariepinus* were investigated during the period from October 2015 to September 2016 in three different water quality environments in the Nile Delta, Egypt. A microhabitat specialization of different monogenean species was detected and showed considerable variations in their site selections from one locality to another. Some monogeneans attained significant preference for particular microhabitats on the gills; however, other monogeneans were randomly distributed on available microhabitats. The monogeneans, *Quadriacanthus aegypticus* and *Macrogyrodactylus clarii* preferred the proximal areas, while *Gyrodactylus rysavyi* preferred the distal area of the gill filaments of the *C. gariepinus* host in all investigated habitats except for *Q. kearni* that inhabited the ventral segment of the gill arches of the catfish host in the three localities. There was a noticeable locality-related variation in microhabitat distribution of the studied monogeneans on the dorsal, middle, and ventral segments of the catfish host. Gill arch II was the most favorable site of attachment for the three *Quadriacanthus* species in all three aquatic habitats and also for *G. rysavyi* in Ammar Drain. In this study, factors influencing population dynamics and those driving ecological interactions of the monogenean microfauna of the catfish host are discussed in detail.

Keywords: Monogenean populations, *Clarias gariepinus*, Aquatic ecosystems.

1. Introduction

Monogeneans are regarded as a highly specific group of fish parasites. These organisms are restricted to a particular host, definite organ, and specific tissue. The gills are vital organs for the survival of the fish and hospitable home for a variety of ectoparasitic monogeneans and ecological equivalents as well. According to Bychowsky (1957), monogeneans are a successful group for probing the adaptation of living organisms, their morphological variations, and association between cohabitants. This type of parasite shows a direct life cycle, and it is narrowly host-specific within species, genus, or family, and can occupy restricted microhabitat(s) on their favorable host(s). Many ecological investigations focused on the relationships of congener taxons (e.g. Kadlec *et al*., 2003, El-Tantawy *et al.*, 2016 and 2018). However, there have been few studies on the ecological interaction between species belonging to two or more monogenean genera as well as between monogeneans and other parasite taxons (e.g. Ramasamy *et al*., 1985; El-Naggar and El-Tantawy, 2003).

The aim of the present study is to investigate and compare the microhabitats of cohabitant monogeneans on the catfish host, and to illustrate the ecological interactions (intraspecific aggregation) among different cohabitant monogeneans of *C. gariepinus*.

2. Materials and Methods

2.1. Area of Investigation

The investigated aquatic habitats are located in the Eastern region of the Nile Delta, Egypt. These ecosystems include:

1. The Damietta Branch of the Nile River in the vicinity of Kafr Al-Tawaila Village, Talkha City, Dakahlia Governorate (31° 7' 31" N, 31° 26' 2" E).
2. Ammar Drain (Drain No. 2): This is one of the largest agricultural drains in the Nile Delta. It terminates nearby the Mediterranean Coast at Gamasa City where waterway stores huge amount of waste released from suburban and agricultural areas (31° 22' 46" N, 31° 29' 23" E).
3. Telbanah Drain: This is a multi-polluted, man-made stream receiving considerable amounts of contaminated water discharged from Dakahlia Spin and Wear Company, Oil and Soap Company, agricultural

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[**] Abbreviations:AS, adhesive sac; ASS, accessory sclerite; B, connecting bar; BP, body proper; CC, cluster of cells; CO, copulatory tube; D, diverticula; DB, dorsal bar; DH, dorsal hamulus; E1, first generation; H, haptor; HA, hamulus; MH, marginal hoohks; MS, massive sclerite; P, papilla; PH, pharynx; SS, supportive sclerites; U, uterus; VB, ventral bar; VH, ventral hamulus; VT, vaginal tube.

effluents, and domestic discharges. (1°05'00" N, 32°0'48" E).

2.2. Host Collection and Arbitrary Division of the Gills

A total of 989 *Clarias gariepinus* fish specimens were collected from November 2015 to October 2016. The fish was caught by special traps and were then immediately fixed in 10 % formaldehyde, and transferred to the laboratory in appropriate containers. The gill apparatus was dissected and individual gills were surveyed for monogenean parasites. The gill apparatus was divided into two gill sets, namely left and right. Gill arches were separated and numbered in an anteroposterior succession (I, II, III, and IV). Each gill arch was divided into three approximately equal segments in a dorsoventral succession (dorsal, middle and ventral). The gill filaments in each holobranch were divided longitudinally into approximately two equal halves, namely proximal and distal. The position of recorded monogeneans is shown as a schematic drawing of the gill arch in Figure1.

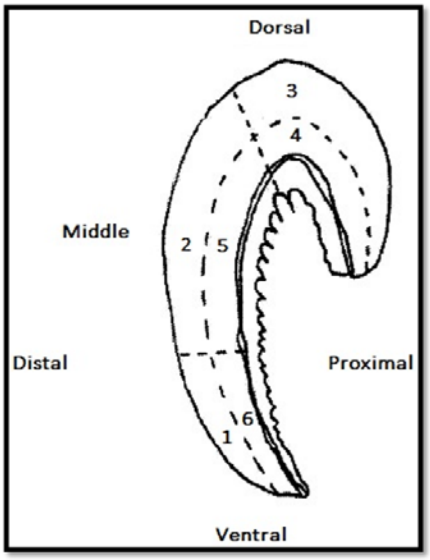

Figure 1. Illustration of gill arch showing its division into six arbitrary area: 1. distal-ventral, 2.distal-middle, 3.distal-dorsal, 4.proximal-dorsal, 5. proximal-middle, 6.proximal-ventral.

Each gill arch (holobranch) was divided into two hemibranchs, namely anterior and posterior. Each division was microscopically examined, and the detected monogenean parasites dislodged off from their attachment sites on the gills with the aid of a fine dissecting needle, and different species were discriminated according to their morphometric features. The isolated monogenean worms were identified using Leitz Laborlux 20 EB light microscope. The identification of the collected *Quadriacanthus* monogenean parasites was done according to Paperna (1961) and El-Naggar and Serag (1985, 1986). The monogeneans *Gyrodactylus rysavyi* were identified according to Ergens (1973) while *Macrogyrodactylus clarii* and *M. congolensis* were identified according to Gussev (1961) and Prudhoe (1957) respectively. Light micrographs showing some morphological features of *Q. aegypticus*, *Q. clariadis*, *Q. kearni*, *M. clarii*, *M. congolensis* and *G. rysavyi* are shown in Figures 2-7, respectively.

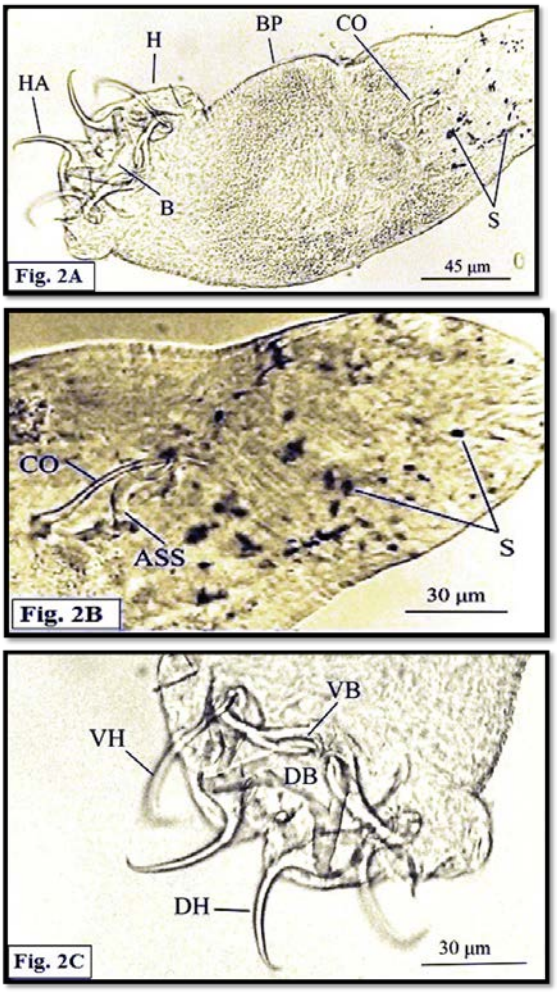

Figure 2.Light micrograph showing some morphological features of *Quadriacanthus aegypticus*. A) Whole mount. Scale bar = 45 µm. B) Copulatory organ. Scale bar = 30 µm. C) Haptoral sclerites. Scale bar = 30 µm.

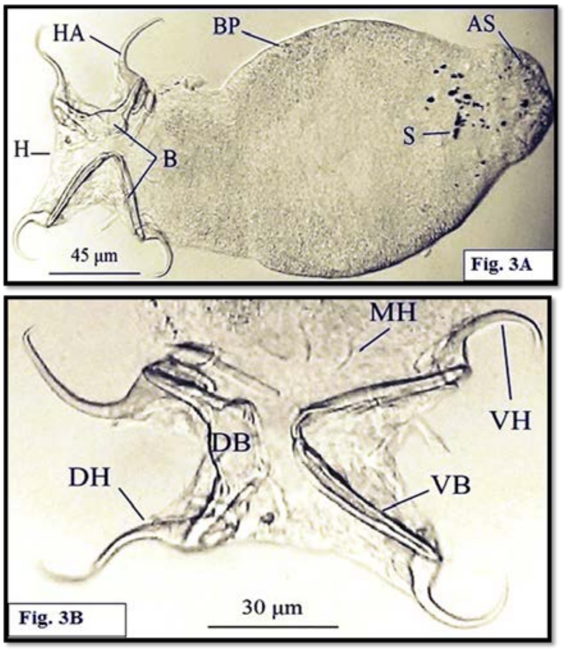

Figure3. Light micrograph showing some morphological features of *Quadriacanthus clariadis*. A) Whole mount. Scale bar = 45 µm. B) Haptoral sclerites. Scale bar = 30 µm.

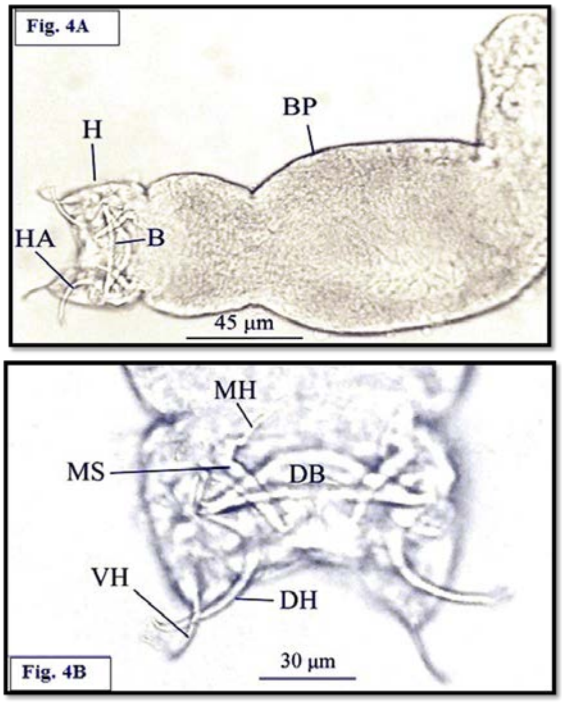

Figure 4. Light micrograph showing some morphological features of *Quadriacanthus kearni*. A) Whole mount. Scale bar = 45 µm. B) Haptoral sclerites. Scale bar = 30 µm.

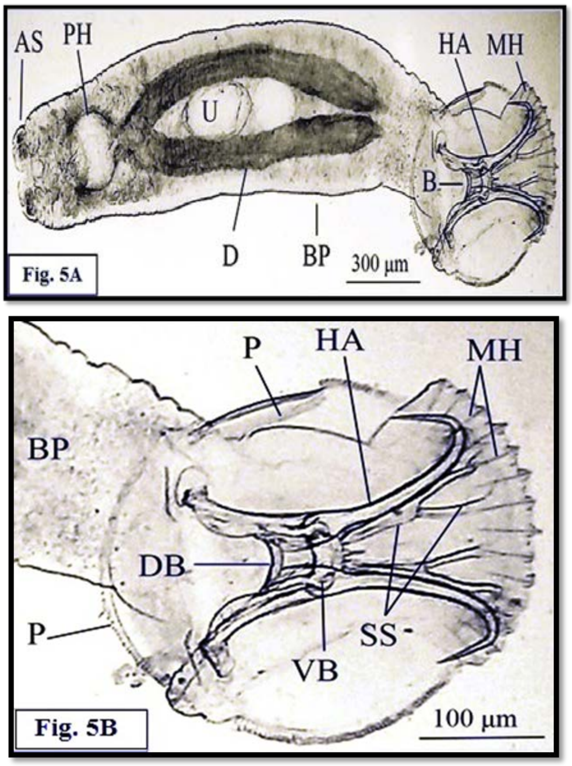

Figure 5. Light micrograph showing some morphological features of *Macrogyrodactylus congolensis*. A) Whole mount. Scale bar = 300 µm. B) Haptoral sclerites. Scale bar = 100 µm.

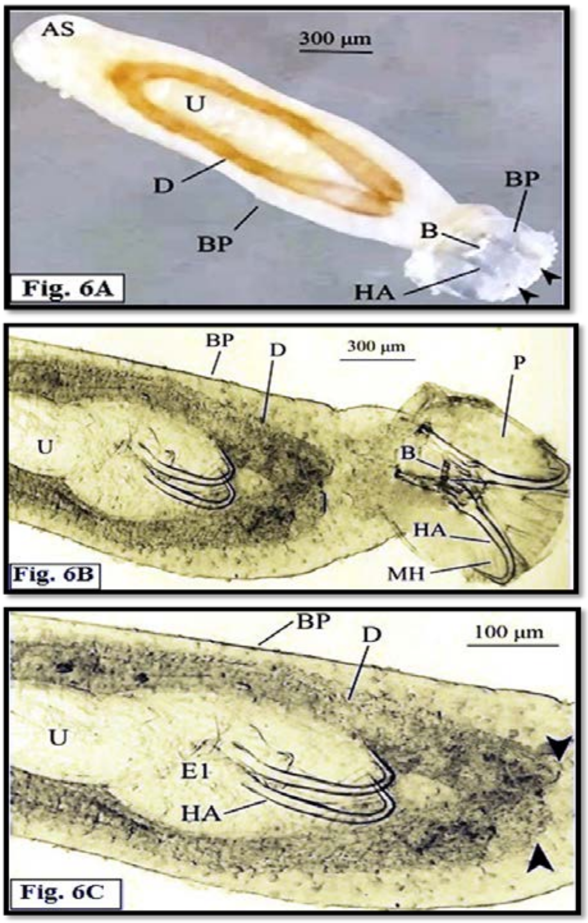

Figure 6. Light micrograph showing some morphological features of *Macrogyrodactylus clarii*. A) Whole mount. Scale bar = 300 µm. B) Posterior region. Scale bar = 300 µm. C) Embryonic load. Scale bar = 100 µm. The arrowheads point to the marginal hooks on the posteriorly projecting flap in Figure 6A and to the blind intestinal limbs (diverticulae) in Figure 6C.

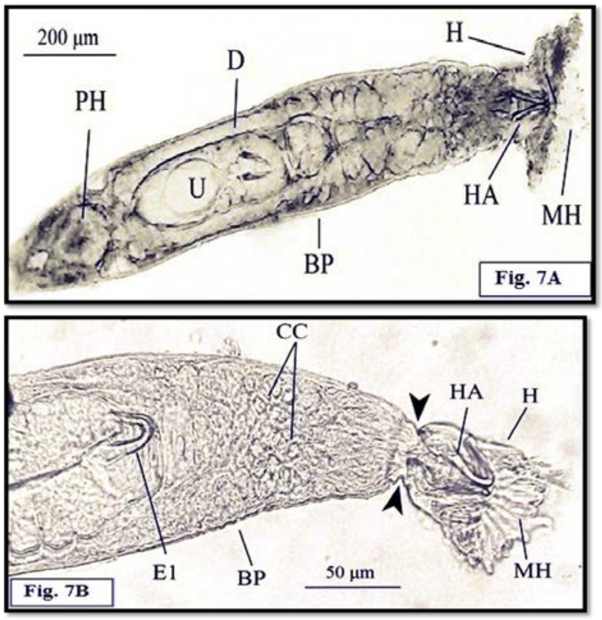

Figure 7. Light micrograph showing some morphological features of *Gyrodactylus rysavyi*. A) Whole mount. Scale bar = 200 µm. B) Posterior region. Scale bar = 50 µm. Note the marked constriction between the body proper and haptor (arrowheads).

The infestation variables (prevalence, intensity, and abundance) of the monogeneans under investigation were calculated according to Bush *et al*. (1997). To survey *Paraquadriacanthus nasalis* and *Gyrodactylus* sp. from the nasal cavities of the catfish host, the anterior dorsal sector of the mouth holding the nasal openings was dissected and kept in an appropriate container. This microhabitat was observed (searched) for monogeneans at the ventral, whitish side, where the internal opening was widened with the aid of a dissecting needle to expose its parasitic load. On the other hand, skin monogeneans on *C. gariepinus* were estimated as a total number on all examined fish/month/locality. Due to their superficial attachment to the surface epithelial layers, macrogyrodactylid and gyrodactylid monogeneans were easily detached during the direct fixation in the field in 10 % formaldehyde, and were transported to the laboratory; only the abundance of skin monogeneans was considered. To isolate the skin monogeneans in each monthly-collected host sample, impurities settled on the bottom of the container were filtered, and the precipitate was transferred to petri dishes containing water to be searched under a stereomicroscope for *M. congolensis* and *G. rysavyi*.

2.3. Ecological Interactions between the Monogeneans of Clarias gariepinus

To estimate the intraspecific aggregation among individuals of a particular monogenean species, a measure of intraspecific aggregation (I) was employed (Ives, 1988 and 1991):

$$I_r = \frac{\frac{V_r}{m_r} - 1}{m_r}$$

Where m_r is the mean number of parasite species, (*r*) individuals per an infested fish, and V_r is the variance in the numbers of parasite species (*r*). The index I_r shows the proportional increase in the number of conspecific competitors experienced by a random individual of species (*r*), relative to a random pattern of distribution.

2.4. Statistical Analysis

All records were represented as mean values. Differences in the distribution of the monogenean species between left and right gill sets, proximal and distal halves of the gill filaments as well as between outer and inner hemibranchs were tested statistically using the Student's *t*-Test on SPSS package (version: 20). On the other hand, differences in the distribution of the studied monogeneans among dorsal, middle, and ventral segments as well as among the four gill arches were tested by the same statistical software using One-Way ANOVA Test. The same test was employed to check for seasonal variations in the prevalence, mean intensity, and abundance of each monogenean species in each ecosystem. Further statistical analysis (PostHoc LSD) was selected to detect the differences between each pair of localities or seasons. Probability (*P*) values ≤ 0.05 were set as significant; those ≤ 0.01 as highly significant, and values ≤ 0.001 as very highly significant; however, *P* values > 0.05 were considered no significant.

3. Results

3.1. Seasonal Population Dynamics of the Monogeneans of Clarias gariepinus

The monogeneans *Quadriacanthus aegypticus (*El-Naggar and Serag, 1986), *Q. clariadis (*Paperna, 1961), *Q. kearni* (El-Naggar and Serag, 1985) and *Gyrodactylus rysavyi* (Ergens, 1973) were recorded throughout the year on catfish from the Nile River, Telbanah Drain, and Ammar Drain. Similarly, *Macrogyrodactylus clarii* (Gussev, 1961) was present on the gills of *C. gariepinus* throughout the year in Ammar Drain; however, it was absent from the host in the Nile River during winter and spring. The congeneric *Macrogyrodactylus congolensis* (Prudhoe, 1957) was found on the skin of *C. gariepinus* at Ammar Drain throughout the year; however, it was not detected on the host during winter and summer at Telbanah Drain and during summer in the Nile River. *Gyrodactylus rysavyi* was only observed on the skin of *C. gariepinus* at Ammar and Telbanaah Drains throughout the year, and during summer in the Nile River. *Gyrodactylus* sp. was found in the nasal cavity of *C. gariepinus* only during autumn at Telbanah Drain and Ammar Drain; however, it was completely absent from the nasal cavity of the catfish host in the Nile River.

3.2. Microhabitat Distribution and Ecological Interactions (Intraspecific Aggregation) of the Gill monogeneans on Clarias Gariepinus

3.2.1. Microhabitat Distribution

Regarding the habitat of the detected monogenea species, the oviparous monogenean *Q. aegypticus, Q. clariadis* and *Q. kearni* were encountered only on the gill filaments and gill lamellae of *Clarias gariepinus*, whereas the viviparous *M. clarii* was found on the gill lamellae, gill rakers, and gill arch. The monogenean *G. rysavyi* occurred on the gills of the catfish host. Tables 1-5 show the percentage of the distribution of *Q. aegypticus, Q. clariadis, Q. kearni, M. clarii and G. rysavyi* respectively on the gills of *C. gariepinus* from the Nile River, Telbanah Drain, and Ammar Drain. As shown from Table 2, the monogeneans *G rysavyi*, *M. clarii* and *Q. kearni* prefer the left gill set than the right one. In contrast, the monogenean *Q. clariadis* showed a preference for the right gill set than the left one.

Quadriacanthus aegypticus occurred at a higher percentage on the outer hemibranch than the inner one (Table 1), this monogenean preferred the proximal over the distal area of the gill filaments of the catfish at the three aquatic habitats (Table 3). *Q. aegypticus* preferred to exist on the middle segment of the gill filaments than the dorsal and ventral ones at Ammar Drain. However, this parasite preferred to exist on the dorsal segment of the gill filaments over the middle and ventral ones in the Nile River and Telbanah Drain (Table 4). This parasite was recorded at the highest percentage of distribution on the second gill arch (holobranch) (Table 5).

Quadriacanthus clariadis was recorded at a higher percentage of distribution on the outer than the inner hemibranch on the gills of *C. gariepinus* inhabiting the Telbanah and Ammar Drains. However, the parasite preferred the inner hemibranch over the outer ones in the Nile River (Table 1). The percentage of the distribution of *Q. clariadis* on the right gill set was higher than that on the left one (Table 2). The percentage of the distribution of this monogenean was higher on the proximal area than the distal one of *C. gariepinus* in the Nile River; however, at Telbanah Drain and Ammar Drain, the parasite exhibited a microhabitat shift and preferentially occupied the distal area. In contrast, *Q. kearni* showed no preference for the proximal over the distal area of the gill filaments of *C. gariepinus*. Similar marked preference for the distal over the proximal area of the gill filaments was obtained for *G. rysavyi* (Table 3).

Table 4 shows that *Q. clariadis* prefers to exist on the dorsal segment of gill holobranch than the middle and ventral ones in the Nile River, but prefers to exist on the middle segment at Ammar Drain and Telbanah Drain. The highest percentage of the distribution of *Q. clariadis* was estimated on the second gill arch in all studied environments (Table 5). A similar preference for the second gill arch was recorded for *Q. clariadis* and *Q. kearni* in all three habitats and for *G. rysavyi* at Ammar Drain. As shown in Table 1, *Q. kearni* tends to exist at a higher percentage on the outer than the inner hemibranch of the catfish in the Nile River, Ammar Drain, and Telbanah Drain. The percentage of the distribution of this monogenean on the left gill set was higher than that on the right set. *Q. kearni* prefers to attach to the proximal half of the gills than on the distal half at Ammar Drain, but the parasite showed no marked preference for the proximal or distal half of the gills in the Nile River and Telbanah Drain (Table 3). It is obvious that *Q. kearni* prefers to live on the ventral segment over the middle and dorsal ones of the gills of *C. gariepinus* at the three ecosystems. Similar to *Q. clariadis*, the highest percentage of distribution was found on the second gill arch of *C. gariepinus* in all investigated areas (Table 5).

Data obtained in Table 1 indicate that the viviparous monogenean *M. clarii* tends mainly to exist at higher proportions on the inner hemibranch of the gills than the outer one of the host at the majority of the studied habitats. The percentage of distribution on the left gill set was higher than that on the right one (Table 2). The parasite preferred to be attached to the proximal half of the gill filaments than the distal one (Table 3). It is clear that *M. clarii* prefers to live on the dorsal and middle over the ventral segment of the gills of *C. gariepinus* at the three ecosystems (Table 4).

As recorded in Table 1, the viviparous monogenean *G. rysavyi* tends to exist at a higher percentage of distribution on the outer hemibranch of the gills of *C. gariepinus* than the inner one at the three studied streams. The percentage of distribution on left gill set was higher than that on the right set (Table 2). The parasite preferred to attach itself to the distal half of the gills than proximal ones at the three investigated areas. Table 4 shows that *G. rysavyi* prefers to live on the middle segment of gill arch of the host in the Nile River and Ammar Drain, but prefers the ventral segment at Telbanah Drain. The highest percentage of the distribution of *G. rysavyi* was on the third gill arch in the Nile River (36.84 %), in the second gill arch at Ammar Drain (58.33 %) and on the first and fourth gill arch at Telbanah Drain (31.25 %).

Table 1. Percentage distribution (%) of Monogenean parasites on the outer and inner gill hemibranches of *Clarias gariepinus* from the River Nile, Telbanah Drain and Ammar Drain.

Monogenean species:	**River Nile**		**Telbanah Drain**		**Ammar Drain**	
	Outer	Inner	Outer	Inner	Outer	Inner
Quadriacanthus aegypticus	59.85	39.41	52.25	47.74	65.61	34.38
Quadriacanthus clariadis	40.00	60.00	53.23	46.76	55.94	44.05
Quadriacanthus kearni	62.00	38.00	57.30	42.69	55.00	45.00
Macrogyrodactylus clarii	50.00	50.00	47.61	52.38	46.00	54.00
Gyrodactylus rysayvi	8.00	2.00	8.00	2.00	8.00	2.00

Table 2. Percentage distribution (%) of Monogenean parasites on the left and right gill sets of *Clarias gariepinus* from the River Nile, Telbanah Drain and Ammar Drain.

Monogenean species:	**River Nile**		**Telbanah Drain**		**Ammar Drain**	
	Left	Right	Left	Right	Left	Right
Quadriacanthus aegypticus	51.82	48.17	56.46	43.53	49.92	48.56
Quadriacanthus clariadis	42.66	57.33	32.24	64.75	49.18	50.27
Quadriacanthus kearni	62.00	38.00	57.30	42.69	55.00	45.00
Macrogyrodactylus clarii	58.33	41.66	57.14	42.85	56.00	44.00
Gyrodactylus rysayvi	63.15	36.84	59.37	40.62	83.33	16.66

Table 3. Percentage distribution (%) of Monogenean parasites on the proximal and distal halves of the gills of *Clarias gariepinus* from the River Nile, Telbanah Drain and Ammar Drain.

Monogenean species:	**River Nile**		**Telbanah Drain**		**Ammar Drain**	
	Proximal	Distal	Proximal	Distal	Proximal	Distal
Quadriacanthus aegypticus	71.53	28.46	60.76	38.44	67.87	32.12
Quadriacanthus clariadis	52.00	48.00	29.02	70.97	22.97	77.02
Quadriacanthus kearni	50.00	50.00	50.29	49.70	57.85	47.50
Macrogyrodactylus clarii	75.00	25.00	71.42	28.57	60.00	40.00
Gyrodactylus rysayvi	15.78	84.21	28.12	71.87	41.66	58.33

Table 4. Percentage distribution (%) of Monogenean parasites on dorsal, middle and ventral gill segments of *Clarias gariepinus* from the River Nile, Telbanah Drain and Ammar Drain.

Monogenean species:	**River Nile**			**Telbanah Drain**			**Ammar Drain**		
	Dorsal	Middle	Ventral	Dorsal	Middle	Ventral	Dorsal	Middle	Ventral
Quadriacanthus aegypticus	48.17	29.92	4.52	39.32	34.05	26.61	27.75	42.38	29.86
Quadriacanthus clariadis	49.33	36.00	14.66	22.63	51.08	26.28	15.40	51.89	32.70
Quadriacanthus kearni	20.00	22.00	58.00	14.13	24.04	61.79	12.85	31.42	55.70
Macrogyrodactylus clarii	25.00	58.33	16.66	42.85	41.66	15.47	34.00	42.00	24.00
Gyrodactylus rysayvi	21.05	47.36	31.57	18.75	34.37	46.87	4.16	79.16	16.66

Table 5. Percentage distribution (%) of Monogenean parasites on the gills (I, II, III and IV) of *Clarias gariepinus* from the River Nile, Telbanah Drain and Ammar Drain.

Monogenean species:	**River Nile**				**Telbanah Drain**				**Ammar Drain**			
	I	II	III	IV	I	II	III	IV	I	II	III	IV
Quadriacanthus aegypticus	22.62	28.4	25.54	23.35	21.65	28.03	25.86	24.44	23.52	33.18	21.71	19.90
Quadriacanthus clariadis	28.88	29.77	20.88	20.44	19.81	23.46	21.55	21.55	20.81	35.13	24.05	20.00
Quadriacanthus kearni	32.00	32.00	24.00	12.00	20.56	36.45	22.22	20.76	22.85	31.78	23.21	25.71
Macrogyrodactylus clarii	0.00	33.33	41.66	25.00	27.38	20.23	25.00	27.38	18.00	36.00	32.00	14.00
Gyrodactylus rysayvi	21.05	31.57	36.84	10.52	31.25	28.12	9.37	31.25	8.33	58.33	12.5	20.83

3.2.2. Intraspecific Aggregation Index

Table 6 represents the intraspecific aggregation values of the gill monogeneans of the catfish host, *C. gariepinus* from the Nile River, Telbanah Drain and Ammar Drain. Except for the value recorded for the viviparous monogenean *M. clarii* from *C. gariepinus* in the Nile River (- 0.17), all the intraspecifc values recorded for all the studied monogenean from the three localities were above zero (Table 6). The maximum intraspecific aggregation value was estimated for *Q. kearni* in the Nile River (7.86). Moderate intraspecific aggregation values were obtained for *Q. clariadis* in the Nile River (2.27) and *G. rysavyi* at Telbanah Drain (2.74).

3.3. Statistical Analysis

Q. aegypticus significantly preferred the proximal area over the distal area of the gills of *C. gariepinus* in the Nile River and Ammar Drain (Student's t-Test: t = 2.186 and 2.340 $p \leq 0.05$, respectively). *Q. clariadis* showed a preference for the proximal half in the Nile River and Ammar Drain. In contrast, this monogenean preferred the distal half at Telbanah Drain. This distribution was significant at Ammar Drain (t = 2.691, $p \leq 0.05$) and Telbanah Drain (t = -1.996, $p \leq 0.05$), but no significant in the Nile River ($p > 0.05$).

The congeneric *Q. kearni* exhibited a significant preference for the distal area in the Nile River (t=-2.696, $p \leq 0.05$) and Ammar Drain (t = - 2.749, $p \leq 0.05$) and Telbanah Drain (t = -2.830, $p \leq 0.01$). Unlike *M. clarii* which showed no preference between the proximal and the distal halves of the gill filaments, the viviparous monogenean *G. rysavyi* showed significant preference for the distal halves in the Nile River (t = -1.987, $p \leq 0.05$), high significant at Ammar Drain (t = - 3.010, $p \leq 0.01$) and very high significant at Telbanah Drain (t = - 4.553, $p \leq 0.001$).

All monogenean species showed no significant preference on the four gill arches, except for *G. rysavyi* at Ammar Drain (One- way ANOVA: F-ratio = 6.667, $p \leq 0.001$). Further statistical analysis (LSD) detected significant preference for the second gill arch over the first, third, or fourth gill arches.

The distribution of *Q. aegypticus* and *M. clarii* on the dorsal, middle, and ventral segments of the gill arches at all study sites was random. A similar distribution pattern was recorded for *Q. clariadis* and *G. rysavyi* in the Nile River and Telbanah Drain. There was a significant preference for the middle segment over the dorsal one by *Q. clariadis* at Ammar Drain (One- way ANOVA: F-ratio = 13.824, $p \leq 0.001$). The oviparous monogenean *Q. kearni* significantly preferred the ventral segment over the dorsal and middle segments in the Nile River (F-ratio = 3.995, $p \leq 0.05$), Ammar Drain (F-ratio = 3.282, $p \leq 0.05$) and Telbanah Drain (F-ratio = 3.254, $p \leq 0.05$). Except for a high significant preference for the outer over the inner hemibranch of the catfish host by the mongenean *G. rysavyi* at the three study sites (Student's *t*-Test: t=3.679, $p \leq 0.001$), all monogenean species were randomly distributed between the outer and inner hemibranchs of the gills of *C. gariepinus* at all study sites.

4. Discussion

Microhabitat specialization and site selection in monogeneans may be influenced by habitat deterioration (e.g. Buchmann and Bresciani, 1998; Chapman *et al*., 2000; Raymond *et al*., 2006). Raymond *et al*. (2006) suggested that oxygen-poor aquatic environments may offer less competitive habitats especially when other gill dwellers are sensible to hypoxic environments. Olowo and Chapman (1996) proposed a higher gill ventilation rate in *Barbus neumayeri* under hypoxic conditions; this may facilitate the transmission and intromission of the monogeneans across the gill ventilation. According to Chapman *et al*. (2000), oxygen-deprived habitats can increase the opportunity of monogenean transmission. El-Naggar *et al*. (2001 and 2004) highlighted the significance of the swimming behavior in the bionomics of *G. rysavyi* from the skin and gill of *C. gariepinus*. The authors observed that *Gyrodactylus* worms displayed a variety of movement patterns including upside-down leech-like movement, elongation, and shortening, searching movement, and self-cleaning acrobat-like displays. The determinants of narrow microhabitat specificity of many gill monogeneans are diverse. According to Holmes (1972), microhabitat specificity in helminth parasites may be ascribed to the direct competition or interactive site segregation among parasites living in the same host. Rohde (1979) demonstrated that monogeneans have highly confined microhabitats, even in the absence of competing species. Wootten (1974) suggested that microhabitat selection on/in the host may be related to physicochemical (abiotic) environments. *G. rysavyi* was found to prefer the second gill arch over others. Similar findings were recorded by Chapman *et al*. (2000) who found that *Afrodiplozoon polycotyleus* was highly site-specific on its host and constituted 78 % of the parasites on filaments of the second gill arch. The authors suggested that this monogenean may select the second gill arch to place itself in an area of maximal laminar flow in the gill. This may indicate that some monogenean species are rheophilic, i.e. favouring lotic streams over lentic ones.

El-Naggar (2012) made a preliminary investigation of the ecological interaction between two gyrodactylid monogeneans, namely *Gyrodactylus rysavyi* and *Macrogyrodactylus congolensis* from the skin of the Nile catfish, *C. gariepinus*, and found that these organisms exhibit significant morphological, ecological, and behavioural differences. Unlike *G. rysavyi*, which is fast-growing, small in size, and attains a high reproductive rate, the cohabitant *M. congolensis* is slow-growing, a large-sized species, and shows a comparatively lower reproductive rate. The author also suggested that the attachment of *M. congolensis* is greatly damaging to the microhabitat, while the attachment of the rival *G. rysavyi* is comparatively less damaging. The output of all experimental infection trials revealed that *G. rysavyi* outnumbered *M. congolensis*, indicating that the former species is a superior competitor, while the latter is an inferior competitor.

The body dimensions of the viviparous monogenean *Macrogyrodactylus clarii* include the total length (2.330 mm), maximum breadth (400 µm), haptor length (460 µm), and haptor breadth (440 µm) (El-Naggar and Serag, 1987). On the other hand, the length of the gill filaments of the adult catfish host do not exceed a few centimeters. The following morphometric features may account for the optimal microhabitat selection by *M. clarii* for the proximal sector of the gill filaments of the catfish host. First, the bases of the gill filaments acquire an upstream location with respect to the hydrodynamic forces watering the gill apparatus and this seems likely to save the energy allocated to neutralize the sweeping action of the water current at the distal extremity of the filaments. Second, the proximal sector is supported and partially sheltered by the massive, cartilaginous plate (branchial arch) on which the gill filaments arrange; this may provide a more nursery living place for the newborn juveniles of *M. clarii*.

Third, comb-like gill rakers attached to the branchial arch act as a trap to suspend a variety of planktons and particulate matter, and prevent them from disturbing the functions of gill lamellae and routine activities of the resident monogenean worms as well. Fourth, the commencement of the movement from the base of gill filaments probably optimizes the opportunities of *M. clarii* to spend long distances whilst scanning the microhabitat and locating a mating partner or avoiding a hostile cohabitant. Fifth, residing in the vicinity of the branchial arch provides an advantage for *M. clarii* to migrate passively across the gill arches without challenging the violence imposed by gill inhabitants and to move, in a leech-like manner, on the roof of the oral cavity of quiescent, nocturnal host in order to join a closely-spaced fish. Sixth, viviparous monogeneans of the catfish host are irritable, attaining permanent mobility and migration than the cohabitant monogeneans (El-Naggar *et al*., 2001) and crustacean copepods (El-Naggar, 2001) and it is wise to segregate their niche and partition the resources.

In the present study, the monogeneans *Q. aegypticus* and *M. clarii* preferred the proximal area, while *G. rysavyi* preferred the distal area of the gill filaments of the host in all investigated habitats. *Q. clariadis* showed no preference for the proximal or distal area of gill filaments of *C. gariepinus* in the Nile River, however it showed a marked preference for the distal area over the proximal in Telbanah Drain and Ammar Drain. Difference in microhabitat distribution may be correlated with the limnological features of aquatic ecosystem; the three investigated streams showed a marked variation in physicochemical and heavy-metal parameters of water. These variations may alter the behavioral and biological activities of fish, which in turn will modify the bionomics of monogeneans living on that host (El-Naggar *et al.*, 2017).

Except for *Q. kearni* that inhabited the ventral segment of the gill arches of the host in the three localities, there was a noticeable locality-related variation in the microhabitat distribution of the studied monogeneans on the dorsal, middle, and ventral segments of the catfish host. This may be correlated with the difference in the infestation levels of the monogeneans of the catfish inhabiting the three localities; it may also be related to the habitat characteristics in each locality. Higher infestation levels may obligate some species to conduct a microhabitat shift to avoid competition with other cohabitants with identical ecological requirements. However, differences in the sample size and quality (proportion of male and female host individuals, length and size classes of examined fish) may affect the obtained data.

The present observations indicated that no preference was conducted by *Q. aegypticus*, *Q. clariadis*, *Q. kearni*, *M. clarii* and *G. rysavyi*, for the left or right gill sets of *C. gariepinus*. Nonsignificant preferences for the left and right gill sets were recorded by several authors (Hagras *et al*., 2000; Raymond *et al*., 2006; Rubio-Godoi, 2008; Jeannette *et al*., 2010; Iannacone and Alvarino, 2012). These findings indicate that the fish hosts are symmetric and acquire equal amounts of water flowing on the left and right sides of the body.

The viviparous monogenean *M. clarii* from *C. gariepinus* in the Nile River recorded an intraspecific aggregation index below zero (- 0.17), indicating that the distribution pattern of this monogenean will be regular or uniformed. In contrast, all remaining monogeneans of *C. gariepinus* from the three localities were above zero, indicating that an increase in the number of conspecifics expected an aggregated or a clumped distribution pattern. Studying the aggregation of nine congeneric monogenean species of the genus *Dactylogyrus* on the gills of the roach, *Rutilus rutilus* by Simkova *et al*. (2001) indicated that at low infestation levels intraspecific competition may lead to a slight effect on the microhabitat distribution of the parasite.

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