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ORIGINAL ARTICLE

Community structure, seasonal dynamics, and impact of some biological parameters of the African catfish *Clarias gariepinus* on the infection level of the helminth parasites

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Abstract
Fish parasitic diseases impose a major economic concern on aquaculture. Identified parasites of *Clarias gariepinus* include one monogenean, *Macrogyrodactylus clarii* (gills), three digeneans *Orientocreadium batrachoides, Eumasenia bangweulensis* and *Sanguinicola* sp. (intestine), two cestodes *Tetracampose ciliotheca* and *Monobothrioides chalmersius* (intestine) and two nematodes *Paracamallanus cyathopharynx* and *Procamallanus pseudolaeviconchus* (intestine and stomach). Most nematodes, digeneans and cestodes occurred in all months of the study period. However, *M. clarii* and *Sanguinicola* sp. disappeared for 6 and 8 months of the year, respectively. The digenean group was the most dominant followed by the cestode and nematode groups, respectively. The nematodes attained the highest infection rate over the digeneans and cestodes while the monogenean *M. clarii* recorded the lowest infection rate. The infection level of examined parasites varied seasonally, but no overall significant pattern was detected. *E. bangweulensis* showed a highly significant difference for all parameters seasonally. A higher prevalence was obvious in males than females for most parasites, and the opposite for the mean intensity except for *P. pseudolaeviconchus* which was significantly different between females and males in the mean abundance. There were variations in the relationship between the host condition factor and helminth parasite infection levels. *O. batrachoides, E. bangweulensis* and *P. cyathopharynx* recorded the highest infection level in class II. The mean prevalence was highly significantly different between host classes for *T. ciliotheca*, *M. chalmersius* and *P. pseudolaeviconchus.*

Keywords Fish diseases · Clariidae · Nile Delta · Ecological parameters · Prevalence · Biodiversity · Host condition factor

Introduction

Fish parasitic diseases impose a major economic concern on aquaculture. In addition, 73% of the freshwater cultured species have diseases that are mainly associated with parasites (Lakra et al. 2006). Warm weather in Egypt is considered a great reason for the spread of parasites which led to many worse effects on fish (Eissa et al. 2013). In general, parasites of fishes cause serious economic losses due to high mortalities, tissue damage and retardation of fish growth (El-Asely et al. 2015). In Oba reservoir, Nigeria, infection of *Clarias gariepinus* Burchell, 1822 (Clariidae) by *Monobothrium* sp. Diesing, 1863, *Tetracampose ciliotheca* Wedl, 1861 (Syn: *Polyonchobothrium clarias* Woodland, 1925), *Neoechinorhynchus rutile* Müller, 1780*, Anomotaenia* sp. Cohn, 1900, *Procamallanus pseudolaeviconchus* Moravec & Van As, 2015 (Syn: *P. laevionchus*) and *Paracamallanus cyathopharynx* Baylis, 1923 Yorke et Maplestone, 1926, causes a reduction in the growth rate of the fish (Ajala and Fawole 2014).

The African catfish, *C. gariepinus* is parasitized by many external and internal helminth parasites including monogeneans, digeneans, cestodes and nematodes (El-Naggar and Serag 1987; El-Naggar et al. 1992, 1993; Hamada and El-Naggar 2003; Abdel-Gaber et al. 2015). The monogenean parasites of this host fish received a great deal of attention at morphological, ecological, and ultrastructural levels (El-Naggar et al. 2007, 2017, 2019; Mashaly et al. 2019). The study of host-parasite community structure all year round is important for providing data on their seasonal dynamics and subsequently the effect of environmental factors on their infection levels (Khan and Thulin 1991). Great attention has

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been paid to the parasite community structures of different fish hosts since the change in diversity and structure can be used as indicators of ecosystem health and integrity (Duesk et al. 1998). Mashaly et al. (2020) found that most monogeneans of the genus of *Quadriacanthus* Paperna, 1961 (Dactylogyridae) infesting the gills of *C. gariepinus* have their maximum infestation levels during spring and/or summer and their lowest levels were recorded during autumn and/or winter. Except for a few ecological studies (see Abdel-Gaber et al. 2015; Ali et al. 2020), most studies done on endoparasites of *C. gariepinus* were concentrated on morphological characters (El-Naggar et al. 1992; Ibrahim et al. 2008; Abdel-Gaber et al. 2016; Hussein et al. 2020).

The aim of the current work is to illustrate the community structure, monthly occurrence, and ecological parameters (prevalence, mean intensity and abundance) of parasitic helminths of *C. gariepinus* living in the River Nile (Damietta branch) at Mansoura City, Nile Delta. Moreover, it seems important to determine whether these parasites show monthly and seasonal changes in these parameters with the moderate change in temperature between seasons (15–31 °C) (Mashaly et al. 2020) in North Egypt. The condition factor of a fish depends mainly on the fish's length and weight in its determination and is considered by some authors to be a good indicator of the physiological and general health conditions of the fish (Schmitt and Dethloff 2000; Lizama and Ambrosio 2002). Therefore, the present work was designed to determine this factor in addition to the host sex of *C. gariepinus* and investigate their possible effects on the infection levels of identified parasites.

Materials and methods

Collection of *C. gariepinus*

A total of 154 African catfish, *C. gariepinus* were caught in trammel nets monthly from March 2020 to February 2021, from the Damietta branch of the River Nile at Mansoura City (coordinates: 31°02′47.2″ N, 31°21′12.2″ E). The study area lies in the subcontinental climatic limit with four seasons namely, spring (March–May), summer (June–August), autumn (October—November) and winter (December—February). Living fish were delivered to the Faculty of Science aquarium, Mansoura University, in a container filled with freshwater where they were dissected and examined for helminth parasites using a stereomicroscope.

Determination of the fish's biological parameters

The sex of each fish specimen was distinguished, by dissection of the reproductive organs and examination of external genitalia. To identify the condition factor, the fish's weight and length were measured. The fish sample condition factor (K) was calculated according to Barnham and Baxter (1998) as follows:

$$K = 100W/L^3$$

where K = condition factor, W = weight of fish, and L = length of fish (cm).

The calculated condition factor of examined C. *gariepinus* was between 0.34 and 1.0. The fish samples were grouped into three classes: class I (0.34–0.56, bad condition), class II (0.57–0.79, good condition), and class III (0.80–1.0, excellent condition).

Identification of helminth parasites

Some collected helminth parasites were examined alive using a phase-contrast microscope while others were stained and prepared as whole mounts and later examined by light microscope. The monogenean parasites were identified according to Ergens (1973), the digeneans according to El-Naggar et al. (1992, 1993) and Plehn (1905), the cestodes according to Hamada and El-Naggar (2003) and Kuchta et al. (2012), and the nematodes according to Moravec (1998) and Moravec and Van As (2015).

Ecological parameters

These parameters include dominance, prevalence, mean intensity, and abundance. The dominance of intestinal parasites was determined according to Roohi et al. (2014) as follows:

$$\text{Dominance} = \frac{\text{N}}{\text{N sum}} \times 100$$

where N = abundance of a particular parasite species and N sum = total abundance of all identified parasite species. Niedbala and Kasprzak (1993) classified the helminth parasites into the following categories in accordance with dominance: eudominant (> 10%), dominant (5.1–10%), subdominant (2.1%-5%), recedent (1.1–2%), and subrecedent (< 1.0%) of a specific species. Individuals of each parasite species in each fish were counted. All other ecological parameters were calculated according to Margolis et al. (1982).

Statistical analysis and treatment of data

The relationship between helminth parasite infection levels in *C. gariepinus* and the seasons was determined using the SPSS package's One-way ANOVA (version 25 IBM). Where the significant differences are found, the Multiple Range Comparisons (Least Significant Difference) were selected from the Post Hoc tests (Tukey HSD) on the same statistical package to detect the variances between infection levels of different helminth parasites and different seasons. Additionally, the significance of differences in the helminth parasite infection levels between male and female fish was determined using the student's t-test. The selected probability levels are non-significant ($p > 0.05$), significant ($p \leq 0.05$), highly significant ($p \leq 0.01$) and very highly significant ($p \leq 0.001$).

Results

Community structure, monthly occurrence, dominance, and infection levels

The detected parasites are one monogenean *Macrogyrodactylus clarii* Gussev, 1961 from the gills, three digeneans, *Orientocreadium batrachoides* Tubangui, 1931, *Eumasenia bangweulensis* Beverley-Burton, 1962, and *Sanguinicola* sp. Plehn, 1905 from the intestine, two cestodes *Tetracampose ciliotheca* Wedl, 1861 and *Monobothrioides chalmersius* Woodland, 1924 from the intestine and two nematodes *Procamallanus pseudolaeviconchus* Moravec & Van As, 2015 and *Paracamallanus cyathopharynx* Baylis, 1923 Yorke et Maplestone, 1926from the stomach and the intestine.

It is obvious from Table 1 that *O. batrachoides* and *P. cyathopharynx* are present in all months of the year. However, *T. ciliotheca* and *M. chalmersius,* and *P. pseudolaeviconchus* are found during all months except November. *M. clarii* is absent during 6 months (February–June and August) while *E. bangweulensis* is absent throughout the year except for July, August, September, December, and February. Finally, *Sanguinicola* sp. occurs only during October, December, January, and February.

Concerning dominance (Table 2), the digenean parasites were the most dominant species followed by cestodes and nematodes, respectively. Also, *O. batrachoides, E. bangweulensis,* and *M. chalmersius* showed a dominance value greater than 10% (eudominant species) while *T. ciliotheca* and *P. cyathopharynx* and *P. pseudolaeviconchus* registered a dominance value ranging between 5.1 and 10% (dominant species). However, *Sanguinicola* sp. recorded a dominance value of less than 1% (subrecedent species).

The overall infection rate of *C. gariepinus* with all detected parasites is 87.66% (Table 3). Generally, the nematode group attained the highest infection rate while the monogenean group recorded the lowest rate. The nematode *P. cyathopharynx* attained the highest mean prevalence while the digenean *E. bangweulensis* showed the lowest mean prevalence. Concerning mean intensity (Table 3) *E. bangweulensis* recorded the highest while *Sanguinicola* sp. showed the lowest. The most abundant parasite was *E. bangweulensis* whereas the least was *Sanguinicola* sp. (Table 3).

Fluctuations in seasonal infection levels

Seasonal mean prevalence (Table 4)

T. ciliotheca, *M. chalmersius*, *P. cyathopharynx* and *P. pseudolaeviconchus* attained their maximum mean prevalence in winter and the minimum in summer (Table 4). In contrast, *M. clarii* and *Sanguinicola* sp. registered the maximum mean prevalence in summer and the minimum in winter. The digenean *O. batrachoides* attained its maximum mean prevalence in autumn and the minimum in summer while *E.*

Table 1 Monthly occurrence of helminth parasites infecting *Clarias gariepinus* throughout the year

Season	Month	*M. clarii*	*O. batrachoides*	*E. bangweulensis*	*Sanguinicola* sp.	*T. ciliotheca*	*M. chalmersius*	*P. cyathopharynx*	*P. pseudolaeviconchus*
Spring	March (2020)	–	+	–	–	+	+	+	+
	April	–	+	–	–	+	+	+	+
	May	–	+	–	–	+	+	+	+
Summer	June	–	+	–	–	+	+	+	+
	July	+	+	+	–	+	+	+	+
	August	–	+	+	–	+	+	+	+
Autumn	September	+	+	+	–	+	+	+	+
	October	+	+	–	+	+	+	+	+
	November	+	+	–	–	–	–	+	–
Winter	December	+	+	+	+	+	+	+	+
	January (2021)	+	+	–	+	+	+	+	+
	February	–	+	+	+	+	+	+	+

bangweulensis achieved its maximum mean prevalence in spring and the minimum in winter.

The digenean *E. bangweulensis* showed a highly significant mean prevalence between different seasons (F = 8.23, $p \leq 0.01$). A significant mean prevalence was recorded for *M. clarii* (F = 3.88, $p \leq 0.05$), and *T. ciliotheca* (F = 4.25, $p \leq 0.05$) and non-significant mean prevalence for the other helminth species among various seasons. According to Multiple Range Comparisons, the mean prevalence of *E. bangweulensis* exhibited a highly significant difference between spring and summer ($p \leq 0.01$) and between summer and winter ($p \leq 0.01$) but was significant between summer and autumn ($p \leq 0.02$). Moreover, a significant difference was documented for the mean prevalence of *M. clarii* and *T. ciliotheca* between spring and autumn ($p \leq 0.05$).

Seasonal mean intensity (Table 5)

O. batrachoides, *E. bangweulensis* and *P. cyathopharynx* attained their maximum mean intensity in spring while the

Table 2 Dominance (%) of the gastrointestinal parasites of *Clarias gariepinus*

Parasite classes	Parasite species	Dominance of each parasite species (%)	Dominance of each taxonomic group (%)
Digenea	*Orientocreadium batrachoides*	34.06	60.47
	Eumasenia bangweulensis	25.79	
	Sanguinicola sp.	0.62	
Cestoda	*Tetracampose ciliotheca*	6.81	25.34
	Monobothrioides chalmersius	18.53	
Nematoda	*Paracamallanus cyathopharynx*	9.21	14.17
	Procamallanus pseudolaeviconchus	4.96	

Table 3 Overall infection of *C. gariepinus* and overall prevalence, mean intensity and abundance of helminth parasites infecting *C. gariepinus* throughout the year

Parasite classes	Parasite species	Overall prevalence (%)	Overall mean intensity	Overall abundance	Infection rate of different classes of parasite spp.	Overall infection
Monogenea	*Macrogyrodactylus clarii*	12.3	6.5	0.8	12.3%	87.66%
Digenea	*Orientocreadium batrachoides*	44.8	7.3	3.3	52.6%	
	Eumasenia bangweulensis	5.8	58.4	3.4		
	Sanguinicola sp.	6.5	1.6	0.1		
Cestode	*Tetracampose ciliotheca*	18.8	3.3	0.6	35.1%	
	Monobothrioides chalmersius	16.9	12.8	2.2		
Nematode	*Paracamallanus cyathopharynx*	45.5	2.5	1.1	54.5%	
	Procamallanus pseudolaeviconchus	24.0	2.3	0.5		

Table 4 Seasonal fluctuations in the prevalence of helminth parasites of *C. gariepinus*

Season	Monogenea	Digenea			Cestoda		Nematoda	
	M. clarii	*O. batrachoides*	*E. bangweulensis*	*Sanguinicola sp.*	*T. ciliotheca*	*M. chalmersius*	*P. cyathopharynx*	*P. pseudolaeviconchus*
Spring	^{a} 8.66	^{a} 42.47	(+)^{a} 15.76	(−)^{a} 0.00	^{a} 16.70	^{a} 11.23	^{a} 43.52	^{a} 30.21
Summer	(+)^{ab} 36.67	(−)^{a} 36.11	1.67	(+)^{a} 10.56	(−)^{a} 10.00	(−)^{a} 10.00	(−)^{a} 36.67	(−)^{a} 11.67
Autumn	^{b} 1.67	(+)^{a} 61.30	^{b} 1.52	^{a} 7.73	^{a} 20.74	^{a} 25.13	^{a} 48.74	^{a} 23.83
Winter	(−)^{ab} 0.00	^{a} 57.78	(−)^{ab} 0.00	(−)^{a} 0.00	(+)^{a} 43.33	(+)^{a} 25.56	(+)^{a} 50.00	(+)^{a} 44.44

minimum value for *O. batrachoides* and *P. cyathopharynx* was in summer and for *E. bangweulensis* in winter. In contrast, *Sanguinicola* sp. reached its maximum mean intensity in autumn and the minimum in spring. *M. clarii* recorded its maximum mean intensity during summer and the minimum in winter, while *T. ciliotheca*, *M. chalmersius* and *P. psudolaeviconchus* showed their maximum mean intensity in winter and the minimum in spring for cestodes and summer for *P. psudolaeviconchus*.

Seasonal differences in the mean intensities were very highly significant for *E. bangweulensis* ($F = 56.203$, $p \leq 0.001$). According to Multiple Range Comparisons, the digenean *E. bangweulensis* recorded a very highly significant difference in the mean intensity between spring and summer ($p \leq 0.001$), summer and autumn ($p \leq 0.001$), and between summer and winter ($p \leq 0.001$). Contrary, there was no significant difference between the mean intensities of the studied parasite species according to the One-way ANOVA test.

Seasonal mean abundance (Table 6)

The helminth parasites *E. bangweulensis*, *P. cyathopharynx,* and *P. pseudolaeviconchus* recorded their maximum mean abundance during spring and the minimum during summer for *P. pseudolaeviconchus* and winter for both *E. bangweulensis* and *P. cyathopharynx*. *T. ciliotheca*, *M. chalmersius* and *O. batrachoides* showed their maximum mean abundance in winter and the minimum in spring for *T. ciliotheca*, *M. chalmersius* and summer for *O. batrachoides*. *M. clarii* reached its maximum mean abundance in summer and the minimum in winter while *Sanguinicola* sp. attained its maximum mean abundance in autumn and the minimum in winter.

E. bangweulensis recorded very highly significant seasonal difference in the mean abundance ($F = 16.732$, $p \leq 0.001$) while *T. ciliotheca* recorded a significant seasonal difference ($F = 3.940$, $p \leq 0.05$). According to Multiple Range Comparisons, *E. bangweulensis* showed a highly

Table 5 Seasonal fluctuations in the mean intensity of helminth parasites infecting C. *gariepinus*

Season	Monogenea	Digenea			Cestoda		Nematoda	
	M. clarii	*O. batrachoides*	*E. bangweulensis*	*Sanguinicola sp.*	*T. ciliotheca*	*M. chalmersius*	*P. cyathopharynx*	*P. pseudolaeviconchus*
Spring	^{a} 2.11	(+)^{a} 9.60	(+)^{a} 75.72	(−)^{a} 0.00	(−)^{a} 2.06	(−)^{a} 3.17	(+)^{a} 4.07	^{a} 2.43
Summer	(+)^{a} 5.23	(−)^{a} 2.98	1.00	^{a} 1.00	^{a} 2.83	^{a} 6.44	(−)^{a} 2.00	(−)^{a} 1.67
Autumn	^{a} 3.00	^{a} 8.06	^{a} 0.67	(+)^{a} 1.83	^{a} 3.81	^{a} 12.05	^{a} 2.18	^{a} 2.33
Winter	(−)^{a} 0.00	^{a} 7.00	(−)^{a} 0.33	^{a} 1.00	(+)^{a} 4.00	(+)^{a} 21.67	^{a} 3.00	(+)^{a} 3.33

Groups with the same letter are not significantly different and groups that are significantly different get different letters. Highest value = (+), Lowest value (−)

Table 6 Seasonal fluctuations of the mean abundance of helminth parasites of *C. gariepinus*

Season	Monogenea	Digenea			Cestoda		Nematoda	
	M. clarii	*O. batrachoides*	*E. bangweulensis*	*Sanguinicola sp.*	*T. ciliotheca*	*M. chalmersius*	*P. cyathopharynx*	*P. pseudolaeviconchus*
Spring	^{a} 0.28	^{a} 4.40	(+)^{a} 11.50	^{a} 0.00	^{a}(−) 0.35	(−)^{a} 0.39	(+)^{a} 1.53	(+)^{a} 0.73
Summer	(+)^{a} 2.48	(−)^{a} 1.06	0.03	^{a} 0.12	^{b} 0.38	^{a} 0.86	^{a} 0.83	(−)^{a} 0.30
Autumn	^{a} 0.15	^{a} 4.62	^{a} 0.03	(+)^{a} 0.16	^{ab} 0.66	^{a} 3.26	^{a} 0.97	^{a} 0.50
Winter	(−)^{a} 0.00	(+)^{a} 5.20	(−)^{a} 0.00	(−)^{a} 0.00	^{ab}(+) 1.67	(+)^{a} 3.80	(−)^{a} 0.80	^{a} 0.70

Groups with the same letter are not significantly different and groups that are significantly different get different letters. Highest value = (+), Lowest value = (−)

significant difference in the mean abundance between spring and summer ($p \leq 0.01$), summer and autumn ($p \leq 0.01$), and between summer and winter ($p = 0.002$). Additionally, a significant difference was noticed for *T. ciliotheca* between spring and summer ($p \leq 0.05$).

Host sex and parameters of infection levels (Table 7)

M. clarii and *P. cyathopharynx* showed their maximum mean prevalence values in females while that of the remaining helminth parasites were in males (Table 7). The mean intensity of *Sanguinicola* sp., *T. ciliotheca,* and *P. pseudolaeviconchus* showed their maximum intensity in males and the remaining parasites *M. clarii, O. batrachoides*, *E. bangweulensis,* and *M. chalmersius* were in females. The nematode *P. cyathopharynx* recorded the same mean intensity in both males and females. The mean abundance of *M. clarii*, *Sanguinicola* sp., *T. ciliotheca,* and *P. pseudolaeviconchus* was higher in males while *O. batrachoides*, *E. bangweulensis*, *M. chalmersius,* and *P. cyathopharynx* showed maximum values in females.

P. pseudolaeviconchus was the only parasite to show a significant difference between males and females in the mean intensity and mean abundance ($p \leq 0.05$) while all helminth parasites of *C. gariepinus* had no significant difference in their mean prevalence between males and females ($p > 0.05$).

The condition factor and infection level parameters (Figs. 1, 2, 3)

The mean prevalence of *M. clarii* and *M. chalmersius* rises when the condition factor of the host increases. However, the highest mean prevalence was detected in class II for *O. batrachoides, E. bangweulensis,* and *P. cyathopharynx* while the lowest was recorded in class II for *Sanguinicola* sp., *T. ciliotheca,* and *P. pseudolaeviconchus* (Fig. 1). *T. ciliotheca, M. chalmersius,* and *P. pseudolaeviconchus* showed a highly significant difference in their mean prevalence between various classes of the host condition factor ($p \leq 0.01$) while *E. bangweulensis* showed only a significant difference ($p \leq 0.05$). However, for all other helminth parasite species, there was no significant variation in the mean prevalence between various condition factor classes ($p > 0.05$).

For the monogenean *M. clarii,* the mean intensity increases with the increase of the host condition factor while the mean intensity of *Sanguinicola* sp. and *P. pseudolaeviconchus* declines as the host condition factor increases. However, the maximum mean intensity was detected in class II for *O. batrachoides, E. bangweulensis*, *T. ciliotheca*, *M. chalmersius* and *P. cyathopharynx* (Fig. 2). Statistically, *M. chalmersius* showed a highly significant difference ($p \leq 0.01$) in its mean intensity between different classes of the host condition factor, while all other parasite species showed a non-significant variation in the mean intensity over different classes of the host condition factor ($p > 0.05$).

Concerning the mean abundance, *M. clarii* showed a rise in its mean abundance as the host condition factor increased (Fig. 3). The maximum mean abundance was detected in class II for *O. batrachoides, E. bangweulensis*, *M. chalmersius,* and *P. cyathopharynx,* but the minimum mean abundance was recorded in class II for the other parasite species. All studied parasitic helminths recorded a non-significant variation in the mean abundance between various classes of the host condition factor ($p > 0.05$).

Discussion

The African catfish *C. gariepinus* was found to harbor one monogenean *M. clarii,* three digeneans *O. batrachoides, E. bangweulensis*, and *Sanguinicola* sp., two cestodes *T. ciliotheca* and *M. chalmersius*, and two nematodes *P. cyathopharynx* and *P. pseudolaeviconchus* at the Damietta branch of the River Nile. *Sanguinicola* sp. is recorded for the first time in this locality in Egypt. However, it was previously described as *Sanguinicola clarias* Imam et al. 1984 from *C. gariepinus* captured by local fishermen in two other aquatic habitats of Egypt, Cairo Governorate (lower Egypt) by Imam et al (1984) and Beni-Suef Governorate (Upper

Table 7 Mean prevalence (%), mean intensity and mean abundance of parasites infecting males and females of *Clarias gariepinus*

Parasite species	Mean prevalence		Mean intensity		Mean abundance	
	Male	Female	Male	Female	Male	Female
Macrogyrodactylus clarii	11.81	13.04	2.02	2.18	0.88	0.78
O. batrachoides	99.20	53.73	5.01	7.03	2.73	4.33
E. bangweulensis	5.50	5.39	10.25	12.20	2.34	3.91
Sanguinicola sp.	5.32	4.72	0.83	0.36	0.09	0.06
T. ciliotheca	25.06	19.17	2.29	1.71	1.14	0.55
M. chalmersius	18.79	11.98	5.79	11.21	1.12	2.76
P. cyathopharynx	43.97	50.00	2.55	2.55	0.92	1.36
P. pseudolaeviconchus	30.01	18.07	2.78	1.18	0.69	0.32

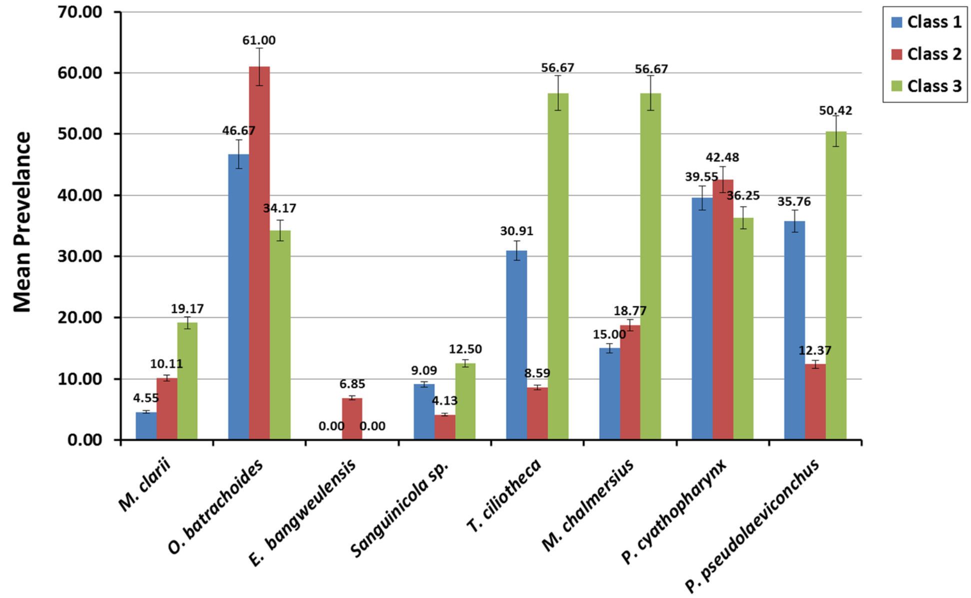


Fig. 1 Mean prevalence of helminth parasites infecting different condition factor classes of *Clarias gariepinus*

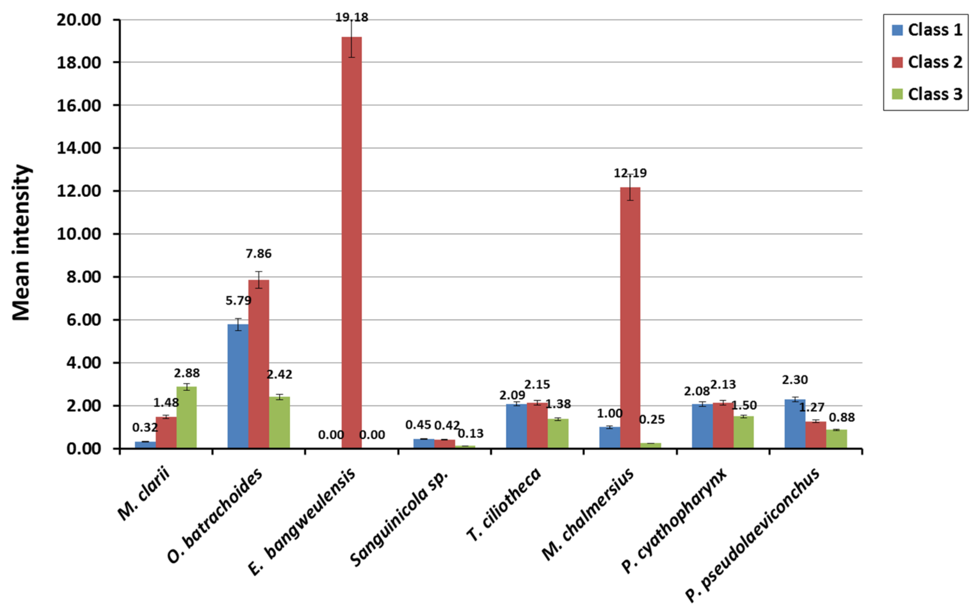
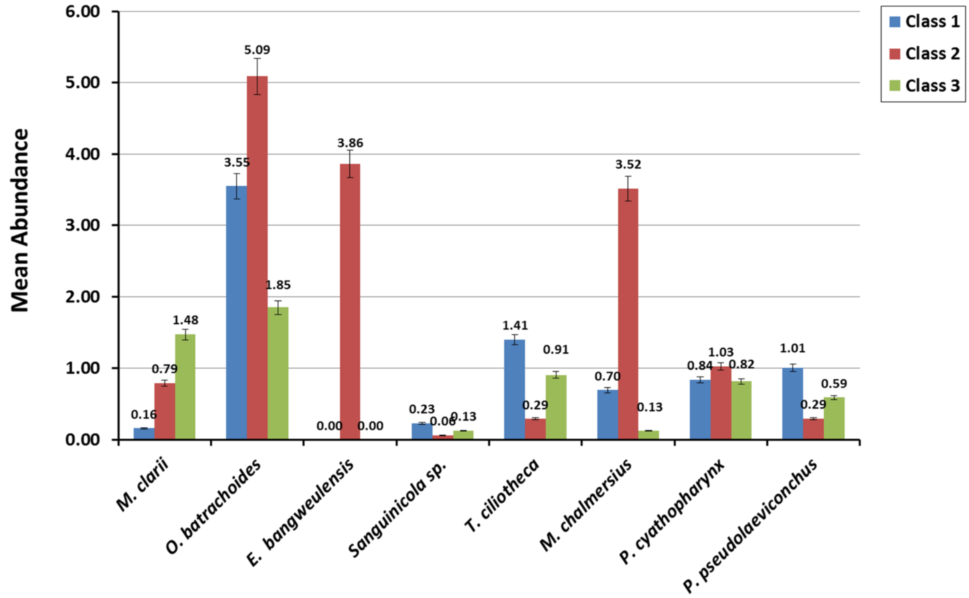


Fig. 2 Mean intensity of helminth parasites infecting different condition factor classes of *Clarias gariepinus*

Egypt) by Imam and El-Askalany (1990). There is a need for more morphological and molecular studies of *Sanguinicola* sp. to get a precise identity of this parasite using more advanced types of equipment like Scanning Electron microscopy (SEM). All other currently identified parasites were previously recorded in the same locality by many authors (see El-Naggar and Serag 1987; El-Naggar et al. 1997, 1992, 1993; Hamada and El-Naggar 2003; El-Tantawy et al 2018). Although El-Tantawy et al. (2018) have recorded *Allocreadium sudanensis* Saoud, Abdel-Hamid and Ibrahim, 1974 from the Damietta branch of the River Nile, no trace has been found of this parasite in the present study. It was interesting to note a complete absence of some helminth parasites from parasitic fauna of *C. gariepinus* from the Damietta branch of the River Nile and their occurrence on the same host in other communities along the River Nile. Abdel-Gaber et al (2016) described 2 digenean intestinal parasites *Pseudoholorchis clarii* Bayoumy, Abd El-Monem and Abd El-Atti 2013 and *Glossidium pedatum* Looss 1899 from *C. gariepinus* of the River Nile in Beni-Suef Governorate. None of these parasites was detected in the present study or other studies carried out in the present locality. In Manzala lake, Abdel-Gaber et al (2015) recorded only 4 helminth intestinal parasites from *C. gariepinus*: *P. pseudolaeviconchus*, *Camallanus polypteri* Kabre and Petter 1997 (Camallanidae), *T. ciliotheca* Woodland 1925 (Ptychobothriidae), and

Fig. 3 Mean abundance of helminth parasites infecting different condition factor classes of *Clarias gariepinus*



O. batrachoides. However, *C. polypteri* was not observed in the present study. Ali et al (2020) detected only two gastrointestinal parasites *T. ciliotheca* and *P. pseudolaeviconchus*, from *C. gariepinus* in Qaluobaya Governorate near Cairo. These variations in the community structure of intestinal helminth parasites infecting the same host that inhabits different localities in Egypt could be attributed to the variations in water physicochemical parameters and to the occurrence or absence of the parasite intermediate host.

Except for *Sanguinicola* sp. and *E. bangweulensis*, most digeneans, cestodes, and nematodes of *C. gariepinus* were recorded throughout the year, this indicates that the host fish *C. gariepinus* is highly susceptible to helminth parasite infection. However, the gill monogenean parasite *M. clarii* was missing during 6 months of the year (February to June and August) and the digenean *Sanguinicola* sp. was absent in all months except October, December, January, and February. A similar long absence of *M. clarii* was recorded by Hagras et al. (1999) in the same locality but during December, January, February, and April. The variation in the missing months for *M. clarii* from the same locality along different years indicates that there is no regular pattern for this behaviour which can be affected by the water environmental condition, the size (length and weight) of the collected host fish (Hagras et al. 1995) and/or to the reproductive activity of the parasite that may be affected by the temperature. The long missing of *Sanguinicola* sp. for 8 months of the year and its occurrence in the coldest months could be related to its life cycle, particularly the intermediate host.

Among the intestinal parasite groups of the present study, the digenean group was the most dominant followed by the cestode and nematode groups, respectively. Most gastrointestinal parasitic species were eudominant or dominant except *P. pseudolaeviconchus* and *Sanguinicola* sp. which were subdominant and subrecedent, respectively (Kasprzak and Niedbala 1993). In this respect, the present dominance pattern resembles that reported by Allam et al. (2023) where the digenean parasites of the African catfish *Bagrus* spp. Fabricius, 1775 (Bagridae) are more dominant than nematodes. However, Groenewold et al. (1996), noticed that the dominance of both the digenean *Cryptocotyle lingua* (Creplin, 1825) Fischoeder, 1903 (Herophidea) and the nematode *Hysterothylacium* sp. Ward and Magath, 1917 (Anisakidae) are greater than that of the other helminth parasites infecting the intestine of four fish species inhabiting the Wadden Sea. In contrast, Li et al. (2009) found that the nematode *Procamallanus fulvidraconis* Li, 1935 was the dominant species of the catfish *Pelteobagrus fulvidraco* Richardson, 1846 (Bagridae) in all lakes of the Yangtze River in China. Moreover, the nematodes were found to be the dominant gastrointestinal parasite species of the white croaker *Micropogonias furnieri* Desmarest, 1823 (Sciaenidae), from Rio de Janeiro, Brazil (Alves and Luque 2001).

It is noteworthy that the catfish *C. gariepinus* recorded a considerably high overall infection rate with parasitic helminths (87.66%). A similar high infection rate (78.82%) of helminth parasites was recorded for *C. gariepinus* at Abbasa fish farm in El-Sharkia Governorate Egypt by Radwan et al. (2021) who attributed this to the feeding habit of the catfish (bottom-feeding carnivores). This behaviour may aid in rising a load of gastrointestinal parasites by feeding on aquatic creatures that contain the infective stages of these parasites. The high rate of helminth parasite infection (65%) of *C. gariepinus* at Manzala Lake was attributed by Abdel-Gaber et al. (2015) to the high contamination level of the Lake by many pollutants that were poured into the lake from numerous drainage canals. Mgbemena et al. (2020) found that human-caused contamination of the Chanchaga River was the reason for the high overall prevalence of endoparasites for *Tilapia zillii* Gervais, 1848 (Cichlidae) (91.2%) and *C. gariepinus* (88.2%). Mashaly et al. (2020) reported that Manzala Lake has more chlorides, sulphates, total dissolved solids, lead, cadmium, and sodium than was typically permitted. However, the Damietta River Nile branch recorded a higher mean value of dissolved oxygen (DO) than that of Manzala Lake (Mashaly et al. 2020). Water-dissolved oxygen is regarded as a crucial component for aquatic fauna survival and is used as an indicator of a healthy environment. In the current work, the infection rate of *C. gariepinus* with helminth parasites in the Damietta River Nile branch is apparently higher than that recorded by Abdel-Gaber et al (2015) for the same host at Manzala Lake which means that factors other than pollution can cause the high infection rate.

The nematode parasites of the present study attained the highest infection rate over the digeneans and cestodes while the monogenean *M. clarii* recorded the lowest infection rate. These data resemble the results reported for the helminth parasites of the same host by Abdel-Gaber et al. (2015) at Manzala Lake and Kawe et al. (2016). However, in Qaluobaya Governorate, Egypt, Ali et al. (2020) found that the cestode *T. ciliotheca* had prevalence higher than that of *P. pseudolaeviconchus*. Some authors suggested that ingestion of copepods and molluscs by *C. gariepinus* may be the reason for the high infection rate of *C. gariepinus* by cestodes as they act as intermediate hosts for the larval stages of many cestodes (Paperna 1996; Eyo et al. 2013; Biu and Akorede 2013; Eyo and Iyaji 2014).

The level of parasitic infections of the examined parasitic helminths, in the current work, varied seasonally, but no overall significant pattern was noticed, and each parasite species reacted differently towards the seasonal changes over the study period. However, *E. bangweulensis* was the only parasite to show a highly significant difference in all ecological parameters between different seasons whereas *T. ciliotheca* showed a seasonal significant difference only in the mean prevalence and mean abundance. The cestodes showed their maximum mean prevalence and mean intensity in winter while the nematodes in spring and/or winter. With rare exceptions, spring and/or autumn were the seasons when digeneans attained their highest infection level. However, the monogenean *M. clarii* registered its highest infection levels in summer. These data resemble those obtained by El-Tantawy et al. (2018) who proved that most helminth parasites infecting *C. gariepinus* of the Damietta branch of the River Nile and Mansouria Canal have an increased infection level from winter to spring, However, Mashaly (2014) found that most intestinal parasites had their highest prevalence and mean intensity during spring or summer seasons. At Abbasa Fish Farm, in EL-Sharkia Governorate, Radwan et al. (2021) reported the highest parasitic infection of *C. gariepinus* with helminth parasites in summer. The low infestation level of *M. clarii* in winter months was attributed by Hagras et al. (1999) to the decline in temperature which strongly affects the reproductive activity of these viviparous parasites and to the increased immune response of the host at low temperatures.

All helminth parasites of *C. gariepinus* showed no significant difference in their mean prevalence between males and females while *P. pseudolaeviconchus* was the only parasite to show a significant difference between males and females in the mean abundance and mean intensity. Nevertheless, most parasitic helminths in the current investigation have a higher prevalence in males and a higher mean intensity in females. A similar result was recorded for parasitic helminths of *C. gariepinus* in Qaluobaya Governorate (Ali et al. 2020), and in the Lekki lagoon, Nigeria (Akinsanya and Otubanjo 2006). However, Abdel-Gaber et al. (2015), recorded a higher prevalence in females although there was no significant difference in the infection rate between the sexes. In North-central Nigeria, Ayanda (2009) found that both males and females of *C. gariepinus* had a similar prevalence of intestinal helminth infection. The present and previously recorded variations in the infection levels between males and females of *C. gariepinus* support the suggestion of the presence of other factors that can affect the infection level of these parasites. Allam et al. (2023) suggested the following factors: host biotic parameters (size and feeding habit) and water abiotic factors (physicochemical parameters, heavy metals concentration, pH, oxygen, and temperature).

The present investigation showed variations in the relationship between helminth parasite infection levels and proposed classes of host condition factor. No specific pattern can be seen. However, higher values for all infection parameters of *O. batrachoides, E. bangweulensis* and *P. cyathopharynx* were recorded in the class II host condition factor than in other classes. Moreover, a highly significant difference in the mean prevalence between different host classes was detected for *T. ciliotheca*, *M. chalmersius* and *P. pseudolaeviconchus* while a significant difference in the mean prevalence was noticed for only *E. bangweulensis.* This is a good indication that the host condition factor may influence the level of infection of parasitic helminths. An increase in the prevalence of parasitic helminths was reported by Mansour et al. (2003) as the host size increases. Abdel-Gaber et al. (2015) found no significant difference in the parasitic infection among the three size classes of *C. gariepinus* at Manzala Lake, although fish of larger sizes had more infections. Similar data were reported by Allam et al. (2023) for the parasitic helminths of *Bagrus* spp. in the Damietta River Nile branch. In contrast, Tasawar et al. (2007) and Kawe et al. (2016) showed that smaller fish had a greater parasite load. Mgbemena et al. (2020) attributed the higher prevalence value of helminth parasites on big-sized fish to their feeding habit.

Author contributions AFET, MIM and MMEN made a substantial contribution to the conception and design of the study. All authors contributed to data acquisition. AFET collected fish, examined the parasites, and photographed them. All authors analyzed and interpreted the data. AFET has written the first draft of the manuscript and all authors revised it critically. All authors read and approved the final manuscript.

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Declarations

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval No experiments were performed on live fish. All applicable institutional, national, and international guidelines for the care and use of animals were followed. Mansoura University ethics approval no. Sci-Z-M-2020–8.

Consent to participate Authors, declare that they have participated in this work.

Consent to publication Authors declare that they know the content of this manuscript and agreed to submit it for publishing.

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