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PARASITIC INFECTIONS AND HISTOPATHOLOGICAL CHANGES IN THE SQUEAKER FISHES, *SYNODONTIS SERRATUS* AND *SYNODONTIS SCHALL* FROM LAKE NASSER, EGYPT

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ABSTRACT

This work describes the parasitic infections in wild *Synodontis serratus* and *Synodontis schall* from Lake Nasser, Egypt and the histopthological impacts of these parasites on the infected fish. A total number of 100 *Synodontis serratus* and 100 *Synodontis schall* were collected alive from several and various localities of the lake during 2018. One cestode: *Wenyonia virilis*, three nematodes: *Cithariniella citharini*, *Procamallanus laeviconchus* and *Spirocamallanus pseudospiralis* (new locality record) and one zoonotic encysted metacercaria of trematode: *Centrocestus formosanus* (new hosts record) were identified from both fish species; in addition to, one cestode: *Proteocephalus sulcatus* and one acanthocephalan: *Rhadinorhynchus* sp. (new host record) were only recorded from *Synodontis schall*. The infection rates of examined fish; *Synodontis serratus* and *Synodontis schall* were 54% and 78% respectively. This study evaluated clinical signs, postmortem lesions, organ or tissue susceptibility, incidence, intensity of infection, seasonal prevalence and histopathological alterations induced by these parasitic infections. Interestingly, the musculature of the fish was free from any parasitic infections and safe for human consumption provided that the fish would be eviscerated and adequately cooked. This work provides analysis of fish-parasite fauna which is a very helpful tool for implementing control and preventative measures against parasitic diseases especially the zoonotic ones.

Key words: *Synodontis serratus*, *Synodontis schall*, *Spirocamallanus pseudospiralis*, *Centrocestus formosanus*, *Rhadinorhynchus* sp.

INTRODUCTION

In the world there are 13,000 freshwater fish species, 25% of them are in African freshwater bodies (Lévêque *et al.*, 2008). The catfish, *Synodontis* species of the family Mochokidae are freshwater tropical fish of high commercial value in most African countries; they inhabit rivers and lakes especially the Nile and its tributaries, and represent an important food fish (Bishai and Abu Gideiri, 1967; Steffens, 2006 and Eyo and Effanga, 2018).

Synodontis species are of the contemporary fish species in Lake Nasser after tilapias (the predominant species). They are small to medium sized fish, omnivorous, feeding mainly on animal food (fish, worms, mollusks and insects), some food of plant origin, phyto- and zooplankton (Bishai *et al.*, 2000). They support the commercial fisheries in Egypt (Mekkawy and Hassan, 2011). *Synodontis serratus* and *Synodontis schall*; are from the most common fish of family Mochokidae in Egypt, distributed in the whole River Nile and Lake Nasser. They popularly known as korkar, gargour or squeakers due to the sounds they make when removed from the water by rubbing their spines together (Latif, 1974 and Bishai and Khalil, 1997).

Parasites can act as severe pathogens competing for food with the fish host, thereby depriving them of essential nutrients and inhibiting their growth leading to morbidity or even mortality, rendering the fish more vulnerable to predators (Azadikhah *et al.*, 2014 and Omeji *et al.*, 2015) as well as, they may have zoonotic threats to animal and human consumers (Hamouda *et al.*, 2018 and Hamouda, 2018). *Centrocestus formosanus* is a minute trematode species of family Heterophyidae which has zoonotic importance (Darwin and Fried, 2007 and Jong-Yil *et al.*, 2013). It inhabits the intestine of piscivorous birds and mammals as final hosts while; the snails including *Melanoides tuberculata* act as the first intermediate hosts (Yousif *et al.*, 2016); as well as, various species of freshwater fishes, frogs, and toads act as second intermediate hosts (Sohn and Chai,

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2005 and Han *et al.*, 2008). However, human infections with this fluke have been documented so the zoonotic potential of this trematode should be regarded as a public health issue especially for humans eating undercooked or raw infected fish (Mehrdana, 2014). The parasitic infections of wild fish are common where the ecological requirements for intermediate hosts, final hosts and parasite transmission are met (Feist and Longshaw, 2008).

To date, there is dearth of information on parasitic diseases infecting *Synodontis* spp. especially in Egypt; most reports concern surveys on parasites of some fish species of Lake Nasser (El-Naffar *et al.*, 1983 and Saoud and Wannas, 1984) as well as, some researchers focus on certain parasites as Moravec (1974 and 1994), Fahmy *et al.* (1976), Imam *et al.* (1991), Al-Bassel (2003) and Rabei (2009) so the fauna of parasitic infections in *Synodontis serratus* and *Synodontis schall* of Lake Nasser remains little known; this study was planned to investigate the parasites infecting these two fish species in the lake recording the clinical signs, postmortem lesions, organ or tissue susceptibility, prevalence, seasonal incidence, intensity and the histopathological changes induced by these detected parasites.

MATERIALS AND METHODS

Study area and fish samples

The present research was carried out in Lake Nasser (southern region of Egypt), located between latitudes 22º 00' - 23 º 58' N and longitudes 31 º 19' - 33 º 19' E, 900 km from Cairo.

A total number of 200 wild Mochokidae, 100 *Synodontis serratus* and 100 *Synodontis schall* (Table 1) were collected alive from various localities of Lake Nasser seasonally (25 fish of each species/season) from January to December 2018. Fish were transported as quickly as possible to the laboratory of Fish Diseases, Faculty of Fish and Fisheries Technology, Aswan University, for clinical and parasitological examinations.

Clinical, postmortem and parasitological examinations

The investigated fish were weighed and measured then they were euthanized rapidly by cervical dislocation prior to dissection according to AVMA (2013) (Research ethics committee of the University, approval no.12/2017). The procedure complies with national and local animal welfare laws, guidelines and policies. The fish were subjected to full clinical, postmortem and parasitological examinations according to the methods described by Noga (2010) and Eissa (2016).

Collected cestodes and acanthocephalans were left in the refrigerator at 4^0C for few hours till complete relaxation, and then fixed in AFA (alcohol- formol - acetic acid). For permanent preparation, they stained with acetic acid alum carmine, dehydrated in ascending grades of ethanol series, cleared and mounted in Canada balsam or DPX. The isolated nematodes were kept in glycerin alcohol (70% ethanol plus 5% glycerol) then washed in 70% ethanol, cleared in lacto phenol and mounted in glycerol gelatin. Collected parasites were identified according to Khalil (1964), Arai (1989), Scholz and Salgado-Maldonado (2000), Moravec and Van As (2004), Ibraheem and Mackiewicz (2006), Scholz *et al.* (2009), and Moravec & Scholz (2017).

Organ or tissue susceptibility, prevalence and seasonal incidence for each detected parasite were recorded.
Intensity of infection was recorded according to the following formula:

Intensity of infections = total number of a particular parasite species in a sample of a host species / number of infected individuals of the host species in this sample.

Obtained results were statistically analyzed using the mean and the standard error of the mean (SEM) by using the IBM SPSS statistics version 22 (SPSS 2013).

Histopathological examination

Tissue specimens from intestine, stomach, liver, kidney, spleen and gills of the infected fish showing gross lesions were kept in 10% formalin and processed for histopathological evaluation, using the routine paraffin embedding method as described by Bancroft and Gamble (2007).

RESULTS

Clinical examination of *Synodontis serratus* and *Synodontis schall* revealed no pathognomonic lesions except presence of some hemorrhagic patches on different parts of infected fish's skin (Fig. 1 A) as well as, congested gills with excessive mucus secretions. The postmortem findings of naturally infected fish revealed severely congested stomach, intestine, liver, spleen and kidney (Fig. 1 C) especially in case of *Proteocephalus sulcatus* infection (Fig. 1 B). Visible parasites could be seen by naked eyes in the stomach and intestine.

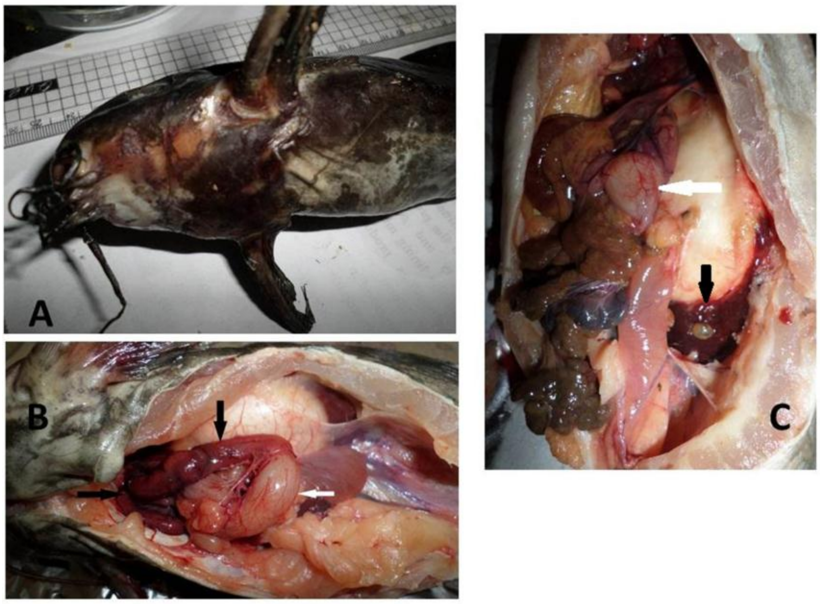

Fig. 1: A: *Synodontis serratus* infected with internal parasites showing hemorrhagic patches on the abdomen.
B: *Synodontis schall* infected with *Proteocephalus sulcatus*, *Cithariniella citharini* and *Procamallanus laeviconchus* showing severely congested intestine (black arrows) and congested stomach (white arrow).
C: *Synodontis serratus* infected with *Procamallanus laeviconchus* showing congested stomach (white arrow) and kidney (black arrow).

The following parasites were identified, on the bases of the morphological examinations:

Wenyonia virilis (Woodland, 1923)
Host: *Synodontis serratus* and *Synodontis schall*

Wenyonia virilis is a Caryophyllidean tapeworm; has a monozoic body type, containing only a single set of male and female genital organs. The adult is elongated, dorsoventrally flattened and measuring 7–21mm long. The scolex is conical, may be round to flatten in cross-section and approximately 10% of the total worm length (Fig. 2).

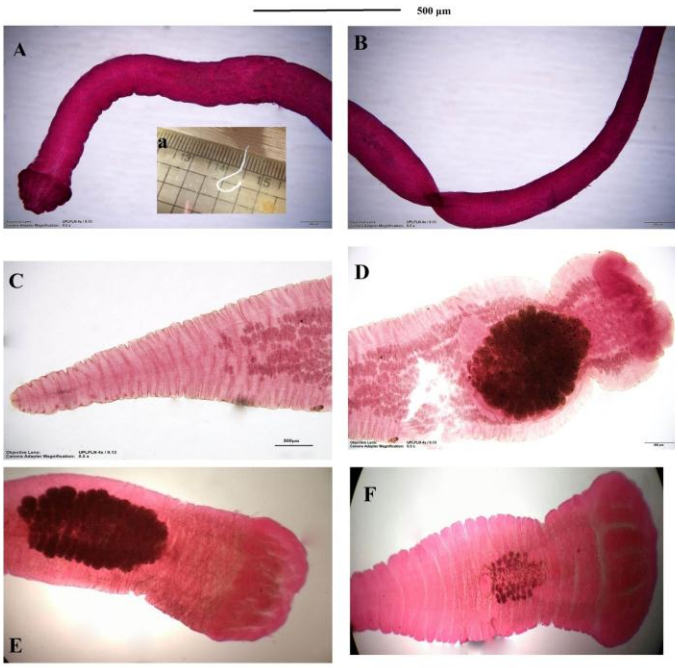

Fig. 2: Different developmental stages of *Wenyonia virilis*
A: Anterior end of adult stage stained with acetic acid alum carmine x 4, a: Whole mature cestode.
B: Posterior end of adult stage stained with acetic acid alum carmine x 4,
C, D, E and F: Different developmental stages stained with acetic acid alum carmine x 4. Scale bar = 500 µm.

Proteocephalus sulcatus (Goeze, 1782)
Host: *Synodontis schall*

Proteocephalus sulcatus is a Proteocephalidean segmented tapeworm, their testes, ovary, vitelline follicles, and uterus are medullary. Immature proglottids are wider than long to square while mature proglottids are very few in number and slightly longer than wide. Scolex is unarmed, wider than neck with four suckers. Testes are medullary, spherical to oval, in 1 or 2 incomplete layers, forming 1 field between osmoregulatory canals and ovary. Ovary is bilobed, with very wide and short lobed lateral wings. (Fig.3).

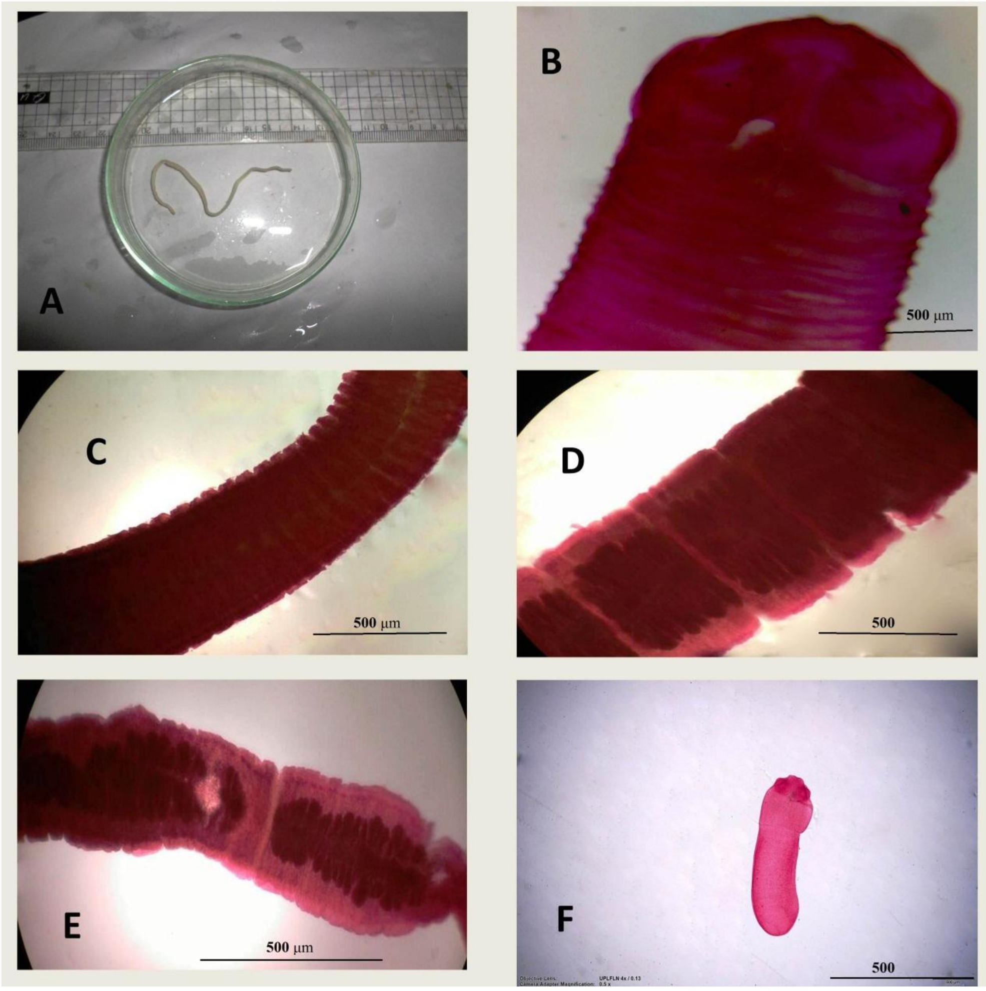

Fig. 3: *Proteocephalus sulcatus*
A: Whole, mature cestode.
B: Scolex stained with acetic acid alum carmine x 4,
C and D: Immature segments stained with acetic acid alum carmine x 4,
E: Mature segments stained with acetic acid alum carmine x 4,
F: Small developmental stage stained with acetic acid alum carmine x 4.
Scale bar = 500 µm.

***Rhadinorhynchus* sp.** (Rudolphi, 1802)
Host: *Synodontis schall*

The acanthocephalan parasite; *Rhadinorhynchus* sp. is isolated for the first time from *Synodontis schall* of Lake Nasser and this may be a new host record. The male is white in color with long, cylindrical body, measuring up to 2 centimeters and has subcylindrical proboscis that enlarged slightly anteriorly, armed with 14-16 longitudinal rows of 26 hooks each and the ventral hooks of anterior two-thirds of proboscis are weaker, slightly shorter than others. Testes are elongate and tandem in posterior half of the trunk. Cement glands are nearly as long as both testes (Fig. 4).

Fig. 4: *Rhadinorhynchus* sp. isolated from *Synodontis schall*:
A: Male stained with acetic acid alum carmine x 4, scale bar = 500 µm.
B: Wet mount of anterior end x 20, scale bar = 100 µm.
C: Proboscis showing arrangement of hooks stained with acetic acid alum carmine x 40, scale bar = 50 µm.

Citharinіella citharini (Khalil, 1964)
Host: *Synodontis serratus* and *Synodontis schall*

Citharinіella citharini is very small nematode, measuring few millimeters, whitish in color and possess a delicate cuticle. The oesophagus is cylindrical, uniform in diameter and ends in a single bulb which separate by a constriction (isthmus) from the end of corpus. The intestine is straight and narrow. The female is longer than male measuring 6.5 - 7.5 mm long. The body become narrow behind the anal opening and forms a long pointed tail. There are two ovaries; the anterior is slightly below the bulb and the posterior in front of the vulva. The uteri are filamentous; coil and fill with eggs which are connect together with filaments inside the uterus. Eggs are immature, oval in shape, flat from one side and convex from the other. The male is small and strongly curved posteriorly, measuring 3.5 - 4.5 mm long. The tail is long, pointed and curved ventrally. A single testis is located anteriorly to a level slightly posterior to the excretory pore. A single spicule is present (Fig. 5).

Fig. 5: *Citharinіella citharini*
A: Whole nematode attached to the intestinal wall x 20, scale bar = 100 µm.
B: Whole mount x 4, scale bar = 500 µm.
C: Anterior end x 10, scale bar = 200 µm. Oes.; Oesophagus- Oes.B.; Oesophgeal bulb- Int; Intestine.
D: Middle part of female showing eggs inside it x 20, scale bar = 100 µm.
E: Posterior end of female x 20, scale bar = 100 µm.
F: Eggs x 40, scale bar = 50 µm. Eg.f.; Egg filament

Procamallanus laeviconchus (Wedl, 1861)
Host: *Synodontis serratus* and *Synodontis schall*

A small to medium-sized nematode, measuring 2.7-6.5mm long with thick, roughly transversely striated cuticle. Live specimen is red in color. Buccal capsule is yellowish and barrel-shape. Muscular esophagus is slightly shorter than glandular esophagus. Males are smaller than gravid females. The two spicules of male are simple, with sharply pointed distal tips and the tail is conical, with rounded tip. The female uterus contains numerous coiled larvae. Anterior ovary is well developed, extend anteriorly to region of glandular esophagus and posterior ovary is absent. The female tail is conical, with 3 small finger-shaped processes (Fig. 6).

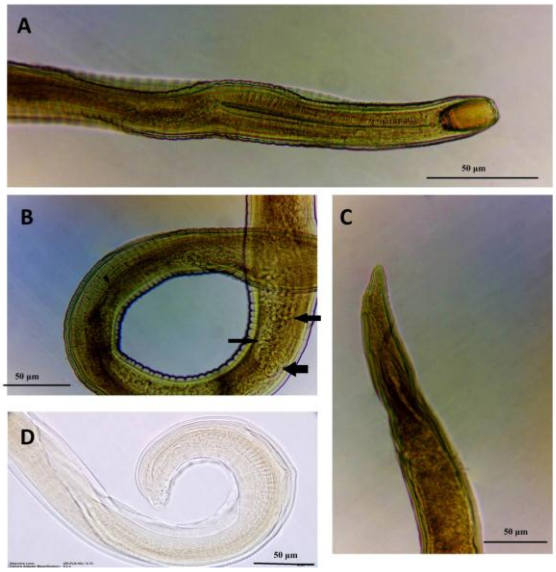

Fig. 6: *Procamallanus laeviconchus*
A: Anterior end x 40,
B: Female's middle part filled with coiled larvae (arrows) x 40,
C: Posterior end of male x 40, D: Posterior end of female x 40, scale bar = 50 µm.

Procamallanus* (*Spirocamallanus*) *pseudospiralis (Moravec and Scholz, 2017)
Host: *Synodontis serratus* and *Synodontis schall*

The nematode is medium-sized, measuring 2 - 2.5 cm long. Live worm is red in color resemble *Procamallanus laeviconchus* but longer than it and the buccal capsule is barrel-shaped, with 8–11 spiral ridges. The excretory pore is usually at level of anterior end of glandular esophagus. Tail of gravid female is conical, with short, abruptly narrowed distal end and tip is sharply pointed (Fig. 7). The present finding of this parasite represents new locality record.

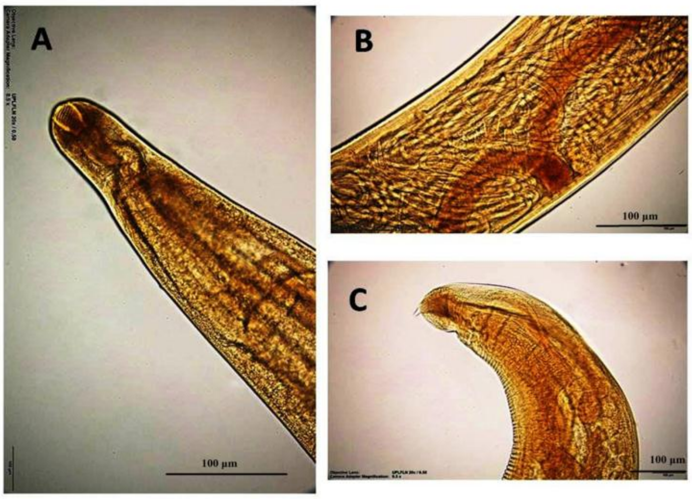

Fig. 7: *Spirocamallanus pseudospiralis*
A: Anterior end of female x 20, scale bar = 100 µm.
B: Female's middle part filled with coiled larvae x 20, scale bar = 100 µm.
C: Posterior end of female x 20, scale bar = 100 µm.

Encysted metacercariae (EMC) of *Centrocestus formosanus*

Host: *Synodontis serratus* and *Synodontis schall*

The encysted metacercariae are oval in shape, contain pear-shaped parasites with an X-shaped excretory bladder occupying the greater part of the posterior body. (Fig. 8). The present finding of this parasite represents new hosts record.

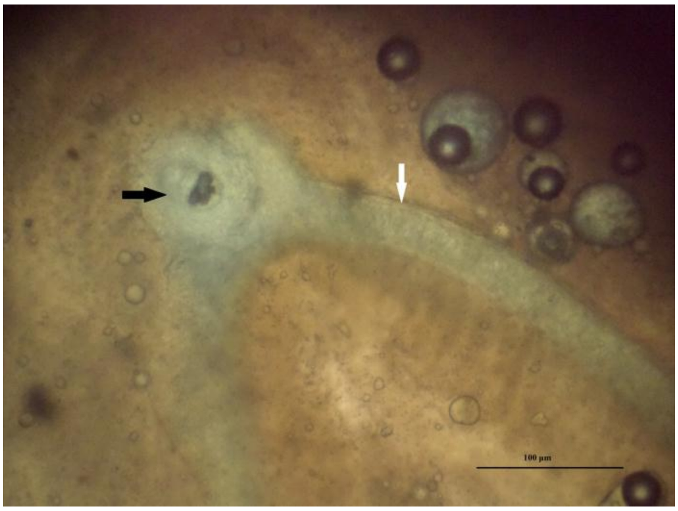

Fig. 8: EMC of *Centrocestus formosanus* (black arrow), migrating tunnel (white arrow) x 20, scale bar = 100 µm.

Of the 100 *Synodontis serratus* examined, only 54% recorded to be infected with at least one parasite while of the 100 *Synodontis schall* examined, 78 % recorded to be infected with at least one parasite (Table 1).

Table 1: Examined fish species and total prevalence of infection during the period of January to December 2018.

Fish species	Weight (M± SEM) gm	Length (M± SEM) cm	No. of examined fish	No. of infected fish	Prevalence of infection
Synodontis serratus	188.033± 33.62	25.33 ± 2.06	100	54	54
Synodontis schall	373.20±111.64	29.25 ± 2.03	100	78	78

M (Mean), SEM (Standard error of the mean).

The intestine was the main target organ of infection for both fish species (Table 2, 3). The organ or tissue susceptibility, relative and intensity of parasitic infections in *Synodontis serratus* and *Synodontis schall* were summarized in Table 2, 3 respectively. Five parasitic species were detected in *Synodontis serratus*: *Wenyonia virilis*, *Citharinella citharini*, *Procamallanus laeviconchus*, *Spirocamallanus pseudospiralis* and EMC of *Centrocestus formosanus* with prevalence of 25%, 40%, 36%, 12% and 23% respectively. Meanwhile, seven parasitic species were detected in *Synodontis schall*: *Wenyonia virilis*, *Proteocephalus sulcatus*, *Rhadinorhynchus* sp., *Citharinella citharini*, *Procamallanus laeviconchus*, *Spirocamallanus pseudospiralis* and EMC of *Centrocestus formosanus* with prevalence of 36%, 60%, 7%, 44%, 23%, 5% and 11% respectively (Table 2, 3).

In this study, *Citharinella citharini* was the most prevalent parasite in *Synodontis serratus* (40%) while *Proteocephalus sulcatus* was the most prevalent in *Synodontis schall* (60%) (Table 2, 3).

Citharinella citharini was recorded to be the highest parasite intensity burden in *Synodontis serratus* and *Synodontis schall* with intensities of 12.32±1.92 and 11.4±1.35 respectively (Table 2, 3).

Table 2: Organ or tissue susceptibility, relative prevalence and intensity of parasitic infections in *Synodontis serratus* from Lake Nasser during the period of January to December 2018.

Parasite Taxa	Organ susceptibility	No. of examined fish	No. of infected fish	Prevalence of infection	Intensity of infection	
					Min/Max	(M ± SEM)
CESTODA						
Wenyonia virilis	Intestine	100	25	25	1/7	2.96±0.34
NEMATODA						
Cithariniella citharini	Intestine	100	40	40	1/55	12.32±1.92
Procamallanus laeviconchus	Stomach and intestine	100	36	36	1/7	3.13±0.28
Spirocamallanus pseudospiralis	Intestine	100	12	12	1/3	1.66±0.33
TREMATODA						
EMC of *Centrocestus formosanus*	Gills	100	23	23	2/22	10.6±0.22

EMC (Encysted metacercariae), Min (Minimum), Max (Maximum), M (Mean), SEM (Standard error of the mean)

Table 3: Organ or tissue susceptibility, relative prevalence and intensity of parasitic infections in *Synodontis schall* from Lake Nasser during the period of January to December 2018.

Parasite Taxa	Organ susceptibility	No. of examined fish	No. of infected fish	Prevalence of infection	Intensity of infection	
					Min/Max	(M ± SEM)
CESTODA						
Wenyonia virilis	Intestine	100	36	36	1/7	3.02±0.26
Proteocephalus sulcatus	Intestine	100	60	60	1/6	2.28±0.157
ACANTHOCEPHALA						
Rhadinorhynchus sp.	Intestine	100	7	7	1/3	1.57±0.29
NEMATODA						
Cithariniella citharini	Intestine	100	44	44	2/40	11.4±1.35
Procamallanus laeviconchus	Stomach and intestine	100	23	23	1/6	2.82±0.29
Spirocamallanus pseudospiralis	Intestine	100	5	5	1/2	1.2±0.20
TREMATODA						
EMC of *Centrocestus formosanus*	Gills	100	11	11	2/15	8.81±1.42

EMC (Encysted metacercariae), Min (Minimum), Max (Maximum), M (Mean), SEM (Standard error of the mean)

The seasonal incidence of parasitic infections among investigated *Synodontis serratus* and *Synodontis schall* were recorded in Table 4, 5 respectively.

Higher infection rates of *Synodontis serratus* with *Wenyonia virilis*, *Cithariniella citharini* and *Procamallanus laeviconchus* were observed during spring (48%, 72% and 52%) respectively, meanwhile *Spirocamallanus pseudospiralis* and EMC of *Centrocestus formosanus* prevailed in winter (24% and 32% respectively) (Table 4).

In *Synodontis schall*, higher infection rates of *Wenyonia virilis*, *Cithariniella citharini* and *Procamallanus laeviconchus* were observed during spring (48%, 60% and 32%) respectively. *Proteocephalus sulcatus* showed a higher infection rate in summer (88%) while, *Rhadinorhynchus* sp. recorded a higher infection rate in winter (12%). *Spirocamallanus pseudospiralis* showed higher infection rates in both spring and autumn (8%) for each season. EMC of *Centrocestus formosanus* revealed a higher infection rate in autumn (20%) (Table5).

Table 4: Seasonal incidence of parasitic infections among investigated *Synodontis serratus* from Lake Nasser during the period of January to December 2018 (number of fish in each season=25).

Parasites	Seasons							
	Spring		Summer		Autumn		Winter	
	No.	%	No.	%	No.	%	No.	%
Wenyonia virilis	12	48	8	32	3	12	2	8
Cithariniella citharini	18	72	11	44	8	32	3	12
Procamallanus laeviconchus	13	52	10	40	9	36	4	16
Spirocamallanus pseudospiralis	3	12	2	8	6	24	1	4
EMC of *Centrocestus formosanus*	5	20	6	24	8	32	4	16

EMC (Encysted metacercariae)

Table 5: Seasonal incidence of parasitic infections among investigated *Synodontis schall* from Lake Nasser during the period of January to December 2018 (number of fish in each season=25).

Parasites	Seasons							
	Spring		Summer		Autumn		Winter	
	No.	%	No.	%	No.	%	No.	%
Wenyonia virilis	12	48	10	40	9	36	5	20
Proteocephalus sulcatus	18	72	22	88	17	51	3	12
Rhadinorhynchus sp.	1	4	1	4	2	8	3	12
Cithariniella citharini	15	60	12	48	10	40	7	28
Procamallanus laeviconchus	8	32	7	28	3	12	5	20
Spirocamallanus pseudospiralis	2	8	1	4	2	8	0	0
EMC of *Centrocestus formosanus*	1	4	3	12	5	20	2	8

EMC (Encysted metacercariae)

Histopathological examination

Gastric mucosa of *Synodontis serratus* infected with *Procamallanus laeviconchus* showed marked degenerative changes of the gastric glands (Fig. 9 A).

Gills of *Synodontis serratus* infected with *Centrocestus formosanus* showed nodular lesions associated with parasitic infestation in the cartilage of the gill filaments and revealed marked hyperplasia of the chondrocytes (Fig. 9 B, C).

Kidney of *Synodontis serratus* infected with *Procamallanus laeviconchus, Cithariniella citharini* and *Centrocestus formosanus* showed degeneration of the renal tubules and depletion of the melanomacrophages centers (Fig. 9 D); while the liver showed degeneration of the hepatocytes (Fig. 10 A) as well as, the spleen showed marked depletion of melanomacrophages centers (Fig. 10 B).

The histopathological features of *Synodontis schall*'s intestine infected with both *Proteocephalus sulcatus* and *Cithariniella citharini* showed severe congestion of the blood vessels within the lamina propria (Fig. 10 C) as well as, luminal necrotic mass was present (Fig. 10 D). The liver showed marked necrosis of the pancreatic portion (Fig. 11 A); while the Kidney showed marked congestion, haemorrahge, tubular degeneration and interstitial leukocytic infiltration (Fig. 11 B, C).

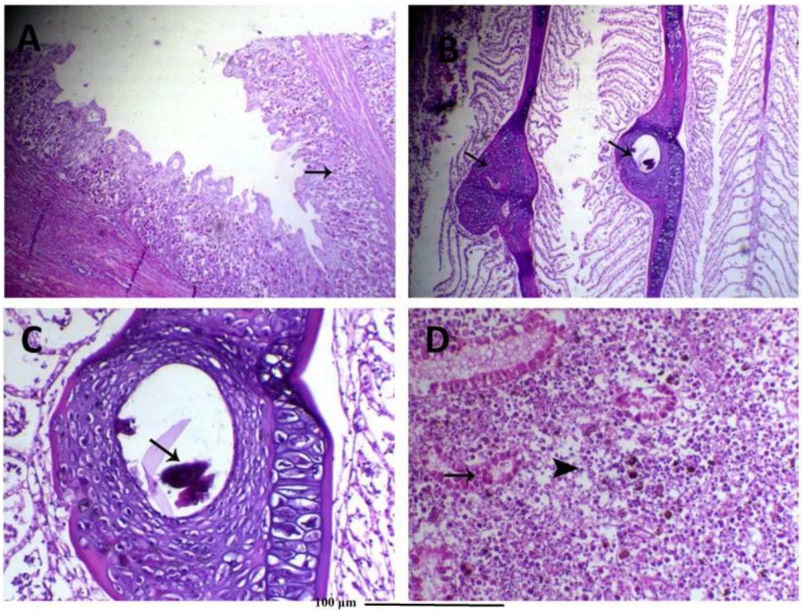

Fig. 9: A: Gastric mucosa of *Synodontis serratus* infected with *Procamallanus laeviconchus* showing marked degenerative changes of the gastric glands (arrow), H&E, X100,
B: Gills of *Synodontis serratus* showing nodular lesions associated with skeletal EMC of *Centrocestus formosanus* (arrows), H&E, X100,
C: Gills of *Synodontis serratus* showing nodular lesions associated with EMC of *Centrocestus formosanus* infestation in the cartilage of the gill filaments (arrow) and revealing marked hyperplasia of the chondrocytes, H&E, X200,
D: Kidney of *Synodontis serratus* infected with *Procamallanus laeviconchus*, *Cithariniella citharini* and EMC of *Centrocestus formosanus* showing degeneration of the renal tubules (arrow) and depletion of the melanomacrophages centers (arrowhead), H&E, X200, scale bar = 100 µm.

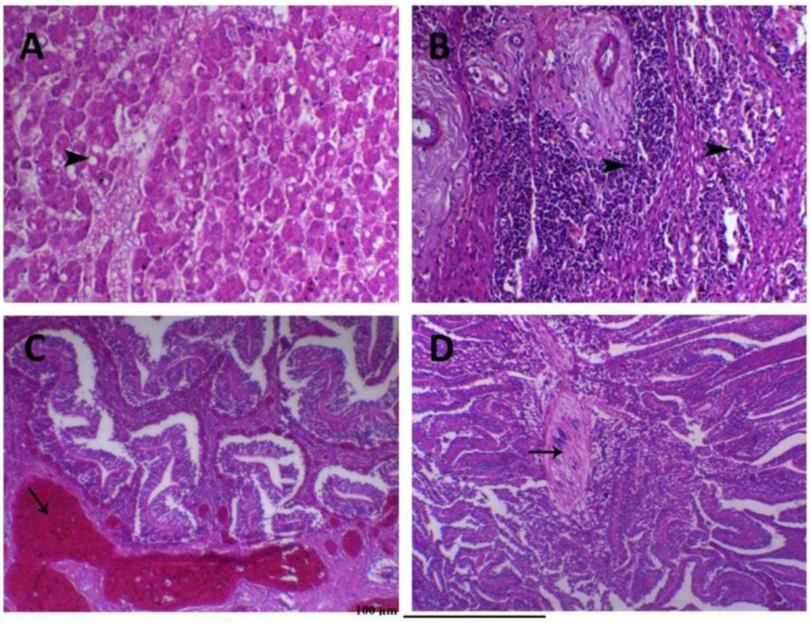

Fig. 10: A: Liver of *Synodontis serratus* infected with *Procamallanus laeviconchus*, *Cithariniella citharini* and EMC of *Centrocestus formosanus* showing degeneration of the hepatocytes (arrowhead indicates fatty changes), H&E, X200,
B: Spleen of *Synodontis serratus* infected with *Procamallanus laeviconchus*, *Cithariniella citharini* and EMC of *Centrocestus formosanus* showing marked depletion of melanomacrophages centers (arrowheads), H&E, X200,
C: Intestine of *Synodontis schall* infected with *Proteocephalus sulcatus* and *Cithariniella citharini* showing severe congestion of the blood vessels within the lamina propria (arrow), H&E, X100,
D: Intestine of *Synodontis schall* infected with *Proteocephalus sulcatus* and *Cithariniella citharini* showing luminal necrotic mass which may be related to dead parasite (arrow), H&E, X100, scale bar = 100 µm.

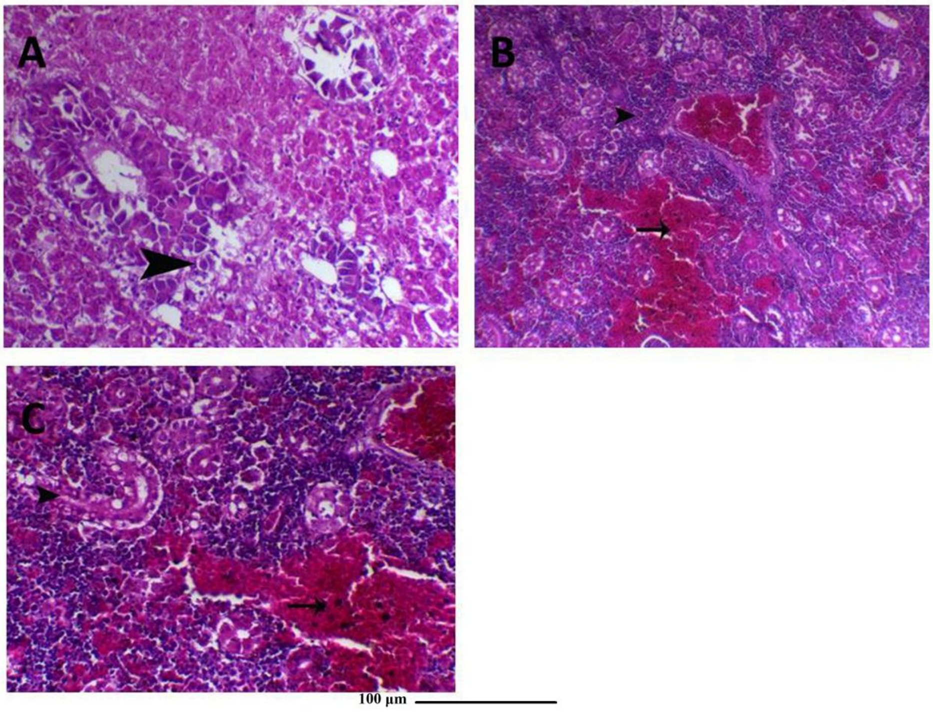

Fig. 11: *Synodontis schall* infected with *Proteocephalus sulcatus* and *Cithariniella citharini*:
A: Liver showing marked necrosis of the pancreatic portion (arrowhead), H&E, X200,
B: Kidney showing marked congestion, haemorrahge (arrow) and interstitial leukocutic infiltration (arrowhead), H&E, X 100,
C: Kidney showing marked haemorrahge (arrow), tubular degeneration (arrowhead) and interstitial leukocutic infiltration, H&E, X200, scale bar = 100 µm.

DISCUSSION

Studies on parasitic fauna in the squeaker fishes; *Synodontis serratus* and *Synodontis schall* are still scarce especially in Egypt. Understanding the occurrence, organ or tissue susceptibility, relative prevalence, seasonal incidence, intensity and histopathplogical alterations induced by the parasites in these fish species is thus vital when implementing protective measures and planning disease management strategies (Subasinghe *et al.*, 2001 and Crafford *et al.*, 2014).

The detected cestodes, acanthocephalan, nematodes and trematode in the fish examined have complicated life cycles; as they need intermediate hosts such as snails, leeches and some crustaceans for propagation and transmission to fish (Paperna, 1996; Ferguson, 2011; Ramadan, 2012 and Hamouda, 2014). Hemorrhagic patches on different parts of the fish's body and congested gills were always found on the infected fish due to blood congestion and hemorrhages at the point of cercariae penetration and leeches attachment. Excessive mucus secretion may act as a defensive mechanism to diminish the irritant effect of the pathogen.

Severely congested intestine and stomach may be due to the detected parasites in intestine and stomach which embed themselves between the villi of the intestine and the lining mucosa of stomach causing local damage and may be peritonitis. Some helminthes produce toxic metabolic by-products which harm their hosts, causing occlusion of blood vessels, intestine and other ducts so internal organs revealed congestion and inflammation. Some adult worms discharged proteolytic enzymes, degrading the gastric and intestinal tissues (Woo, 1995).

Siluriform including *Synodontis* fish spp. are the most common hosts for cestodes in Africa. The first intermediate hosts of Caryophyllaeid cestodes are oligochaete worms, Tubifex and allied genera while first intermediate hosts of *Proteocephalus* are copepods, a second larval stage, pleurocercoids, develops in fish species non compatible as definitive hosts (Hoffman, 1967). All these hosts are available nearly all over the year in Lake Nasser and these clarify the high infection rate of cestodes in these fish species in the lake. The genus *Wenyonia* (Woodland, 1923) was reported only from Africa which involved eight species. Khalil and Polling (1997) reported three species of *Wenyonia* from the Nile: *W. minuta*; *W. acuminate* and *W. virilis* from Egypt. The morphological characteristics of the *Wenyonia virilis* parasite isolated in this study resembled the previously described *W. virilis* (Ibraheem and Mackiewicz, 2006 and Bjoern *et al.*, 2011). Eighteen species of Proteocephalidean tapeworms have been described from freshwater fishes in Africa (De

Chambrier *et al.*, 2009) from which *Proteocephalus sulcatus* of this study resembled the previously recorded by De Chambrier *et al.* (2007); Scholz *et al.* (2009) and Azadikhah *et al.* (2014). Scholz *et al.* (2009) described *Proteocephalus glanduligerus* from *Clarias* cf. *anguillaris* from Sudan.

The morphological description of *Rhadinorhnchus* sp. reported in the present study was similar to that described by (Arandas Rego, 1987 and Arai, 1989) and it is the first time to detect it from *Synodotis schall* so it may be new host record. Acanthocephalans are thorny headed, worldwide distributed parasites; the adults inhabit the fish's intestine and feed on the intestinal walls (Alava and Aguirre, 2005). The infections of fish with Acanthocephalans revealed severe pathological lesions because of their hooked proboscis which attach to the host intestinal wall. They have complex life cycles, including arthropods as the intermediate hosts, fishes, birds, amphibians and mammals as the definitive hosts (Dudinak and Snabel, 2001) so it is normal to be found in the lake where all the ecological factors required for their hosts' propagation are available.

Citharinella citharini was recorded by many authors from *Synodontis* spp. in Egypt (Moravec, 1974 & 1994; Fahmy *et al.*, 1976; El-Naffar *et al.*, 1983; Imam *et al.*, 1991; Al-Bassel, 2003 and Rabei, 2009) but Moravec and Van As (2015a) considered it *Citharinella khalili*. Koubková *et al.* (2010) recorded three species of *Citharinella*; *C. citharini, C. khalili, and C. gonzalesi*, from the squeaker (Mochokidae: Siluriformes) fishes from Senegal, West Africa.

Procarnallanus laeviconchus is one of the most prevalent and widespread nematodes in Africa, taking fish as final hosts and copepods as intermediate hosts (Moravec, 1974). It was described for the first time from *Synodontis schall* from Egypt by Wedl (1861). Later, it was recorded from different fish species including *Clarias gariepinus* and *Bagrus bajad* (Hamouda, 2018) while; Moravec & Van As (2004) isolated it from *Synodontis vanderwaali* and *S. nigromaculatus* in Botswana.

Some authors consider that, *Spirocamallanus* is a subgenus of *Procamallanus* because it separated from it only by the presence of spiral thickening in the internal surface of buccal capsule of both sexes (Moravec and Sey, 1988 and Rodrigues *et al.*, 1991) but others consider it as separate genus (Chabaud, 1975 and Petter, 1979). Moravec and Van As (2015b) recorded it from fishes of the Okavango River, Botswana while, Moravec and Scholz (2017) recorded *Spirocamallanus pseudospiralis* from *Synodontis schall* in the Sudan and the Democratic Republic of the Congo. To the best of our knowledge, there have been no published reports on isolation of *Spirocamallanus pseudospiralis* from *Synodontis* spp. and other fish species of Lake Nasser, so it is considered new locality record.

In this study, EMC of *Centrocestus formosanus* were found in the gill filaments of *Synodontis serratus* and *Synodontis schall* of Lake Nasser for the first time recording new hosts record and adding these fish to the actually known second intermediate hosts for these parasites. Saad (1994) isolated *Centrocestus unequiorchalis* n. sp. from the gills of *Oreochromis niloticus* at Aswan governorate and Hamouda (2018) isolated EMC of *Centrocestus formosanus* from the gills of *Bagrus bajad* from Lake Nasser. Morphological identification of *Centrocestus formosanus* EMC was similar to that recorded by (Abd Al-Aal *et al.*, 2008; Reda *et al.*, 2010; Hamouda, 2014 and Hamouda, 2018).

It is worth mentioning that, Lake Nasser is rich in insect larvae, mollusks, oligochaetes, snails, freshwater shrimps and many others (Bishai *et al.*, 2000) which act as first intermediate hosts for the detected parasites, as well as, fish as second intermediate host in some cases and finally piscivorous birds, fish and reptiles as definitive final hosts. This may explain the high parasitic group burden in the examined *Synodontis serratus* (54%) and *Synodontis schall* (78%) in addition to, the omnivore nature of the examined fish.

In the present work, the intestine was the most susceptible organ of infection for both investigated fish species and this may be due to the fact that alimentary canal is a primary route of infection in fish and other vertebrates (Ringo *et al.*, 2007). The GIT may provide ease of access for the pathogens with relatively non- aggressive immune response of the host; and availability of attachment sites and access to nutrients (Secombes and Chappell, 1996).

In the present study, *Wenyonia virilis* was recorded with total prevalence of 25 % and 36% from *Synodontis serratus* and *Synodontis schall* respectively and this result was nearly similar to those recorded by El-Naffar *et al.* (1983) who recorded *Wenyonia virilis* from *Synodontis serratus* and *Synodontis schall* with prevalence of 31.3% and 32.5% respectively from Lake Nasser while, Saoud & Wannas (1984) did not report any cestotal infections in these two fish species of the lake. Ibraheem and Mackiewicz (2006) recorded the immature stages of *Wenyonia virilis* from *Synodontis schall* at the River Nile, Egypt with prevalence of 44%.

Proteocephalus sulcatus was recorded from *Synodontis schall* with prevalence of 60% and this result was nearly similar to that recorded by El-Naffar *et al.* (1983) who recorded it from *Synodontis schall* of Lake Nasser with prevalence of 65.7%.

Cithariniella citharini was recorded with total prevalence of 40 % and 44% from *Synodontis serratus* and *Synodontis schall* respectively with intensities of 12.32±1.92 and 11.4±1.35 respectively. This result was higher than that recorded by El-Naffar *et al.* (1983) who recorded it from *Synodontis serratus* and *Synodontis schall* with prevalence of 26.6% and 28.5% respectively and lower than recorded by Rabei (2009) who isolated it from *Synodontis schall* of Lake Nasser with prevalence of 65.1% and worm burden varied from 10 – 50 per host.

Procarnallanus laeviconchus was recorded with prevalence of 36 % and 23% from *Synodontis serratus* and *Synodontis schall* respectively with intensities of 3.13±0.28 and 2.82±0.29 respectively and this result was somewhat different than that recorded by Dougnon *et al.* (2012) who isolated it from *Synodontis schall* with prevalence of 32.1% from South Benin and Omeji *et al.* (2015) who recorded it from *S. Schall* with prevalence of 7.33% from Nigeria. Moravec and Scholz (2017) recorded it from *S. Schall* in the River Nile, Sudan (one fish infected from the two examined fish with intensity of 7).

Spirocamallanus pseudospiralis isolated from *Synodontis serratus* and *Synodontis schall* with prevalence of 12 % and 5% respectively with intensities of 1.66±0.33 and 1.2±0.20 respectively. Moravec and Scholz (2017) recorded it from *S. Schall* in the River Nile, Sudan (the two examined fish were infected with intensity of 7 and 12 per fish.

EMC of *Centrocestus formosanus* was isolated with prevalence of 23 % and 11% from *Synodontis serratus* and *Synodontis schall* respectively.

Some of the detected parasites were of nearly uniform frequency during the different seasons; most probably due to high temperature in the lake is maintained nearly throughout the year. This favors the development of snails, invertebrate hosts and the final hosts (fish, crocodiles, frogs, snakes and aquatic birds).

The histopathology induced by *Centrocestus formosanus* infected the gills of *Synodontis serratus* was identical to that recorded by Mehrdana *et al.* (2014) who recorded cartilage hypertrophy, epithelial and mucous cell hyperplasia, clubbing and lamellar fusion associated with EMC of *Centrocestus* sp. infected *Xiphophorus maculatus* fish. Rezaie *et al.* (2017) reported severe damages and fusions of the gills of grass carp and common carp infected with *Centrocestus formosanus* as well as, Hamouda (2018) recorded the same lesions from *Bagrus bajad* infected with *Centrocestus formosanus*. Infections with EMC of *Centrocestus formosanus* associated with structural and functional damages of gills with a lower tolerance to hypoxia and a decrease respiratory efficiency (Paperna, 1991 and Santiago Bass *et al.*, 2007) so, these parasites have adverse effects on fish leading to significant economic losses in fish industry.

The histopathological lesions induced by *Proteocephalus sulcatus* and *Citharinella citharini* infected *Synodontis schall*'s intestine were somewhat similar to that recorded by Azadikhah *et al.* (2014) who reported the pathological changes induced by *Proteocephalus sulcatus* infecting European catfish (*Silurus glanis*) from Iran as mechanical damages and inflammation of the intestine.

The results in this study may differ completely or partially with many studies and this could be attributed to abiotic and biotic conditions of the environments where the studies were carried.

CONCLUSION

In conclusion, the present work provides the first recent study in details on parasitic infections in wild *Synodontis serratus* and *Synodontis schall* from Lake Nasser. It is of great interests that, the two examined fish species harbor EMC of *Centrocestus formosanus* in their gills which have adverse effects confirmed histopathologically on infected fish as well as, they also have a zoonotic potential and may be considered a public health threat, if raw or inadequately processed fish are ingested so evisceration of fish after catching and adequately cooking are recommended. The disposal of infected fish parts or viscera in water should be prohibited. Extended investigations about the impacts of the detected parasitic infections on survival, gross rate, fecundity and immunity of the two fish species are recommended to ensure successful fishery management plans. Further studies on *Rhadinorhynchus* sp. (new host record), *Spirocamallanus pseudospiralis* (new locality record) and the zoonotic *Centrocestus formosanus* (new hosts record) are needed and urged. The fish musculature was free from parasitic infection and safe for human consumption. Fish-parasite fauna analysis is very helpful for implementing preventative and control measures against parasitic diseases. This study will be a useful tool for further advanced investigations about the detected parasites.

Compliance with ethical standards

Ethics approval

This work was approved by the ethics approval form (12/2017).

Conflict of interest

Author declared that there is no any conflict of interest.

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الاصابات الطفيلية والتغيرات النسيجية المرضية فى نوعين من القراقير (اسماك الشال) ببحيرة ناصر- مصر

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تم فى هذه الدراسة استبيان الاصابات الطفيلية فى نوعين من اسماك الشال (سينودنتس سراتس وسينودنتس شال) ببحيرة ناصر وتقييم التغيرات النسيجية المرضية الناتجة عنها فقد تم فحص ١٠٠ سمكة من سينودنتس سراتس و١٠٠ من سينودنتس شال تم جمعهم من اماكن مختلفة بالبحيرة خلال عام ٢٠١٨م وتم فى كلا النوعين من الاسماك عزل : ١ سستودا (وينيونيا فيريلز) و ٣ نيماتودا (سيسيرينيلا سيسيرنى – بروكاملينس ليفيكونكس و سبيروكاميلينس سودوسبيراليز -طفيل جديد بالبحيرة) و ١ حويصلة لديدان التريماتودا (سنتروستس فورماسنس –لاول مرة فى الشال ولها القدرة على عدوى الانسان). كما تم عزل ١ سستودا (بروتيوسيفالس سلكاتس) و ١ من اكانثوسيفيلا (رادينورينكس سبيشز لاول مرة فى الشال) من السينودنتس شال فقط.اظهر سينودنتس سراتس اصابة طفيلية بنسبة ٥٤% و سينودنتس شال بنسبة ٧٨%. هذه الدراسة سجلت الاعراض الظاهرية والصفة التشريحية ومعدل وشدة الاصابات والمعدل الفصلى للاصابات والتغيرات النسيجية المرضية التاتجة عن هذه الطفيليات. ومن المثير للاهتمام ان لحوم هذه الاسماك خالية من الطفيليات وامنة للاستهلاك الادمى شرط ان يتم نزع احشاء الاسماك فور صيدها وتسويتها جيدا. هذه الدراسة امدتتنا بتحليل لطفيليات هذه الاسماك مما يساعدنا فى التخطيط للوقاية منها وخصوصا تلك التى تنتقل للانسان.