Uttar Pradesh Journal of Zoology

Volume 45, Issue 21, Page 376-386, 2024; Article no.UPJOZ.4347
ISSN: 0256-971X (P)

Helminths Parasite Communities in *Heterotis niloticus* (Cuvier, 1829) in the Sô River (Benin, West Africa) : A Prelimanary Study

Nounagnon Darius Tossavi [a,b*], Ezin Cossi Davy [c], Bernadin Bouko [b], Rachad Sidi [c] and Alphonse Adité [c]

[a] Unité de Recherche en Aquaculture et Gestion des Pêches (URAGeP), Ecole d'Aquaculture, Université nationale d'Agriculture, BP 43 Kétou, Bénin.
[b] Laboratoire de Parasitologie et Ecologie Parasitaire (LPEP), Université d'Abomey-Calavi, 01 BP 526 Cotonou, Bénin.
[c] Laboratoire d'Hydrobiologie et de Recherche sur les Zones humides (LHyREZ), Université d'Abomey-Calavi, 01 BP 526 Cotonou, Bénin.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.56557/upjoz/2024/v45i214647

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://prh.mbimph.com/review-history/4347

Original Research Article

Received: 23/09/2024
Accepted: 26/11/2024
Published: 30/11/2024

ABSTRACT

Heterotis niloticus, the african bonytongue, is a fish species living in shallow waters. Its feeding ecology makes it an omnivorous species capable of reaching large sizes. It is a rare species in the catches except from well-known areas and seasons. A total of 39 *H. niloticus* individuals from Sô

**Corresponding author: Email: anadarioth@gmail.com;*

***Cite as:** Tossavi, Nounagnon Darius, Ezin Cossi Davy, Bernadin Bouko, Rachad Sidi, and Alphonse Adité. 2024. "Helminths Parasite Communities in Heterotis Niloticus (Cuvier, 1829) in the Sô River (Benin, West Africa) : A Prelimanary Study". UTTAR PRADESH JOURNAL OF ZOOLOGY 45 (21):376-86. https://doi.org/10.56557/upjoz/2024/v45i214647.*

river were subjected to parasitological examination in order to identify the diversity of parasites. Physicochemical water parameters such as pH, temperature, dissolved oxygen (O_2), Nitrite (NO_2), Electrical Conductivity (EC), turbidity and total dissolved solids (TDS) were recorded. The sex and the size of any fish were reported. Indices characterizing the parasitic infracommunity and the component community were determined. Total prevalence was 97.43%, with five parasite species identified, comprising 3 heterogenous parasites and 2 monoxenous parasites and a community of 529 individuals. Male fish were more infested than females *($P < .05$)* while the mean abundance and intensity were largely in favor of acanthocephalans *($P < .05$)*. There was no significant correlation ($P > .05$) between the physicochemical parameters and the parasite prevalence. The physico-chemical profile revealed therefore an acceptable living ecosystem for fish. However, the high presence of heterogenous parasites suggests that further investigations over a longer sampling period could highlight the biotic or abiotic factors favorable to this multiplication of each recorded parasite group.

Keywords: Heterotis niloticus; parasite; water parameters; infracommunity; hteroxenous.

1. INTRODUCTION

In recent decades, water quality has continued to deteriorate despite the creation and adoption of laws or regulations and the provision of substantial resources to rehabilitate and maintain the integrity of aquatic ecosystems (Didier et al. 1997, Grayman et al. 2012, Cosgrove and Loucks 2015). In Benin, most water courses and plans are subjected to strong anthropization. About the Sô River, it is clear that human activities have affected the quality of the available water resources and the biocenosis (fish, crustaceans, mollusks and others) (Dovonou 2008). This pressure is specifically related to transactions and the tourist attraction of the area (Dovonou 2008).

However, water quality monitoring based exclusively on (1) the concentration of pollutants in the water and (2) the measurement of physico-chemical parameters does not always provide a good assessment of the health of the ecosystem (USEPA 2002; Brack et al. 2015). Although these parameters are easy to measure and allow routine monitoring, they are biased in the process of assessing and monitoring the overall integrity of ecosystems (Fausch et al. 1990; CBD 2022). Measures integrating living beings (Cairns and Dickson 1971; Gammon, 1980; Lu and Lopes 2022) are therefore needed to assess the overall bioecological functioning of the ecosystem (Djidohokpin et al. 2016).

The Osteoglossid *H. niloticus* is a fish with particular characteristics that lives in marshes and shallow with relative adjacent vegetation. It is also found in flooded and less oxygenated areas due to the presence of a supra-branchial organ which tolerates low oxygen levels (Aubenton 1955). It is the only bonytongue species present in tropical Africa (Holden and Reed 1972; Moreau 1974) and widespread in the Nile region, Sudan, Central Africa, Senegal, etc. (Moreau 1982; Levêque et al. 1990). In Benin, the first parasite investigation on this fish was carried out more than 30 years ago with the identification of some cnidarian species belonging to the genera *Myxobolus* and *Myxidium* (Sakiti 1997). On the other hand, in other countries such as neighbouring Nigeria, several authors have identified helminth parasites in *H. niloticus* (Akinanya et al. 2007, Danyaro et al. 2018, Akinsanya et al. 2020). However, Goater et al. (2013), Sures et al. (2017) and Akinsanya et al. (2020) consider that helminths, especially intestinal helminths, are indicators of the presence of trace metals in the environment. Furthermore, studies in the Sô River have shown that *H. niloticus* feeds preferentially on deritus, aquatic insects, microcrustaceans and seeds (Adité et al. 2005, 2013). The present study, which provides an overview of the parasitic fauna of *H. niloticus* associated to the influence of the physicochemical water quality, is only one part of a series of research activities that will attempt to shed light on the possible relationships between the consumption of microcrustaceans and the gastrointestinal parasitic fauna as a function of metal-induced pollution.

2. MATERIALS AND METHODS

2.1 Area Study

The Sô River is a secondary channel of the the lower delta of Ouémé River. It flows southward, parallel to the Oueme, for about 100 km across a floodplain covering approximately 1000 km^2

under the influence of seasonal rainfall (Van Thielen, 1987). The Sô River (6˚34.97 N; 2˚23.75 E) is located in the subequatorial region with two alternating dry seasons and rainy seasons (Fig. 1).

2.2 Water Collection and Assessed Parameters

The water quality in this study is assessed using seven variables related to the water that were determined through available standard methods either *in situ* for the pH, Dissolved Oxygen (DO), temperature, and turbidity. Water samples were collected from the river to the laboratory to evaluate the water's Electric Conductivity, Nitrites, and Total Dissolved Solids (TDS). Those parameters were collected twice a month on each side of the river. Results were presented as average values followed by the standard error.

2.3 Fish Collection and Parasite Fauna Analysis

The study carried out from january to march 2021. Specific fish traps for *H. niloticus* were placed in the plains in the middle of the root plants along the river. The traps were removed twice a week and put in plastic buckets covered with large mesh netting so as not to suffocate the fish. Samples were transported by car to the laboratory. Each fish individual was measured for total length (TL) using a measuring board graduated to the nearest 0.1 mm and weighed (W) using a balance to the nearest 0.1 g. Every individual fish was submitted to sexual identification either by observation of its external genital orifice or based on the gonad's observation after dissection. Their external body was examined roughly with a hand lens for ectoparasitic species such as crustaceans and hirudineans. Smears of the skin, gills, and fins were also examined for other ectoparasites.

Fish were euthanized using Tricaine methanesulfonate (MS-222) for dissection. Organs such as the intestine and other viscera were removed and placed in a petri dish. They were inspected for parasites or cysts under a stereomicroscope. Any parasites found were removed and immediately placed in a saline solution to prevent them from drying out.

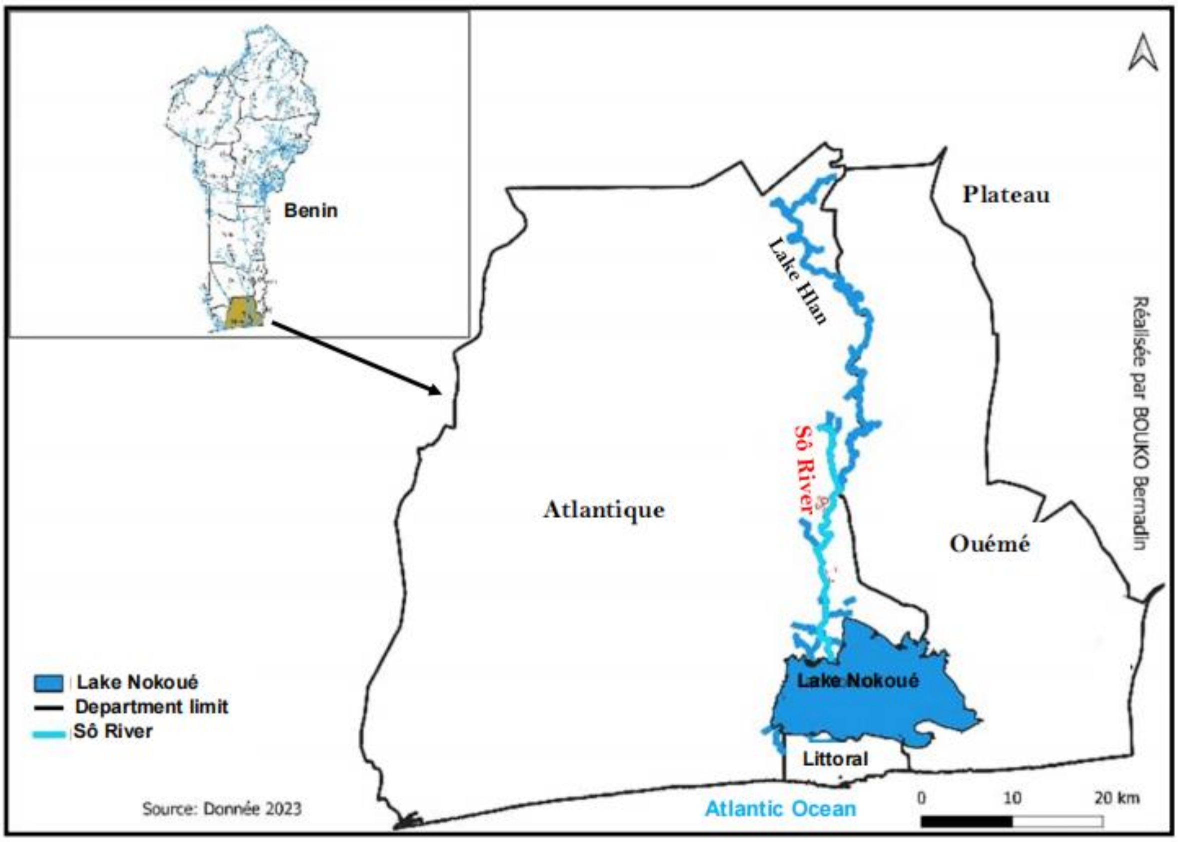

Fig. 1. Mapping of study area showing Sô River

They were then observed as fresh material under the low-power stereomicroscope, then fixed with 10% buffered formalin before examination under a phase contrast light microscope to obtain more detailed information on their morphological structure. Some parasites were also preserved in 70% ethanol depending on their condition. The determination keys given by Yamaguti (1961) and Paperna (1980, 1996) were used for Cestoda, Nematoda and Copepoda whereas Monogenea species identification was made following the method described by Dossou and Euzet (1993).

2.4 Data Analysis

Parasite diversity was established in the fish sampled using structuring infra-communities (all parasites of all taxa of a host species in a given locality and at a given time) and component communities (all parasite species associated with a single host species). Data relating to the prevalence (P), mean abundance (MA), and mean intensity (MI) of the infra-community were used according to Bush et al (1997). MA and MI were also delivered according to the sex of the fish. The infection rate was assessed for single and poly-infections to understand whether parasites co-infested the same fish. As the prevalence is assessed, parasite species were considered as dominant (Do), satellite (Sa), and rare (Ra), respectively, when P > 50 %, 50% > P > 10 % and P < 10% (Valtonen et al. 1997). The test of chi square was used to assess the possible difference between prevalence within male and females and the test of Pearson correlation for possible influence due to limnological parameters on parasite prevalence. The analyses were carried out using R stat software and the data were considered significant at 95%.

3. RESULTS

3.1 Parasite Communities in *Heterotis niloticus*

Table 1 showed that two groups of parasites were identified consisting of 5 metazoan parasites. They were classified as one species of monogena (*Dactylogyrus* sp.), Cestoda (similar to *Bothriocephalus* sp.), and copepoda (*Chonopeltis* sp.) respectively, and two species of Acanthocephalan (*Acanthocephala* sp1 and *Acanthocephala* sp2). A total of 529 individuals of those helminths was collected. The dominant group in the parasitic community of *H. niloticus* was the phylum Acanthocephala, representing 95.84% (507 individuals) of the total parasites collected. There were more heterogenous parasite species than monoxenous ones.

3.2 Parasite Prevalence and Typology of Fish by Size and Sex

The fish sampled were relatively large, ranging from 30 to 70 cm in total length, and divided into four size classes with 10 cm modalities. The first two classes, 30 to 40 cm and 40 to 50 cm, were numerically significant (84.61%) compared with 15.39% for the last two classes, 50 to 60 cm and 60 to 70 cm (Table 2). Only one fish out of the total number examined was not infected. Acanthocephalans were observed in all infected fish, while monogeneans were found in only 2 out of 39 fish, Cestoda were collected in 8 out of 39, and copepoda in 12 out of 39 fish. The number of parasitic individuals per infected fish was well over 10. Almost all the fish (around 98%) were infected by at least one parasite, while less than 20% were infected by at least two parasites (Table 2). All individuals in the 50-60 cm class were subject to poly-infections.

Table 1. Parasite community descriptors in *Heterotis niloticus* from river Sô

Descriptors	Value
Total number of fish	39
Total number infected	38
Component total number of parasites	529
Component community species richness	5
Infracommunity mean species richness	5.7 ± 2.1
Overall MA	13.56
Overall MI	13.92
Component dominant species	*Acanthocephala* sp.
Heteroxenous species	3
Monoxenous species	2
H_{sp}/M_{sp}	3/2

Hsp = heterogenous species; Monoxenous species

Table 2. Parasite prevalence of mono-infection and co-infection in *Heterotis niloticus* divided in length-class

Length (cm)	Total examined	Single or multiple infection	
		Single parasite species at least (%)	≥ Two parasites species least (%)
30-40	17	16 (94.11)	2 (11.76)
40-50	16	16 (100)	1 (6.25)
50-60	3	3 (100)	3 (100)
60-70	3	2 (100)	1 (33.33)
Total	**39**	**38 (97.43)**	**7 (17.94)**

The identified parasites were collected from the gills, stomach and intestine (Table 3). The mean abundance and intensity of the parasites collected were nil in female fish, except for acanthocephalans, where the mean abundance and intensity were at least twice higher in male fish than in female fish (Table 3). Moreover, Acanthocephalans exhibited a mean abundance evaluated at 450, 180, and 29 times greater than that of cestodes, monogeneans, and copepods respectively. Consequently, the mean intensity of acanthocephala was 275, 138, and 25 times higher than that of cestoda, monogeneans and copepoda respectively (Table 3). All the recorded parasites were recognized as rare species in the parasite community.

3.3 Water Quality and Correlation

The water quality profile is shown in Table 4. The correlations established between the limnological parameters and the prevalence of parasites are recorded in Table 5. Only turbidity has shown a positive correlation with all parasites. While pH was negatively correlated with Cestodes alone. OD and EC were negatively correlated with two parasites while TDS, nitrite and temperature presented a negative correlation with three different parasites. No significant difference was reported.

4. DISCUSSION

4.1 Parasite Community

Much attention has been paid to intensifying the production and marketing of fish and other aquatic animal resources in order to mitigate the dearth of animal protein. Unfortunately, this important measure has not been accompanied by strong actions linked to the health of these fish organisms, and parasitic or bacterial diseases could well sabotage the commitments of the various stakeholders. The present study highlighted the parasites that unfortunately could infest the species *H. niloticus* in its natural ecotome. In fact, although parasites are often considered to be in equilibrium with their hosts specifically, any tendency for the host/parasite relationship to be altered by any factor can be a source of mortality, disease, or rejection of the fish by the consumer (Pratoomyot et al. 2015, Charo-Karisa et al. 2021). Thus, the very high occurrence of parasitic individuals collected in this sample raises great concern but suggests that conditions are quite favorable for parasite multiplication. The presence of parasite species certainly influences host biodiversity, albeit in the medium or long term. Pariselle et al. (2011) argue that this is a way of studying the history of the biotope and the hosts. The total parasite prevalence in this study was very high compared with that reported by Bouko et al. (2023) on *Sarotherodon melanotheron* in the southern continuum of the river Sô and by Bouko et al. (2024) on *Oreochromis niloticus* from Lake Toho-Todougba. The low presence of monogeneans during this period of the year is paradoxical given to Allalgua et al. (2015, 2021) who considered that Dactylogyridae multiply fairly rapidly during the warm season. Furthermore, in environmental parasitology, studies over the last two decades have reported that endoparasites represented useful evidence of accumulation (Sures and Reimann, 2003; Vidal-Martinez et al. 2010, Le et al. 2018).

Better still, the Hsp/Msp ratio was not favorable to monoxenous species. This implies that despite the high number of parasitic individuals, the risk of parasite transmission to other hosts could not be as high (Hidayati et al. 2019). The level of parasitic infection in the Sô River would therefore be limited and there would not be many euryxenic parasites (Mehlhorn 2008). Parasites from the other fish species sheltered by this river must be investigated further. That was the case for trophically transmitted parasites, as reported by Siko et al. (2018) concerning *Clarias gariepinus*, involving the fish's feeding habits, as in the case of the species under study (Adité et al. 2013).

Table 3. Site of infection, Mean abundance (MA), and Mean intensities (MI) of parasites in *H. niloticus*

Groupe	**Monogena**			**Acanthocephala**			**Cestoda**			**Copepoda**		
Sites of infestation	**Gills**			**Stomach and intestine**			**Intestine**			**Gills**		
Epidemiological Parameters	**P(%)**	**AB**	**IM**	**P(%)**	**AB**	**IM**	**P(%)**	**AB**	**IM**	**P(%)**	**AB**	**IM**
Males	5.12	0.05	0.06	65.86	9.05	8.30	20.51	0.02	0.03	30.77	0.32	0.33
Femelles	0	0	0	31.57	3.64	4.78	0	0	0	0	0	0
Type of species	Rare			Dominant			Satellite			Satellite		

Table 4. Water physicochemical variables in the study area

Parameters	Unit	Average ± standard error
pH	-	6.8 ± 0.6
Dissolved Oxygen	mgL^{-1}	2.1 ±0.9
Temperature	°C	28.6 ± 2.2
Electric Conductivity (EC)	μscm^{-1}	107.45 ± 3.16
Nitrites (NO_2)	mgL^{-1}	0.56 ± 0.15
Total Dissolved Solids (TDS)	mgL^{-1}	46.75 ± 5.38
Turbidity	cm	40.3 ± 28.2

Table 5. Interaction between parasite prevalence and water physicochemical parameters using Pearson correlation (r)

Parameters		Monogenean	Cestoda	Acanthocephalan	Copepoda
pH	r	0.33	-0.14	0.15	0.88
	P	0.66	0.86	0.85	0.11
DO	r	-0.20	0.21	0.66	-0.44
	P	0.79	0.78	0.34	0.55
T (°C)	r	-0.93	-0.59	0.79	-0.79
	P	0.06	0.41	0.20	0.20
EC	r	0.37	-0.17	-0.51	0.79
	P	0.62	0.82	0.48	0.20
Nitrites	r	-0.71	-0.86	0.14	-0.23
	P	0.28	0.13	0.85	0.76
TDS	r	-0.92	-0.56	0.53	-0.89
	P	0.08	0.43	0.46	0.10
Turbidity	r	0.18	0.37	0.50	0.06
	P	0.81	0.62	0.49	0.94

4.2 Parasite Prevalence

According to several authors (Marcogliese 2002; Siko et al*.* 2018; Houénou Sèdogbo et al*.* 2019), fish with trophic parasitic transmission are often strongly exposed, with a high parasite prevalence and mean intensity. It evokes in respect Adité et al*.* (2013) who present *H. niloticus* as consuming a large variety of pelagic and benthic prey resources. The prevalence was very high, showing that parasitic infection is frequent in these fish. Sandoval-Gio et al. (2008) indicated that some fish express a probable immune resistance to ectoparasite attacks which could explain the very low prevalence of ectoparasites observed in the present study. Poly-parasitic infection was also revealed, however, it was much lower (5.43 times) than mono-parasitic infection. There was therefore a balance between this host population and the parasites, suggesting that parasite specificity was highly developed in this environment. However, living time and exposure surface contribute to polyinfection in fish. Md-Lasmine et al*.* (2021) believe that parasite abundance associated with interspecific interactions could substantially drive infection dynamics due to the weakness induced in the host immune system. Disease dynamics may also be affected because co-infections weaken the transmission and virulence of a pathogen within a host population (Ambekar et al*.* 2004). It should also be noted that poly-infections can generate competition between parasites within the same host (Poulin, 1998), which in turn limits the space and resources available to hosts (Fredensborg and Poulin, 2005). It also generally leads to a drop in the rate of food intake and a reduction in the physical posture of competing individuals (Fredensborg and Poulin, 2005). Other factors such as synchronization with the parasite cycle and the biotope of the parasite, were likely to modify the behavior of fish infected by heteroxenous endoparasites. It should be noted that the prevalence of poly-infection was low whatever the size class. This agreed with the assertions of Lisnerová et al*.* (2022) who believed that the size of macroparasites evolves in proportion to the size of the host.

The study of the parasitic fauna of *Heterotis niloticus* has appeared as a special phenomenon. Unlike some well-studied species, the parasite prevalence of *H. niloticus* was high for authors whose works were known. This is the case for Akinsanya et al. (2007) with a prevalence reaching 60% for specimens between 66 and 90 cm in size. Akinsanya et al. (2020) reported a prevalence of 70% with individuals of sizes varying from 40 to 80 cm. But for Danyaro et al. (2018), the prevalence was estimated at 22% and revealed that individuals larger than 35 cm have the highest prevalence (35.3%). In the present study, although the prevalence was almost identical across the different classes, it is not ignored that fish of larger weight and size were likely to have an enormous parasite load (Olurin and Samorin 2006, Ayanda 2009) given the large contact and infection surface available to the parasites (Roberts 1978; Obano et al. 2010).

As indicated by Danyaro et al. (2018), only four helminth groups were collected. However, the intensity and abundance reported were well above the data presented by Danyaro et al. (2018). Appreciating the high mean abundance as well as the mean intensity of acanthocephalans, Takemoto et al. (2000) and Wali et al. (2016) reported that the intensity of infection by acanthocephalans was significantly higher in male than in female fish. There is therefore a probable influence of sex on the susceptibility of animals to infection. This approved the statements by Ayanda, (2009) and Wali et al. (2016) who believed that genetic predisposition on the one hand and differential sensitivity on the other, linked to hormonal regulation, as well as the sampling period and locality, also represented factors that motivate the increased rate of helminth infection.

4.3 Parasite and Physicochemical Correlation

In recent environmental studies, it was revealed that parasites are influenced by macroenvironmental conditions (Galli et al. 2001, Gilbert & Avenant-Oldewage 2017). Fish survival in the aquatic ecosystem is then governed by the physical and chemical quality of the water (Tossavi et al. 2024). In the present study, water analysis indicated that limnological parameters were within recommended limits for pH, temperature, dissolved oxygen, and electrical conductivity (WHO 1993). However, the high concentration of nitrites and total dissolved solids was a consequence of the non-dilution of organic products concentrated in the environment during the climatic season. It should be noted that the pollution level in this area was not critical, not only because of the renewal of the water but also because there was no industrial activity around this ecosystem. Organochlorine products from the drainage of water from crops and other anthropogenic activities of surrounding populations were also factors likely to increase nitrite and TDS loads and other unassessed parameters as revealed by Svobodova et al. (1993) and Ashmawy et al. (2018). However, the electrical conductivity value assumed a likely zero concentration of heavy metals if considering the approaches of Akinsanya et al. (2020) who suggested that high electrical conductivity indicated the presence of metals dissolved in the water and likely to transmit electrical current. For this reason, assessing the concentration of pesticides and heavy metals in the water and the flesh of the fish would help to better characterize the pollution.

5. CONCLUSION

Fish parasites are affected by water conditions and other unsuspected factors. The focus on the parasites of *H. niloticus* in this study showed that there are both ectoparasites and endoparasites including monoxenous and heteroxenous parasites and only physicochemical parameters did not influence parasites. An investigation interesting the pollutant contamination of this ecosystem and probable metal bioconcentration and parasite mode of transmission could reveal many mysteries about the prevalence of parasites.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

ACKNOWLEDGEMENT

Authors are grateful to the reviewers for their painstaking work in revising the manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

Adité, A., Gbankoto, A., Imorou Toko I. & Fiogbé, E, D. (2013). Diet breadth variation and trophic plasticity behavior of the African bonytongue *Heterotis niloticus* (Cuvier, 1829) in the Sô River-Lake Hlan aquatic system (Benin, West Africa): Implications for species conservation and aquaculture development. *Natural Science 5*(12): 1219-1229. http://dx.doi.org/10.4236/ns.2013.512149

Akinsanya, B., Ayanda, I. O., Fadipe, A. O., Onwuka, B., Saliu, J. K. & (2020). Heavy metals, parasitologic and oxidative stress biomarker investigations in *Heterotis niloticus* from Lekki Lagoon, Lagos, Nigeria. *The End-to-End Journal: Toxicology Reports 7*: 1075-1082.

Akinsanya, B., Hassan, A. A. & Otunbanjo, O. A. (2007). A comparative study of the parasitic helminth fauna of *Gymarchus niloticus* (Gymnarchidae) and *Heterotis niloticus* (Osteoglossidae) from Lakki Lagoon, Lagos, Nigeria. *Pakistan Journal of Biological Sciences 10*(3): 427-432.

Allalgua, A., Guerfi, S., Kaouachi, N., Boualleg, C., Boucenna, I., Barour, C., Menasria, A., & Bensouilah, M. (2015) L'infestation de *Cyprinus carpio* (Cyprinidés) peuplant le barrage Foum El-Khanga (Souk Ahras, Algérie) par les monogènes parasites. *Bulletin de la Société zoologique de France, 140* :217-232.

Allalgua, A., Menasria A., Mouaissia, W., Bensouilah, M. & Kaouachi, N. (2021). Effect of biotic and abiotic factors on the epidemiological index of *Dactylogyrus heteromorphus* El Gharbi, 1994 (Monogenea) parasitizing the algerian barbel *Luciobarbus callensis* (Cyprinidae) inhabiting Foum-El Khanga Dam (Souk-Ahras, Algeria). *Acta Aquatica Turcica, 17*(4): 532–540.

Ambekar, A. N., Bharadwaj, R.S., Joshi, S. A, Kagal, A. S. & Bal, A. M. (2004). Serosurveillance of leptospirosis among sewer workers in Pune, *Indian Journal of Public Health 48*(1) 27–29.

Ashmawy, K. I., Hiekal, F. A., Abo-Akadda, S. S. & Laban, N. E. (2018). The inter-relationship of water quality parameters and fish parasite occurrence. *Alexandria Journal of Veterinary Science, 59* (1): 97-106. DOI: 10.5455/ajvs.299584.

Ayanda, I. O. (2009). Comparison of parasitic helminths infection between sexes of *Clarias gariepinus* from Asa dam Ilorin, north central Nigeria. *Scientific Research and Essays 4* (4): 357-360.

Boucenna, I., Khelifi, N., Boualleg, C., Allalgua, A., Bensouilah, M., & Kaouachi, N. (2018). L'infestation de Luciobarbus Callensis (Cyprinidés) par les copépodes parasites dans le Barrage Foum EL Khanga (Souk-Ahras, AlgériE). *Bulletin de la Société de zoologie de France 143*(4): 199-212.

Bouko, B., Tossavi, N, D., Gandé, J. J. G., Aboki Onzo, A., Zannou, T. B. & Ibikounlé M. (2023). Assessing the diversity of metazoan parasites of *Sarotherodon melanotheron* (Cichlidae) from inlands waters in Southern Benin. *Asian Journal of Research in Zoology, 6*(4): 160-172, AJRIZ 110228; DOI: 10.9734/ajriz/2023/v6i4133.

Brack, W., Altenburger, R., Schüürmann, G., Krauss, M., López Herráez, D., van Gils, J., Slobodnik, J., Munthe, J., Gawlik, B. M., van Wezel, A., Schriks, M., Hollender, J., Tollefsen, K. E., Mekenyan, O., Dimitrov, S., Bunke, D., Cousins, I., Posthuma, L., van den Brink, P. J., López de Alda, M., Barceló, D., Faust, M., Kortenkamp, A., Scrimshaw, M., Ignatova, S., Engelen, G., Massmann, G., Lemkine, G., et al. (2015). The Solutions project: challenges and responses for present and future emerging pollutants in land and water resources management. *Science Total Environment 503–504*: 22–31.

Bush, A. O, Lafferty, K, D., Lotz, J. M. & Shostak, A. W. (1997). Parasitology meets ecology on its own terms: Margolis et al. revisited. *Journal of Parasitology, 83*: 575-583.

CBD (Convention on Biological Diversity) (2022). Expert input to the post-2020 global biodiversity framework: transformative actions on all drivers of biodiversity loss are urgently required to achieve the global goals by 2050, Geneva, Switzerland,13-29 March 2022, Twenty-fourth meeting, 180p.

Charo-Karisa, H., Ali, S. E., Marijani, E., Ibrahim, N.A., Trinh, T. K. Chadag, M. V. v Benzie, J. A. H. (2021). Genetic parameters for black spot disease (diplostomiasis) caused by *Uvulifer* sp. infection in Nile tilapia (*Oreochromis niloticus* L.). Aquaculture, 532, Article ID 736039.

Cosgrove, W. J. & Loucks, D. P. (2015), Water management: Current and future challenges and research directions. *Water*

Resources Research, 51: 4823–4839, doi:10.1002/2014WR016869.

Danyaro, N. M., Miga, H. I., Bichi, A. H., Dabo, N. T. & Ma'aruf, N. (2018). Prevalence of Intestinal Helminth Parasites in *Heterotis niloticus* in Marma Water Channel Along River Hadejia, Jigawa Nigeria? *Dutse Journal of Pure and Applied Sciences (DUJOPAS), 45*(2): 204-212.

Dossou, C. T. & Euzet, L. (1993). *Synodontella* n.g. (Monogenea, Ancyrocephalidae) parasites de Mochokidae africains du genre *Synodontis* Cuvier, 1817. Rev Zool Afr 107(2) :175–185

Fredensborg, B, L. & Poulin, R. (2005). Larval helminths in intermediate hosts: Does competition early in life determine the fitness of adult parasites? *International Journal for Parasitology, 35* (10): 1061-1070. https://doi.org/10.1016/j.ijpara.2005.05.005

Galli, P., Crosa, G., Mariniello, L. M., Ortis & D'Amelio S. (2001). Water quality as a determinant of the composition of fish parasite communities. *Hydrobiologia 452*, 173–179. https://doi.org/10.1023/A:1011958422446

Gilbert B. M. & Avenant-Oldewage, A. (2017). Parasites and pollution: the effectiveness of tiny organisms in assessing the quality of aquatic ecosystems, with a focus on Africa. *Environmental Science Pollution Research*, 1-28, DOI 10.1007/s11356-017-9481-8.

Grayman, W. M., Loucks, D. P. & Saito, L. (Eds.) (2012). Toward a Sustainable Water Future: Visions for 2050, ASCE Press, Reston, Va.

Guegan, J. F., Lambert, A., & Euzet, L. (1988). Etude des Monogenes des Cyprinidae du genre *Labeo* en Afrique de l'Ouest. - I. Genre *Dactylogyrus* Diesing, 1850. *Revue d'hydrobiologie tropicale, 21* :135-151.

Hidayati, D., Prabowo, H. Y., & Soegianto, A. (2019). Infection status of intestinal parasites in Skipjack Tuna (*Katsuwonus pelamis*) from Sendang Biru Waters, Indian Ocean, Indonesia. *Ecology Environment and Conservation 25* (July Suppl. Issue): S100-S105.

Le, Y. T. T., Rijsdijk, L., Sures, B. & Hendriks, A. J. (2014). Accumulation of persistent organic pollutants in parasites. *Chemosphere, 108*: 145-151.

Lisnerová, M., Lisner, A., Delfina, M. P., Cantatore Schaeffner, B, Pecková, H., Tymlb, T., Fiala, I., Bartošová-Sojková, P. & Holzera, A. S. (2022). Correlated evolution of fish host length and parasite spore size: a tale from myxosporeans inhabiting elasmobranchs. *International Journal for Parasitology 52*(2-3) 97–110. https://doi.org/10.1016/j.ijpara.2021.05.008

Lu, J. & Lopes, P. (2022). Integrating Living Organisms in Devices to Implement Care-based Interactions, Conference: UIST '22: The 35th Annual ACM Symposium on User Interface Software and Technology, DOI: 10.1145/3526113.3545629.

Marcogliese, D. J. (2002). Food webs and the transmission of parasites to marine fish. *Parasitology, 124*: Suppl: S83-99. Doi: 10.1017/s003118200200149x.

Mehlhorn, H. (2008). *Encyclopedia of Parasitology:* A-M. Springer: New York.

Mikheev, V. N. (2011). Monoxenous and heteroxenous fish parasites manipulate the behavior of their hosts in different ways. *Biology Bulletin Reviews 1*(5): 446–457. https://doi.org/10.1134/S2079086411050045

Obano, E. E., Ezeri, G. N. O. & Aniye, U. K. (2010). Studies on the parasitic infections in fish in Ovia River at Ikoro, Ovia south West Local Government Area of Edo State, Nigeria. *Bioscience and Research Communications 22*(3) :137.

Olurin, K. B. & Samorin, C. A. (2006). Intestinal helminthes of thefishes of Owa stream, South-west Nigeria. *Research Journal of Fisheries and Hydrobiology. 1*(1): 6-9.

Paperna, I. (1980) Parasites, infections and diseases of fish in Africa. CIFA Tech. Pap., (7): 216p.

Paperna, I. (1996) Parasites, infections and diseases of fish in Africa-an update, CIFA Tech. Paper, 31, FAO, Rome, Italy. 200p.

Poulin, R. (1995). Phylogeny, ecology, and the richness of parasite communities in vertebrates *Ecological Monography 65*: 283-302

Pratoomyot, J., Bron, J. E., Paladini, G. (2015). Economic impacts of aquatic parasites on global finfish production, https://www.researchgate.net/publication/283506528.

Roberts, J. R. (1978) Fish Pathology, Bailliere Tindal, London, 1978, pp. 268–275.

Sakiti N.G. (1997). Myxosporidies et Microsporidies de poissons du Sud-Bénin:

faunistique, ultrastucture, biologie. Thèse de doctorat d'état. UAC. Pp.300.

Sèdogbo Houénou, M., Zannou, T. B., Siko, J. E., Tossavi, N. D., Togla, I, Fiogbé ED, Ibikounlé, M. (2019.) Faune des métazoaires parasites de *Clarias gariepinus* (Clariidae) et de *Oreochromis niloticus* (Cichlidae), deux poissons des whédos du delta supérieur du fleuve Ouémé au sud du Bénin. *International Journal of Biological and Chemical Sciences 13*(2): 983-997

Siko EJE, Sèdogbo Houénou M, Gbankoto A, Imorou Toko I, Tossavi ND & Ibikounle M. (2018). Experimental study of the coccidial infection on growth performance of juvenile of *Clarias gariepinus* Burchell, 1822 (Poisson, Siluridae). *International Journal of Multidisciplinary Current of Research 6*: 877-887.

Sures, B. & Reimann, N. (2003). Analysis of trace metals in the Antarctic host–parasite system *Notothenia coriiceps* and *Aspersentis megarhynchus* (Acanthocephala) caught at King George Island, South Shetland Islands. *Polar Biology, 26*: 680-686

Svobodova, Z., Lloyd, R., Machova, J., Vykusova, B. (1993). Water quality and fish health. EIFAC technical paper no 54.FAO. Rome.

Takemoto, R. M.& Pavanelli, G. C. (2000) Aspects of the ecology of proteocephalid cestodes parasites of Sorubim lima (Pimelodidae) of the upper Parana river, Brazil: structure and influence of host's size and sex. *Brazilian Journal of Biology, 60*: 577–584.

Valtonen, E. T., Holmes, J. C., Koskivaara, M. (1997). Eutrophication, pollution and fragmentation: Effects on parasite communities in roach (*Rutilus rutilus*) and perch (Perca fluviatilis) in four lakes in the Central Finland. *Canadian Journal of Fish Aquatic Science 54*: 572–585.

Van Thielen, R., Hounkpe, C., Agon, G. & Dagba, L. (1987). Guide to the identification of fish and crustaceans in the lagoons and lakes of Lower Benin. Fisheries Department, Cotonou, Benin.

Vidal-Martínez, V. M., Aguirre Macerdo, M. L., Del Rio-Rordrígez, R., Gold-Bouchot, G., Rendon-von Osten, J. & Mirande-Rosas, G. A. (2010). The pink shrimp *Farfantepenaeus duorarum*, its symbionts and helminthes as bioindicators of chemical pollution in Campeche Sound, Mexico. *Journal of Helminthology*, 80: 159-174.

Wali, A., Balkhi, M. H., Maqbool, R., Shah, F. A., Bhat, F. A., Darzi, M., Kumar, A. & Bhat, B. A. (2016). Histopathological alterations and distribution of *Pomphorhynchus kashmirensis* in intestines and their seasonal rate of infestation in three freshwater fishes of Kashmir. *Journal of Entomological and Zoological Studies 4*(5): 22-28.

WHO (World Health Organization), Guidelines for Drinking Water Quality, World Health Organization, Geneva, Switzerland, 1993.

Yamaguti, S. (1961) Systema helminthum, nematodes of vertebrates. Interscience Publishers, Inc., New York, USA, p 1261.

Peer-review history:
The peer review history for this paper can be accessed here:
https://prh.mbimph.com/review-history/4347