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Original

First evidence of *Cichlidogyrus* Paperna, 1960 (Monogenea: Ancyrocephalidae) in *Oreochromis* spp. cultures from Ecuador

Lenin Cáceres-Farías[1,2]; Yanis Cruz-Quintana[1]; Leonela Griselda Muñoz-Chumo[1,3]; Ana María Santana-Piñeros[1*]

[1]Universidad Técnica de Manabí. Facultad de Ciencias Veterinarias. Departamento de Acuicultura, Pesca y Recursos Naturales Renovables. Grupo de Investigación en Sanidad Acuícola, Inocuidad y Salud Ambiental. Bahía de Caráquez, Ecuador.
[2]Aqua*CEAL* Corporation, Ave. Capitán Byron Palacios & General Quisquis, #8 EC230101, Santo Domingo de los Colorados, Ecuador.
[3]Universidad Técnica de Manabí, Instituto de Posgrado, Maestría de Investigación en Acuicultura, Bahía de Caráquez, Manabí, Ecuador.
Correspondencia: ana.santana@utm.edu.ec

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ABSTRACT

Objective. To provide evidence of the presence of two species of monogeneans of the genus *Cichlidogyrus* that cause damage to gill tissue, in tilapia (*Oreochromis* spp.) grown in Ecuador. **Materials and methods.** The gills were placed in a Petri dish with boiling water so that the parasites relax, and later they were fixed in 4% formalin. The samples were checked under a stereoscope microscope. The parasites were counted and preserved in 70% ethanol for their taxonomic identification according to their morphological characteristics. The infection parameters (prevalence, mean abundance, and mean intensity) were calculated for each species of parasite. For the description of histological damages, fragments of parasitized gills were fixed in 10% neutral formalin and processed by the histological paraffin embedding technique. **Results.** *Cichlidogyrus sclerosus* showed highest infection parameters: prevalence of 65%, mean abundance of 24.24 ± 68.62, and mean intensity of 37.62 ± 82.93. *Cychlidogyrus dossoui* was observed in a prevalence of 4.5%, mean abundance of 0.13 ± 0.66, and mean intensity of 3 ± 1.41. Both species caused hyperplasia in lamellae. **Conclusions.** This study constitutes the first report of infestation by *Cichlidogyrus sclerosus* and *C. dossoui* in tilapia culture systems of Ecuador.

Keywords: Aquaculture; histopathology; parasites; fish farming; tilapia (*CAB Thesaurus*).

RESUMEN

Objetivo. Evidenciar la presencia de dos especies de monogeneos del género *Cichlidogyrus* que causan daño al tejido de las branquias, en tilapias (*Oreochromis* spp.) cultivadas en Ecuador. **Materiales y métodos.** Las branquias se colocaron en una caja Petri, se le adicionó agua a punto de ebullición para que los parásitos se relajen, y posteriormente se fijaron en formalina al 4%. Las muestras fueron revisadas en un microscopio estereoscopio. Los parásitos fueron contados

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y preservados en etanol al 70% para su identificación taxonómica según sus características morfológicas. Los parámetros de infección (prevalencia, abundancia e intensidad medias) fueron calculados para cada especie de parásito. Para la descripción de daños histológicos, fragmentos de branquias parasitadas fueron fijados en formalina neutra al 10% y procesado mediante la técnica histológica de inclusión en parafina. **Resultados.** *Cichlidogyrus sclerosus* mostró los parámetros de infección más altos, prevalencia de 65%, abundancia media de 24.24 ± 68.62 e intensidad media de 37.62 ± 82.93. *Cychlidogyrus dossoui* fue observada en una prevalencia de 4.5%, abundancia media de 0.13 ± 0.66 e intensidad media de 3 ± 1.41. Las dos especies causaron hiperplasia en las lamelas. **Conclusiones.** Este estudio constituye el primer reporte de infestación por *Cichlidogyrus sclerosus* y *C. dossoui* en sistemas de cultivos de tilapias del Ecuador.

Palabras clave: Acuicultura; histopatología; parásitos; piscicultura; tilapia (*CAB Thesaurus*)

INTRODUCTION

Around the world, a great diversity of parasite species has been reported infesting *Oreochromis* spp., both in aquaculture and in natural environments (1,2). Among these, the monogeneans of the Gyrodactylidae and Dactylogyridae families are recognized for causing significant economic losses in tilapia aquaculture (3), mainly in the rearing and fingerling phases (4).

Oreochromis spp. were introduced for aquaculture purposes in Ecuador in 1965, becoming one of the three main species of fish in Ecuadorian aquaculture (5). Tilapia production has increased from 18 ton in 1990 to 10,774 t in 2019, with a maximum of 47,733 t in 2010 based almost exclusively from *O. niloticus* (6). Despite its importance both in the local and international markets, little is known about the pathogens and diseases that affect tilapia in Ecuador. Currently there are only two reports of monogeneans in tilapia, both studied *O. niloticus* cultivated in the province of Guayas. In the first, the genera *Dactylogyrus* and *Gyrodactylus* were recorded, but the species were not identified; in the second, *Gyrodactylus cichlidarum* was identified (3).

The genus *Cichlidogyrus* was introduced to America in the 1980s and has been reported infesting tilapia grown in Panama, Brazil, Costa Rica, Colombia, Cuba, Nicaragua, and Mexico (3). Despite its wide distribution in South America, this genus has not been reported in Ecuador. Therefore, the objective of the present work was to register the presence of two species of *Cichlidogyrus* in cultures of *Oreochromis* spp. from Ecuador and describe the histopathological damage caused by parasites.

MATERIALS AND METHODS

Sampling sites. The material was collected from November 2018 in three tilapia farms located in Calceta (0°50´58”S-80°09´36”O), province of Manabí; Puerto Quito (0°06´59”N-79°16´0”O), province of Pichincha and in Alluriquín (0°19´22”S-78°59´43”O), province of Santo Domingo de los Tsáchilas (Figure 1).

Figure 1. Location of sampled farms. The circle shows tilapia farms of *Oreochromis* spp. 1. Calceta; 2. Puerto Quito; 3. Alluriquín.

Parasitological procedures. In each farm, 15 fish were processed for parasitological analysis. With the help of an ichthyometer and a balance, the morphometric data of each fish were obtained (total length [cm] and weight [g]). Subsequently, the body surface, oral cavity, eyes, fins, operculum cavity, gills were checked for each of the fish in search of monogeneans. The gills were placed in individual 125 mL vials and fixed with boiling water. All biological material was transferred to the Centro de Sanidad Acuícola from Departamento de Acuicultura, Pesquería y Recursos Naturales Renovables of the Universidad Técnica de Manabí, where the samples were reviewed under a stereoscopic microscope. The parasites found were collected, counted, and preserved in 70% alcohol in 2.5 mL eppendorf tubes. For the identification of the monogeneans, the artificial digestion technique was used with the digestion liquid being prepared with 0.7 mL of HCl and 0.1 g of pepsin in 100 mL of distilled water. For the identification of the parasites, the key of Pariselle and Euzet was used (7). The identification of the monogeneans was based on the morphology of the sclerotized structures of the haptor and the male reproductive system.

Analysis of the information. The biometric data of the analyzed fish are shown with mean ± standard deviation. The infection parameters (prevalence, mean abundance, and mean intensity) were calculated for each species of parasite (8).

Histological analysis. To describe histological damages, gill fragments of 3 parasitized fish per farm (n = 9) were fixed in 10% neutral formalin for 72 h. The gills were decalcified with 7% hydrochloric acid for 30 min (9) and processed by the histological technique of inclusion in paraffin, cut into thin sections (5 µm), and stained with the routine hematoxylin-eosin (H-E) stains (10). The slides were mounted with Entellan resin (10) and observed with the help of an optical microscope with objectives of 4, 10, and 40x. The images were captured with an 18 MP digital camera attached to the microscope.

Ethical aspects. The animal bioethics procedures of this study have the permission of the Institutional Bioethics Committee of the Universidad Técnica de Manabí, established in volume 021-5 folio 21-5-1.

RESULTS

The minimum, maximum and average values of the biological variables recorded in the analyzed fish are shown below (Table 1).

Table 1. Biological variables recorded in tilapia (*Oreochromis* spp.). The mean values ± standard deviation (SD) are presented; minimum and maximum values.

Farm	Total length (cm)	Weight (g)
1	15±5.6; 10-29.5	90.66±48.28; 15-175
2	16.5±5.83; 11.5-20.5	98.7±56.66; 32-154
3	17±4.4; 10.5-20.5	77.5±45.44; 17.4-127

The following species of monogeneans were found:

Cichlidogyrus dossoui Douëllou, 1993
Infection site: Gills
Locality: Farm from Calceta
Description (Figure 2): (based on 5 monogeneans). Cephalic lobe with 4 pairs of head organs. One pair of eyes. Opistohaptor broader than the body, not separated from the body (Figure 2A). Opistohaptor with 2 pairs of ventral hamuli, 2 pairs of dorsal hamuli, and 7 pairs of hooklets (Figure 2A - B). Ventral Hamuli broad at the base, with a long axis that ends in a point and a well-developed root (Figure 2C). U-shaped ventral bar with rounded extremities. Dorsal hamuli smaller and with a shorter root than the ventral hamuli. Arched dorsal bar with long, asymmetrical branches (Figure 2B). Extremely long hooklets, with the exception of pair 2 which is shorter (Figure 2D). Copulatory organ very large, rounded, and located in the anterior part of the monogeneans (Figure 2E). Curved copulatory tube with an S-shaped accessory part.

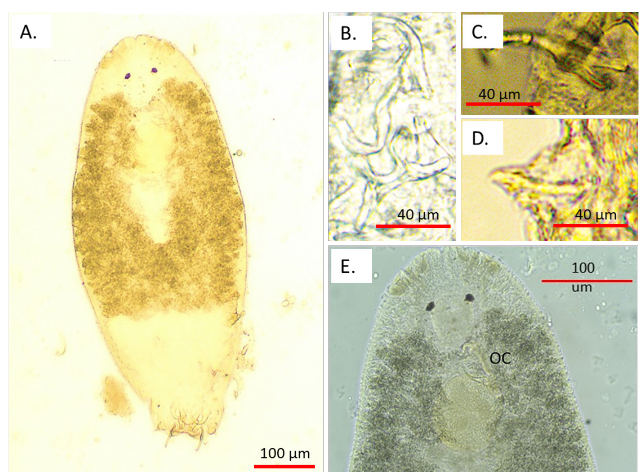

Figure 2. *Cichlidogyrus dossoui* collected from tilapia *Oreochromis* spp. of farms. A: ventral view; B: dorsal and ventral bars, and ventral hamuli; C: detail of the base of dorsal hamuli showing the root. D: detail of hooklet IV. E: cephalic lobe. OC: Copulatory organs.

Other records: *Cichlidogyrus dossoui*, was first described in *Tilapia rendalli*, *Oreochromis mortimeri* and *Serranochromis macrocephalus* collected in Kariba lagoons, Zimbabwe, Africa (11). Later, it was recorded in several species of cichlids from Africa: *O. mossambicus* (12,13); *C. guineensis, C. camerunensis* (14); *Tilapia sparrmanii,* and *Coptodon rendalli* (16). In South America, it has been registered in *O. niloticus*, *O. aureus,* and *O. mossambicus* collected from Mexico (2) and *O. niloticus* from Panama (2).

Cichlidogyrus sclerosus Paperna and Thurston, 1969

Infection site: Gills
Localities: Farms from Calceta, Puerto Quito and Alluriquin.
Description (Figure 3): (based on 15 monogeneans). Cephalic lobe with 4 pairs of head organs with one pair of eyes. Rounded opistohaptor (Figure 3A) with two pairs of hamuli and 7 pairs of hooklets. Short hooklets; 2 shorter pairs without base, other pairs with short base (Figure 3B). Dorsal and ventral hamuli of similar shape and size, without distinctive roots and strongly curved (Figure 3B). Hamuli with filament. V-shaped ventral bar and rounded extremities (Figure 3B). X-shaped dorsal bar with wide grooves. Slightly sclerotic and straight vagina (Figure 3C). Copulatory organ with large accessory part (Figure 3C).

Other records: *Cichlidogyrus sclerosus* was first described in the African continent infesting several species of cichlids: *O. mossambicus*, *O. niloticus*, *O. leucosticus*, *Haplochromis* sp., *O. spilurus niger*, *T. zillii*; *O. mortimeri* and *S. macricephalus* (11,16). This species has also been identified in the Middle East in *O. aureus*, in Asia in *O. mossambicus* and *O. niloticus* (see 11), in America in *O. mossambicus*, and hybrids from *O. urolepis hornorum x O. mossambicus*, *O. aureus,* and *O. hornorum* (11).

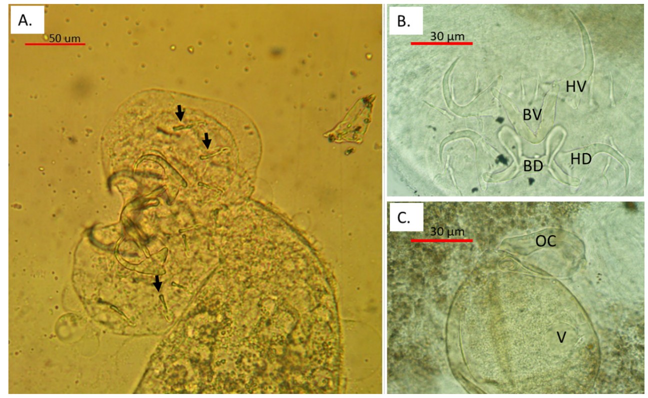

Figure 3. *Cichlidogyrus sclerosus* collected from tilapia *Oreochromis* spp. of farms. A: opistohaptor; B: view of the sclerotized structures of the haptor in the same plane. Note the absence of a root and the similarity in the size of the dorsal and ventral hamuli. C: genital complex. HV: ventral hamuli; HD: dorsal hamuli; BV: ventral bar; BD: dorsal bar. OC: copulatory organs; V: vagina. Arrows show hooklets.

Infection parameters. Of the 45 fish analyzed, 31 (69%) were positive for the presence of at least one species of monogeneans. Of the two species identified, *C. sclerosus* presented the highest infection parameter values (Table 2). *Cichlidogyrus dossoui* was only identified in farm 1 (Calceta) with a prevalence of 13% (Table 2).

Histological damages. The parasitized hosts showed different degrees of hyperplasia in the branchial tissue depending on the intensity of infection (Figures 4A-D), and leukocyte infiltration between secondary filaments. In the lesser parasitized hosts, slight hyperplasia was observed, covering up to 30% of the secondary filaments (Figure 4B); in hosts with medium levels of infection, moderate hyperplasia was observed with fusion of secondary lamellae and abundant mucous cells (Figure 4C). In hosts with abundant parasites, severe hyperplasia was observed completely covering the secondary filaments, congestion of blood vessels with thickening of secondary filaments, and abundant mucous cells (Figure 4D).

Table 2. Infection parameters prevalence, mean abundance and mean intensity of each species of parasite identified in tilapia *Oreochromis* spp. S.D.: standard deviation.

Farm	Parasite species	Prevalence %	Mean abundance (S.D.)	Mean intensity (S.D.)
1. Calceta	*Cichlidogyrus sclerosus*	60	37 ± 115.43	61.67 ± 146.98
	C. dossoui	13.33	0.4 ± 1.12	3 ± 1.41
2. Puerto Quito	*C. sclerosus*	66.67	25.67 ± 31.20	38.5 ± 31.07
3. Alluriquín	*C. sclerosus*	80	10.47 ± 10.15	13.08 ± 9.69

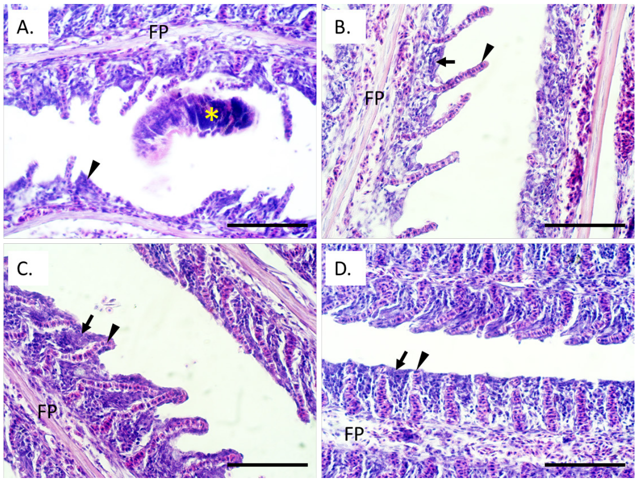

Figure 4. Histological sections of gill tissue of tilapia (*Oreochromis* spp.) parasitized with *Cichlidogyrus* spp. A: displacement and fusion of secondary filaments (arrowhead) due to the presence of *Cichlidogyrus sclerosus* (*). Note moderate hyperplasia between secondary filaments. B: light hyperplasia (arrow) between the secondary filaments (arrowhead) of a host parasitized with 4 *Cichlidogyrus dossoui*. C: moderate hyperplasia (arrow) among the secondary gill filaments (arrowhead) of a host parasitized with 68 *Cichlidogyrus sclerosus*. D: severe hyperplasia (arrow) among secondary gill filaments (arrowhead) of a host parasitized with 452 *Cichlidogyrus sclerosus*. Note the thickening from the congestion of the secondary filaments and the congestion in the primary filament. FP = primary filament. H&E staining, Bar scale = 100 µm.

DISCUSSION

In all of the analyzed tilapia farms, we found the presence of monogeneans belonging to the genus *Cichlidogyrus*. This genus is one of the most diverse groups of monogeneous parasites that infest the family Cichlidae, currently reporting approximately 100 species (15). Originally it was restricted to the rivers and lakes of Africa, however, with the expansion of tilapia aquaculture today it is recorded in both farming and natural environments parasitizing exotic cichlids and native species from around the world (17,18). Despite its wide distribution in South America, (3) this genus has not been reported in Ecuador. Soler-Jiménez et al. (3) erroneously mention that Jiménez (19), in his work on tilapia parasites from Ecuador, reports *Cichlidogyrus* spp.; however, this last author only reported *Dactylogyrus* and *Gyrodactylus* without identifying the species. In this sense, this work constitutes the first record of the genus *Cichlidogyrus* infesting *Oreochromis* spp. of Ecuador.

The monogeneans in this study were identified as *C. dossoui* and *C. sclerosus*. The monogeneans identified as *C. dossoui* presented distinctive morphological characteristics of the species such as: hamuli with well-developed roots, dorsal hamuli smaller than ventral, long III–VII microhooks, sclerotized vagina, and large copulatory organ, with developed accessory parts, curved finger-like extensions, and denticles in the convex part (11). Monogeneans identified as *C. sclerosus* presented the distinctive morphological characteristics of the species, such as: large hamuli with sparse root, short and solid bars, pyriform appendages on the dorsal bar, straight vagina, and a slightly sclerotized and large copulatory organ (7,11). However, the specimens in this study differ from the original description in a lower development of the hamuli root, similarly to that reported in specimens of *C. sclerosus* collected in *Tilapia* (= *Oreochromis*) *mossambica* from Colombia (20). Subsequent studies involving morphometry and / or molecular biology will be necessary to describe the intraspecific variations that may occur throughout the distribution range of these species, as suggested by some authors, who have recommended genetic analysis to reveal the existence of phenotypic plasticity and evolutionary convergence specifically in genus *Cichlidogyrus* (21,22).

Of the two species of monogeneans identified in this study, *C. sclerosus* was found in all three sampled farms, with higher infection parameters (prevalence of 60 % to 80 %, mean abundance of 24.24 ± 68.62, and mean intensity of 37.62 ± 82.93) than *C. dossoui*. The higher infection parameters in *C. sclerosus* are likely due to a greater distribution of this species in tilapia from Ecuador. *Cichlidogyrus sclerosus* has been reported infesting cultivated tilapias in America, Africa, and Asia (3,12,18), and it is considered the most widely distributed *Cichlidogyrus* species in Latin America (3). Similarly, to this study, reports on *O. niloticus*, *O. mossambicus* and *Tilapia zillii* collected in farms in Japan have shown high prevalence (60% – 100%) and variables between farms (18). This difference in the infection parameters between farms could be the result of variations in water quality, as well as in the management measures of aquaculture systems. Ojwala et al. (23) also reported differences in the infection parameters of *C. sclerosus* associated with the physicochemical parameters of the water. Additionally, it has been found that the infection parameters change with environmental variability such as temperature increases and hydrological changes (24,25). This aspect would be important to evaluate in the tilapia farms of Ecuador since there are two very marked climatic seasons in terms of environmental temperature and precipitation; the infections of this parasite are likely to increase during the rainy season, when the environmental temperature increases compared to the dry season.

Cichlidogyrus dossoui was identified in a single farm, with low infection parameters (prevalence of 13%, mean abundance of 0.4 ± 1.12 and mean intensity of 3 ± 1.41). This species has been reported in culture systems of America and Africa (3,12), and in a natural environment, infecting *O. niloticus* from Mexico (3). The infection parameters reported for *C. dossoui* differ between studies, showing prevalence values of 18% to 48% (12,26), likely associated with water quality and density (2). However, although it is less frequent than *C. sclerosus*, when it occurs with high prevalence and average intensity, negative effects have been reported in the hosts (18).

There are few reports of the histopathological damages produced by *Cichlidogyrus* in tilapia. In this study we detected that even in organisms infested with low intensities, the parasites cause hyperplasia of the lamellae, which is consistent with lesions detected in *O. niloticus* infected with monogeneans of this genus (27). Hyperplasia produces a distance between water and blood vessels, affecting gas exchange and osmotic balance; some studies have determined that such damage causes hypoxia, loss of balance and erratic movements (28,29). Additionally, these lesions are the gateway for other pathogens, such as fungi and bacteria (10,30). Although histological damages has not been analyzed in many studies, infections with *C. sclerosus* have shown negative effects on growth rates and host condition factors, respiratory problems, and mortality (10,26), likely associated with abnormalities in the gills.

In this study, two species of the genus *Cichlidogyrus* are reported parasitizing tilapias in farms from Ecuador for the first time. This result is important, since several authors mention that members of this group of parasites severely affect the health status of fish in culture systems with high stocking densities and poor water quality (3,26). It is recommended to extend the study to farms in other areas of Ecuador, with a greater focus on the juvenile phase where these parasites cause more damage, to propose prevention and control measures that minimize the negative impact of these pathogens. *Cichlidogyrus sclerosus* has not only been recorded in tilapia crops globally but has also been found in native fish from various countries (3). Iit is important to study the possible presence and impact of these monogeneans in native species of Ecuador, a country with a great diversity of fish and a high endemism of many species.

Conflict of interests

The authors declare that they have no competing interests.

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REFERENCES

1. Wilson JR, Saunders RJ, Hutson KS. Parasites of the invasive tilapia *Oreochromis mossambicus*: evidence for co-introduction. Aquat Invasions. 2019; 14(2):332–349. https://www.reabic.net/aquaticinvasions/2019/AI_2019_Wilson_etal.pdf

2. Paredes-Trujillo A, Velázquez-Abunader I, Torres-Irineo E, Romero D, Vidal-Martínez VM. Geographical distribution of protozoan and metazoan parasites of farmed Nile tilapia *Oreochromis niloticus* (L.) (Perciformes: Cichlidae) in Yucatán, Mexico. Parasit Vectors. 2016; 9(66). https://doi.org/10.1186/s13071-016-1332-9

3. Soler-Jiménez LC, Paredes-Trujillo AI, Vidal-Martínez VM. Helminth parasites of finfish commercial aquaculture in Latin America. J Helminthol. 2017; 91(2):110–136. https://doi.org/10.1017/S0022149X16000833

4. Gonzales-Fernández JG. Parasitofauna of tilapia cause mortalities in fingerlings in two fishfarms, Lima, Peru. Neotrop Helminthol. 2012; 6(2):219–229. https://sisbib.unmsm.edu.pe/BVRevistas/neohel/v6n2/pdf/a08v6n2.pdf

5. Jacome J, Quezada C, Sánchez O, Pérez JE, Nirchio M. Tilapia en Ecuador: paradoja entre la producción acuícola y la protección de la biodiversidad ecuatoriana. Rev peru de biol. 2019; 26(4):543–550. http://dx.doi.org/10.15381/rpb.v26i4.16343

6. FAO. (2020). Fisheries Division, Statistics and information Branch. FishStatJ: Universal software for fishery statistical time series. Copyright 2020. http://www.fao.org/fishery/statistics/software/fishstatj/es

7. Pariselle A, Euzet L. Systematic revision of dactylogyridean parasites (Monogenea) from cichlid fishes in Africa, the Levant and Madagascar. Zoosystema 2009; 31(4):849-898. https://doi.org/10.5252/z2009n4a6

8. Bush AO, Lafferty KD, Lotz JM, Shostak AW. Parasitology Meets Ecology on Its Own Terms: Margolis et al. Revisited. J Parasitol. 1997; 83(4):575-583. https://www.doi.org/10.2307/3284227

9. Wolf J, Baumgartner W, Blazer V, Camus AC, Engelhardt JA, Fournie JW, et al. Non-lesions, misdiagnoses, missed diagnoses, and other interpretive challenges in fish histopathology studies: a guide for investigators, authors, reviewers, and readers. Toxicol Pathol. 2014; 43: 297–325. https://www.doi.org/10.1177/0192623314540229

10. Steckert LD, Cardoso L, Jerônimo GT, Benites S, Martins ML. Investigation of farmed Nile tilapia health through histopathology. Aquaculture. 2018; 486:161–169. https://www.doi.org/10.1016/j.aquaculture.2017.12.021

11. Douellou L. Monogeneans of the genus *Cichlidogyrus* Paperna, 1960 (Dactylogyridae: Ancyrocephalinae) from cichlid fishes of Lake Kariba (Zimbabwe) with descriptions of five new species. Syst Parasitol. 1993; 25:159–186. https://www.doi.org/10.1007/BF00007007

12. Madanire-Moyo GN, Matla MM, Olivier PAS, Luus-Powell WJ. Population dynamics and spatial distribution of monogeneans on the gills of *Oreochromis mossambicus* (Peters, 1852) from two lakes of the Limpopo River System, South Africa. J Helminthol. 2011; 85(2):146–152. https://www.doi.org/10.1017/S0022149X10000301

13. Madanire-Moyo GN, Luus-Powell WJ, Olivier PA. Diversity of metazoan parasites of the Mozambique tilapia, *Oreochromis mossambicus* (Peters, 1852), as indicators of pollution in the Limpopo and Olifants river systems. OJVR. 2012; 79:1–9. https://doi.org/10.4102/ojvr.v79i1.362

14. Pariselle A, Bitja Nyom AR, Bilong Bilong C. Checklist of the ancyrocephalids (Monogenea) parasitizing Tilapia species in Cameroon, with the description of three new species. Zootaxa. 2013; 3599, 78–86. https://doi.org/10.11646/zootaxa.3599.1.7

15. Fannes W, Vanhove MPM, Huyse T. Redescription of *Cichlidogyrus tiberianus* Paperna, 1960 and *C. dossoui* Douëllou, 1993 (Monogenea: Ancyrocephalidae), with special reference to the male copulatory organ. Syst Parasitol. 2017; 94(1):133–44. https://www.doi.org/10.1007/s11230-016-9685-1

16. Paperna I, Thurston JP. (1969) Monogenetic trematodes collected from cichlid fish in Uganda; including the description of five new species of *Cichlidogyrus*. Rev Zool afric, 1969; 79(1-2):15-33. https://www.cabdirect.org/cabdirect/abstract/19700802719

17. Aguirre-Fey D, Benítez-Villa GE, Pérez-Ponce de León G, Rubio-Godoy M. Population dynamics of *Cichlidogyrus* spp. and *Scutogyrus* sp. (Monogenea) infecting farmed tilapia in Veracruz, México. Aquaculture. 2015; 443:11–15. https://www.doi.org/10.1016/j.aquaculture.2015.03.004

18. Maneepitaksanti W, Nagasawa K. Monogeneans of *Cichlidogyrus* Paperna, 1960 (Dactylogyridae), gill parasites of tilapias, from Okinawa Prefecture, Japan. Biogeography 2012; 14:111–119. https://ir.lib.hiroshima-u.ac.jp/files/public/3/34082/20141016200842209265/Biogeography_14_111.pdf

19. Jiménez R. Enfermedades de tilapia en cultivo. Cámara Ecuatoriana del Libro, Núcleo de Pichincha; 2007. https://isbn.cloud/9789942010735/enfermedades-de-tilapia-en-cultivo/

20. Kritsky DC, Thatcher VE. Monogenetic trematodes (Monopisthocotylea: Dactylogyridae) from freshwater fishes of Colombia, South America. J Helminthol, 1974; 48:59-66. https://doi.org/10.1017/S0022149X00022604

21. Messu Mandeng FDM, Bilong Bilong CF, Pariselle A, Vanhove MPM, Bitja Nyom AR, Agnèse J-F. A phylogeny of *Cichlidogyrus* spp. (Monogenea, Dactylogyridae) clarifies a host-switch between fish families and reveals an adaptive component to attachment organ morphology of this parasite genus. Parasit Vectors. 2015; 8:582. https://doi.org/10.1186/s13071-015-1181-y

22. Vignon M, Pariselle A, Vanhove MPM. Modulatory in attachment organs of African *Cichlidogyrus* (Platyhelminthes: Monogenea: Ancyrocephalidae) reflects phylogeny rather tan host specificity or geografic distribution. Biol J Linn Soc. 2011; 102:694-706. https://doi.org/10.1111/j.1095-8312.2010.01607.x

23. Ojwala RA, Otachi EO, Kitaka NK. Effect of water quality on the parasite assemblages infecting Nile tilapia in selected fish farms in Nakuru County, Kenya. Parasitol Res. 2018; 117(11):3459-3471. https://doi.org/10.1007/s00436-018-6042-0

24. Akoll P, Fioravanti ML, Konecny R, Schiemer F. Infection dynamics of *Cichlidogyrus tilapiae* and *C. sclerosus* (Monogenea, Ancyrocephalinae) in Nile tilapia (*Oreochromis niloticus* L) from Uganda. J Helminthol. 2011; 86(3):302-310. https://doi.org/10.1017/S0022149X11000411

25. Ibrahim MM. Variation in parasite infracommunies of *Tilapia zillii* in relation to some biotic and abiotic factors. Int J Zool. 2012; 8(2):59-70. https://doi.org/10.3923/ijzr.2012.59.70

26. Paredes-Trujillo A, Velázquez-Abunader I, Papiol V, del Rio-Rodríguez RE, Vidal-Martínez VM. Negative effect of ectoparasite burdens on the condition factor from farmed tilapia *Oreochromis niloticus* in the Yucatan, Mexico. Vet Parasitol. 2021; 292:109393. https://www.doi.org/10.1016/j.vetpar.2021.109393

27. Igeh PC, Avenant-Oldewage A. Pathological effects of *Cichlidogyrus philander* Douëllou, 1993 (Monogenea, Ancyrocephalidae) on the gills of *Pseudocrenilabrus philander* (Weber, 1897) (Cichlidae). J Fish Dis. 2020; 43(2):177–184. https://www.doi.org/10.1111/jfd.13121

28. Martins ML, Cardoso L, Marchiori N, Benites de Pádua S. Protozoan infections in farmed fish from Brazil: diagnosis and pathogenesis. Rev. Bras Parasitol Vet. 2015; 24(1):1–20. https://doi.org/10.1590/S1984-29612015013

29. El-Mansy A, Hamada S, Hasan S, El-Sarnagawy D. Histopathology of farmed freshwater fish infested with different helminthes. Egypt J Aquat Biol & Fish. 2011; 15(1):1-13. https://doi.org/10.21608/EJABF.2011.2072

30. Alim DIM, Matter HMA. Histopathological alteration induced in gills of juvenile Nile tilapia *Oreochromis niloticus* upon exposure to two bio-pesticides. Int J Fish Aquat. Stud. 2015; 2(5):80–83. https://www.fisheriesjournal.com/archives/?year=2015&vol=2&issue=5&part=B&ArticleId=454