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Abstract

Monopisthocotyleans of the genus *Cichlidogyrus* are ectoparasites which infest on skin, fins and gills of most teleosts in both capture fisheries and aquaculture. These parasites are often unnoticed, yet they cause damages to the organs they affect thereby increasing susceptibility of the fish to secondary infections. A total of fifty specimens of the introduced Redbelly tilapia *Coptodon zillii* (Gervais, 1848) were collected between November 2014 and April 2015 from Lake Naivasha, Kenya, and studied with the aim of collecting and identifying the gill monopisthocotyleans. Standard methods of parasitological examination were used in the identification of gill monopisthocotyla species. The collected monogeneans were preserved in 4% formalin for morphometric analysis. Seven *Cichlidogyrus* species were identified from the gills based on morphometric features of the opisthaptor and copulatory organs using identification keys. These include: *Cichlidogyrus sclerosus* Paperna & Thurston, 1969; *C. tilapiae* Paperna, 1960; *C. digitatus* Dossou, 1982; *C. aegypticus* Ergens, 1981; *C. vexus* Pariselle & Euzet, 1995; *C. arthracanthus* Paperna, 1960, and *C. yanni* Pariselle & Euzet, 1996. The *C. digitatus* was the most dominant with a prevalence of 42% among the other monopisthocotyleans on *C. zillii* in the lake. These monopisthocotyleans form the first biogeographical record of their occurrence on *C. zillii* in Lake Naivasha, Kenya.

Keywords

Cichlid; Fish ectoparasite; infection levels; Monopisthocotyla; Redbelly tilapia

ORIGINAL ARTICLE

Diversity of Gill *Cichlidogyrus* spp. (Monopisthocotylean) Infecting *Coptodon zillii* (Gervais, 1848) from Lake Naivasha, Kenya

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Abstract

Monopisthocotyleans of the genus *Cichlidogyrus* are ectoparasites which infest on skin, fins and gills of most teleosts in both capture fisheries and aquaculture. These parasites are often unnoticed, yet they cause damages to the organs they affect thereby increasing susceptibility of the fish to secondary infections. A total of fifty specimens of the introduced Redbelly tilapia *Coptodon zillii* (Gervais, 1848) were collected between November 2014 and April 2015 from Lake Naivasha, Kenya, and studied with the aim of collecting and identifying the gill monopisthocotyleans. Standard methods of parasitological examination were used in the identification of gill monopisthocotyla species. The collected monogeneans were preserved in 4% formalin for morphometric analysis. Seven *Cichlidogyrus* species were identified from the gills based on morphometric features of the opisthaptor and copulatory organs using identification keys. These include: *Cichlidogyrus sclerosus* Paperna & Thurston, 1969; *C. tilapiae* Paperna, 1960; *Cichlidogyrus digitatus* Dossou, 1982; *Cichlidogyrus aegypticus* Ergens, 1981; *Cichlidogyrus vexus* Pariselle & Euzet, 1995; *Cichlidogyrus arthracanthus* Paperna, 1960, and *Cichlidogyrus yanni* Pariselle & Euzet, 1996. The *C. digitatus* was the most dominant with a prevalence of 42% among the other monopisthocotyleans on *C. zillii* in the lake. These monopisthocotyleans form the first biogeographical record of their occurrence on *C. zillii* in Lake Naivasha, Kenya.

Keywords: Cichlid, Fish ectoparasite, Infection levels, Monopisthocotyla, Redbelly tilapia

1. Introduction

Monopisthocotyleans are parasitic flatworms of great pathogenic significance globally in both cultured and wild fish while showing a high host specificity [1,2]. They are mainly ectoparasites which are commonly found on host skin and gills [3], but they can also invade the rectal cavity, ureter, body cavity, nostrils, intestine, stomach and even the vascular system [4–6]. They have a direct life cycle and are mostly spread by way of releasing eggs which hatch into free-swimming infective larvae known as oncomiracidia [7]. When they attack the gills in large numbers, they hinder respiration leading to fish mortalities. Their monitoring is considered an essential element of the management strategies of fish health [3,8]. Food and Agriculture Organization (FAO) [9] reported that to satisfy an increasing demand for freshwater fish, extensive research must include studies of their parasites for optimal production levels. The Redbelly tilapia, *Coptodon zillii* (Gervais, 1848) was introduced into Lake Naivasha in 1956 to establish a population for commercial use [10]. Since then, it has established itself and is among the common fishes that are frequently collected in the lake. The fish is economically and ecologically important as food fish in aquaculture, commercial aquarium trade, weed control and recreational fishery [11]. The *C. zillii* hosts several monopisthocotyleans belonging to the genus *Cichlidogyrus* Paperna, 1960 which usually infect cichlids and other freshwater fishes [12]. In Kenya, there is very little information about monopisthocotylea parasites [13–16]. For

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example, the ichthyoparasitological study on *C. zillii* in L. Naivasha by Aloo [17] did not find any ectoparasites, while Otachi *et al.* [13] who examined parasites of commercially important fish species in the lake, recorded that monopisthocotyleans form the bulk of the parasites infesting fish. Their study identified *Cichlidogyrus* spp. in *C. zillii* (formerly knowns as *Tilapia zillii*) with prevalence of 64.5% and mean intensity of 13.5 without segregeting the individual species in this genus. In a later study by Rindoria *et al.* [14] monopisthocotyleans were reported on *Oreochromis niloticus* and *Oreochromis leucostictus* from the same lake. Therefore, this study aimed to identify gill *Cichlidogyrus* species infesting *C. zillii* in Lake Naivasha, Kenya, establish their diversity and also to determine their prevalence and mean intensities.

2. Methodology

2.1. Study area

The study was carried out in Lake Naivasha in which the fish community comprises only introduced species [10]. The lake lies at 00°45′ S and 36°20′ E (Fig. 1) in a closed basin at an altitude of 1890 m above sea level, 190 km south of the equator, within the Eastern Rift Valley of Kenya. It is approximately 160 km^2, with a volume of 4.6 km^3 [18] and has a mean depth of 3.35 m and a maximum depth of 7 m [19]. It is a freshwater lake without a surface outlet but with substantial exchange with groundwater [20].

2.2. Permits and ethical clearance

This study received a research permit from the National Commission for Science and Technology Innovation (NACOSTI) reference No. NACOSTI/P/16/43570/8006. No ethical clearance was required for this study because it was carried out under the routine surveys of Kenya Marine and Fisheries Research Institute (KMFRI) a body mandated to conduct research in fisheries, marine and freshwater ecosystems in Kenya.

2.3. Fish collection

Fifty specimens of *C. zillii* (size ranges 10.8–23.4 (total length in centimetres) and 10.5–220.6 (mass in grams)) were collected using a fleet of gill nets with mesh sizes 5.08, 6.35, 7.62, 8.89, 10.16, and 11.43 cm between November 2014 and April 2015. The fish was identified following the guideline of Skelton [21] and Okeyo and Ojwang [22]. The fish were transported alive in a fish tank with lake water to the laboratory of KMFRI, Naivasha Station.

2.4. Parasite recovery

In the laboratory, the fish were killed by cervical dislocation and dissected [23]. The gills were removed and examined with a stereomicroscope and a motic BA210 compound microscope (Motic Instruments Inc., Richmond, British Columbia, Canada). The monopisthocotyleans were detached from the gills using a pair of fine forceps. Some of the monopisthocotyleans were individually transferred to a drop of ammonium picrate-glycerine [24] on a glass slide for observations of the sclerotized structures as per the methods of Ergens [25]. The preparation was covered with a cover slip and sealed with a transparent nail hardener for examination of the anatomy, additional specimens were flattened and fixed in 4% formalin.

2.5. Morphometric analysis

The sclerotized structures such as the opisthaptor and the copulatory complex were drawn using CorelDRAW Graphics Suite X6 software (Corel Corporation, 2003). Measurements were made with MOTIC software in which a MOTIC camera (MOTICAM 2300, 3.0-pixel USB 2.0) was attached to a MOTIC BA210 compound microscope (Motic Instruments Inc., Richmond, British Columbia, Canada). All measurements are given in micrometres as the mean ± the standard deviation followed by the range in parentheses, as proposed by Gussev [26]. Identification was done using the identification keys by Pariselle and Euzet [12,27]. The method of numbering of the sclerotized parts employed the protocol adopted at ICOPA IV [28]; using the terminology proposed by Pariselle and Euzet [27]: uncinulus for the marginal hooklets; gripus for the large median hooks. The measurements made in this study were as follows: gripus (G): a = total length, b = blade length, c = root length, d = shaft length, and e = point length; male apparatus (MA): penis total length (Pe), heel (He), and accessory piece length (AP); auxiliary plate (Pl); dorsal transverse bar (DB): h = length of auricle, w = maximum width, x = total length and y = distance between auricle; uncinuli length (U); ventral transverse bar (VB): w = maximum width and x = length of one branch; vagina (Vg): L = total length and l = maximum width according to Pariselle and Euzet [29].

Fig. 1. A map of Kenya showing Lake Naivasha - study area. Source: Rindoria et al. [14].

2.6. Infection and diversity characteristics

The prevalence (P) and mean intensities (MI) were determined according to Bush *et al.* [30]. The measures of monopisthocotyleans community structure such as the Shannon–Wiener index, Margalef richness index, Dominance index and Berger–Parker dominance index as proposed by Magurran [31] were determined using the online Biodiversity calculator [32] The Margalef richness index calculated was for the whole component community (for all investigated tilapia).

3. Results and discussion

3.1. Results

Seven species of *Cichlidogyrus* (Monopisthocotylea, Ancyrocephalidae) were found on the gills of *C. zillii.* Two of them: *Cichlidogyrus sclerosus* Paperna and Thurston, 1969 and *C. tilapiae* Paperna, 1960 have previously been reported infecting the *O. niloticus* and *O. leucostictus* in the same lake [14]. The other five species found included: *Cichlidogyrus aegypticus* Ergens, 1981; *Cichlidogyrus arthracanthus* Paperna, 1960; *Cichlidogyrus digitatus* Dossou, 1982; *Cichlidogyrus yanni* Pariselle & Euzet, 1995, and *Cichlidogyrus vexus* Pariselle & Euzet, 1995. A summary of their infection and diversity data (Table 1) is given below.

3.1.1. Cichlidogyrus digitatus Dossou, 1982

The finding of *C. digitatus* (Fig. 2) in this study represents the first biogeographical record from Kenya. This parasite was originally described by Dossou [33] in Benin based on the specimens from the gills of *Coptodon guineensis* and later by Pariselle and Euzet [34]; Pouyaud *et al.* [35] from Benin, Ivory Coast and Guinea on the same type-host. The species has also been reported from various cichlid fishes (*Coptodon dageti*, *C. guineensis*, *C. louka*, *C. brevimanus* and *C. walteri*) from Senegal, Mali, Ivory Coast, Gambia and Guinea in Africa by Pariselle and Euzet, [34]; Pouyaud *et al.* [35]. The latest record from Africa is by Blahoua *et al.* [36] in the man-made Lake Ayame I, Côte d'Ivoire from the type-host.

Table 1. Diversity characteristics of the Cichlidogyrus species on Coptodon zillii from Lake Naivasha, Kenya.

Total component communities	*C. zillii* (n = 50)
Total number of species	7
Total number of organisms	28
Shannon–Wiener index (H)	0.999
Simpson's index (D)	0.558
Berger–Parker index (d)	0.750
Margalef richness index (DMg)	1.801
Dominant species	*C. digitatus*

3.1.2. Cichlidogyrus yanni Pariselle & Euzet, 1996

The finding of *C. yanni* (Fig. 3) in this study represents the first biogeographical record from Kenya. This parasite was originally described by Pariselle and Euzet [34] on the type-host in Guinea, Kogon River and Pouyaud *et al.* [35] in Burkina Fasso Volta Noire River. The parasite has since been reported in various tilapia hosts: *C. dageti*, (Senegal, Mali); *C. guineensis*, (Ivory Coast, Senegal); *C. louka*, (Guinea) *C. walteri* and *C. mariae* (Ivory Coast) in Africa [34,35]. The latest record from Africa is by Blahoua *et al.* [36] in the man-made Lake Ayame I, Côte d'Ivoire from the type-host.

3.1.3. Cichlidogyrus aegypticus Ergens, 1981

The finding of *C. aegypticus* (Fig. 4) in this study represents the first biogeographical record from Kenya. This parasite was originally described by Ergens [37] based on the specimens from the gills of type-host in River Nile Egypt, later from by Dossou [33] in Benin; Burkina Faso and in Ivory Coast by Pariselle and Euzet [34]; Pouyaud *et al.* [35]. The species has so far been reported from other fish hosts from Egypt and Ivory Coast in Africa (*C. dageti*, *Sarotherodon galilaeus*; *O. niloticus; Tilapia busumana*; *C. dageti*; *C. guineensis*; *C. walteri* [34,35,38]. The latest record from Africa is by Ibrahim (2012) from Lake Manzalah, Egypt and Blahoua *et al.* [36] in man-

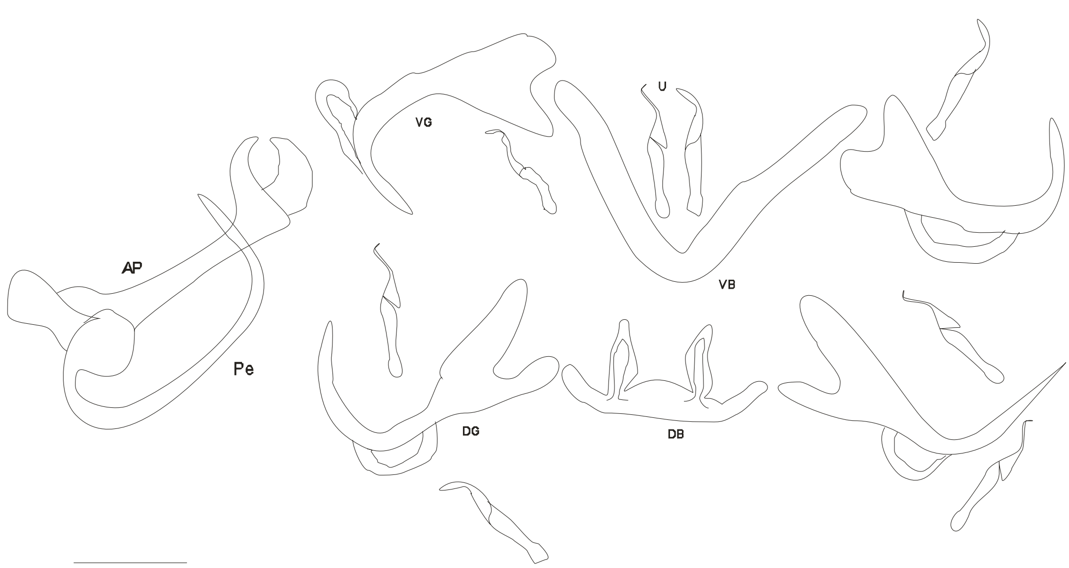

Fig. 2. Cichlidogyrus digitatus Dossou, 1982: Sclerotized parts of copulatory complex and opisthaptoral structures. Abbreviations: AP accessory piece, Pe penis, DB dorsal bar, DG dorsal gripus, VG ventral gripus, VB Ventral bar, U uncinuli (Scale-bar: 50 μm).

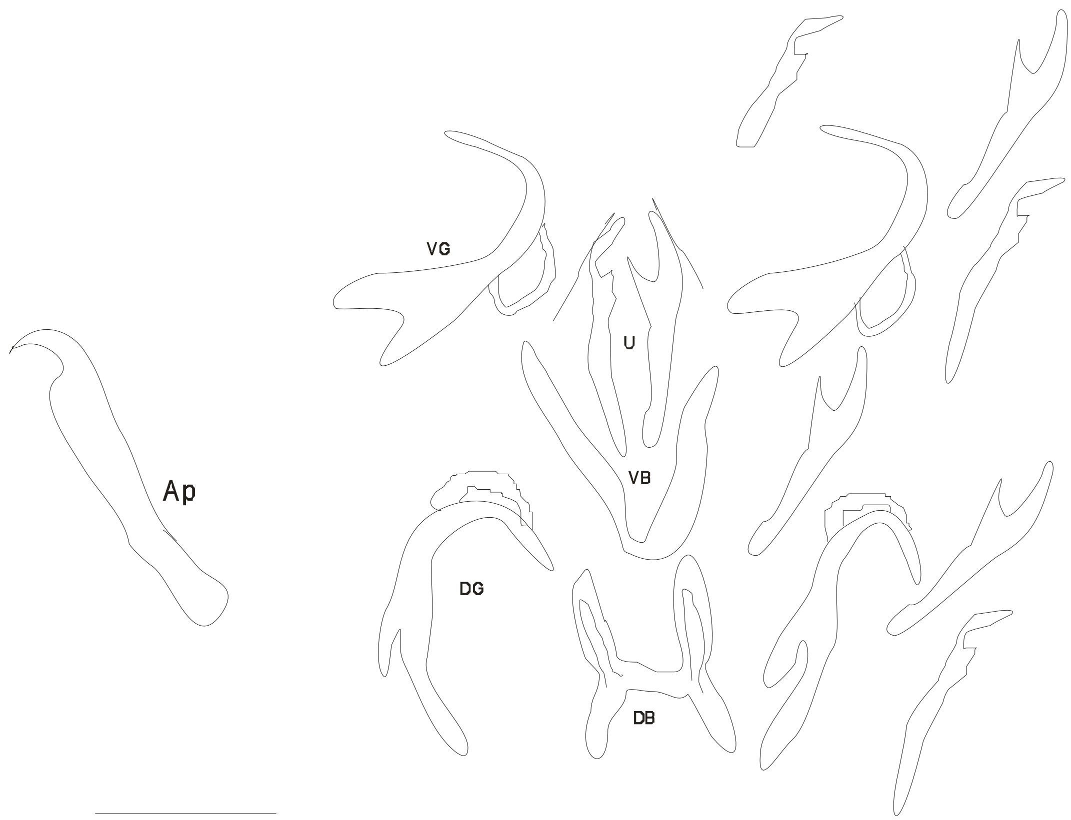

Fig. 3. Cichlidogyrus yanni Pariselle & Euzet, 1995: Sclerotized parts of copulatory complex and opisthaptoral structures. Abbreviations: AP accessory piece, DB dorsal bar, DG dorsal gripus, VG ventral gripus, VB Ventral bar, U uncinuli (Scale-bar: 50 μm).

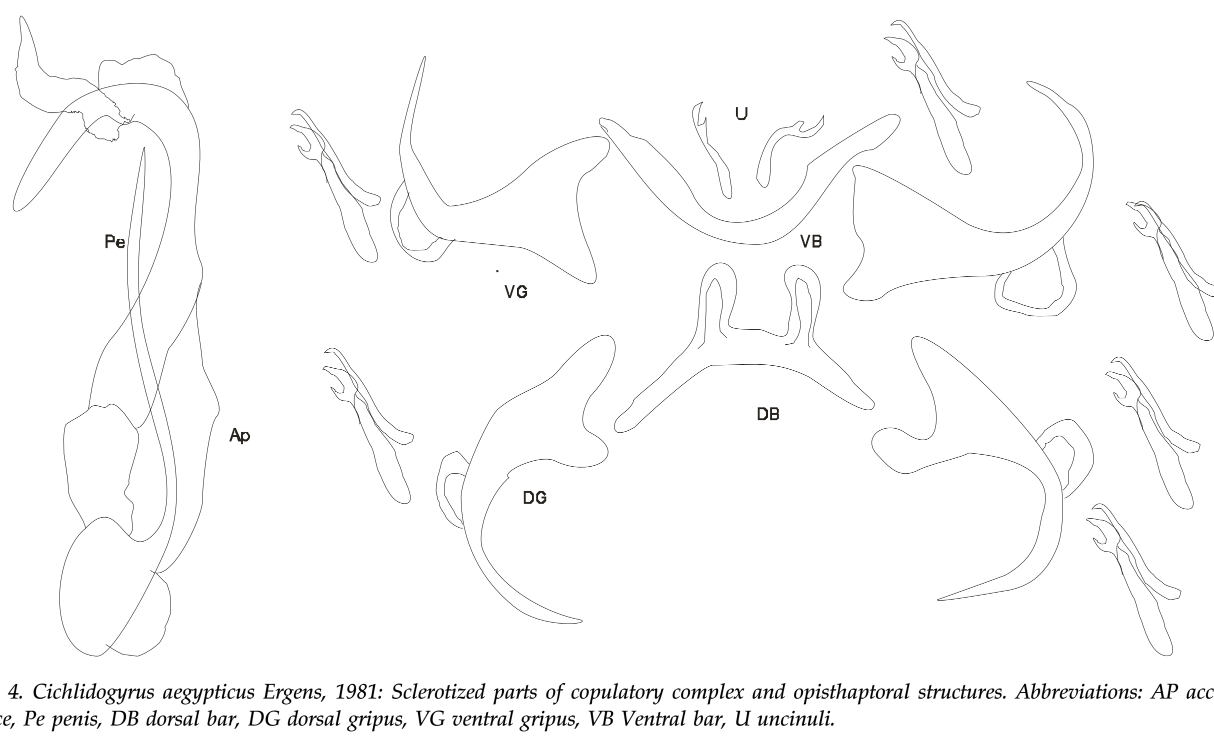

Fig. 4. Cichlidogyrus aegypticus Ergens, 1981: Sclerotized parts of copulatory complex and opisthaptoral structures. Abbreviations: AP accessory piece, Pe penis, DB dorsal bar, DG dorsal gripus, VG ventral gripus, VB Ventral bar, U uncinuli.

made Lake Ayame I, Côte d'Ivoire from the type-host.

3.1.4. Cichlidogyrus arthracanthus Paperna, 1960

The finding of *C. arthracanthus* (Fig. 5) in this study represents the first biogeographical record from Kenya. This parasite was originally described by Paperna [39] based on the specimens from the gills of *C. zillii* in Dor and near Sea of Galilee Israel and later in South Ghana and North Ghana [40–42], Uganda [34,43] and Egypt [35,37]. The species has also been reported from other host fishes from Israel in the Middle East: *Tristramella simonis*; *T. sacra* and Egypt: *S. galilaeus; O. niloticus*; *T. busumana*; *C. dageti*; *C. guineensis*; *C. walteri* [34,35,38] in Africa. The latest record from type-host is by Ibrahim [8] from Lake Manzalah, Egypt, Africa.

3.1.5. Cichlidogyrus vexus Pariselle & Euzet, 1995

The finding of *C. vexus* (Fig. 6) in this study represents the first biogeographical record from Kenya. This parasite was originally described by Pariselle and Euzet [27,34,35] based on the specimens from the gills of *C. guineensis* in Bandama River, Ebrié Lagoon, Ivory Coast in Africa. The latest record from Africa is by Blahoua *et al.* [36] in man-made Lake Ayame I, Côte d'Ivoire from the type-host.

3.2. Infection and diversity characteristics

The *C. digitatus* recorded the highest P = 42%; and MI = 1.91 whereas *C. arthracanthus*, *C. sclerosus*, *C. tilapiae*, *C. vexus* and *C. yanni* all had an equal P = 2% and MI = 1.00. The *C. vexus* had a P = 4% and MI = 2.00 (Figs. 7 and 8).

3.2.1. Species richness

The species richness of the parasite infra-communities harboured by the host was 1.80 which almost agrees with Ibrahim [8] who recorded a richness of 1.87 on the same host. The diversity of parasite communities was 0.442 which is

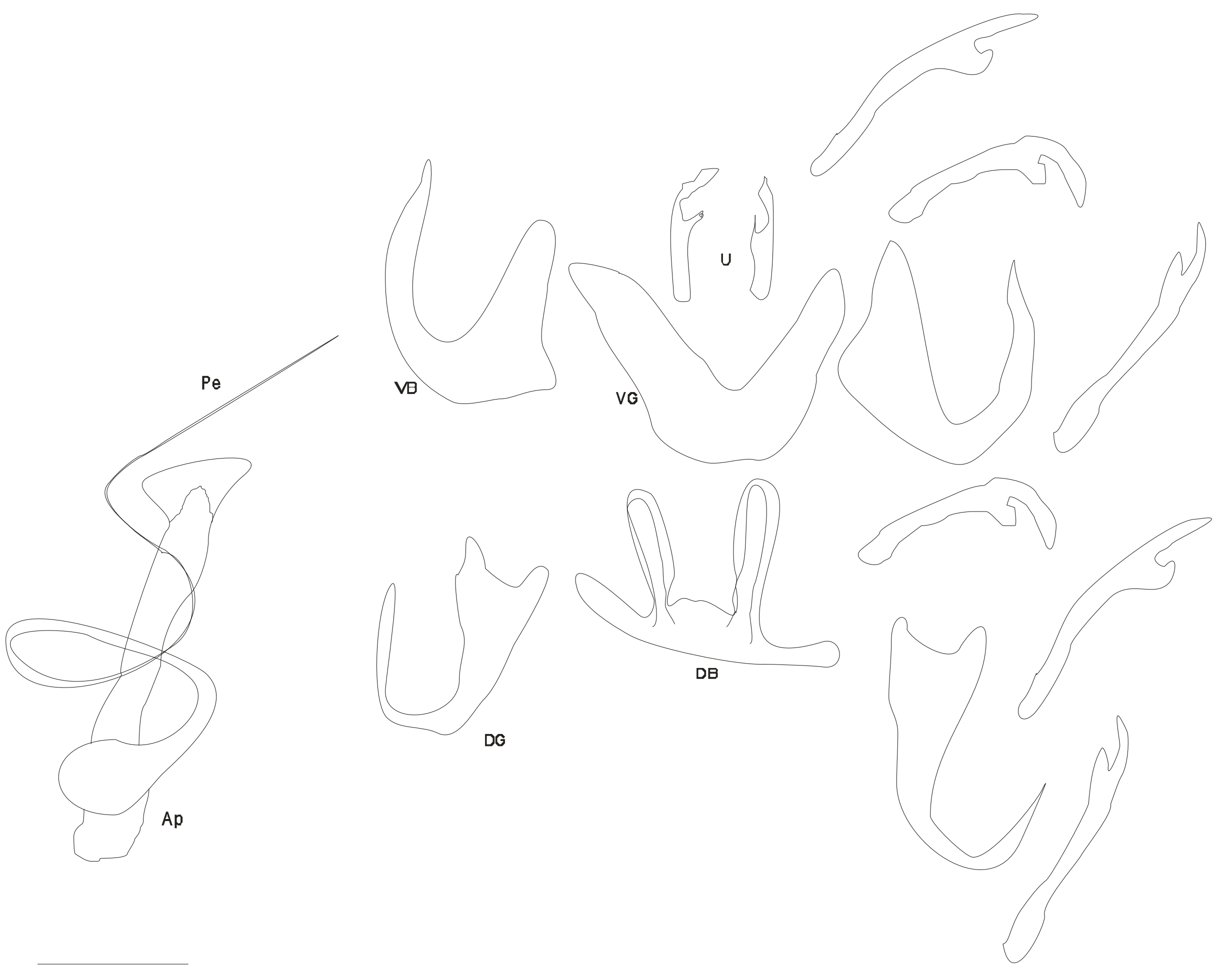

Fig. 5. Cichlidogyrus arthracanthus Paperna, 1960: Sclerotized parts of copulatory complex and opisthaptoral structures. Abbreviations: AP accessory piece, Pe penis, DB dorsal bar, DG dorsal gripus, VG ventral gripus, VB Ventral bar, U uncinuli (Scale-bar: 50 μm).

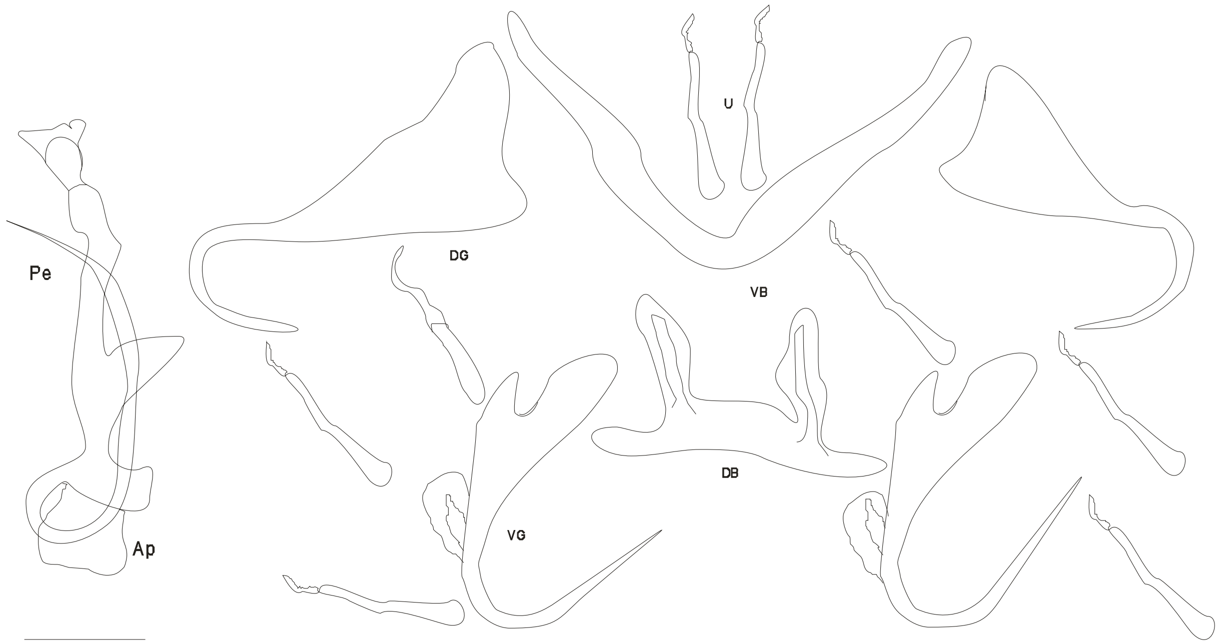

Fig. 6. Cichlidogyrus vexus Pariselle and Euzet, 1995: Sclerotized parts of copulatory complex and opisthaptoral structures. Abbreviations: AP accessory piece, Pe penis, DB dorsal bar, DG dorsal gripus, VG ventral gripus, VB Ventral bar, Uncinuli (Scale-bar: 50 μm).

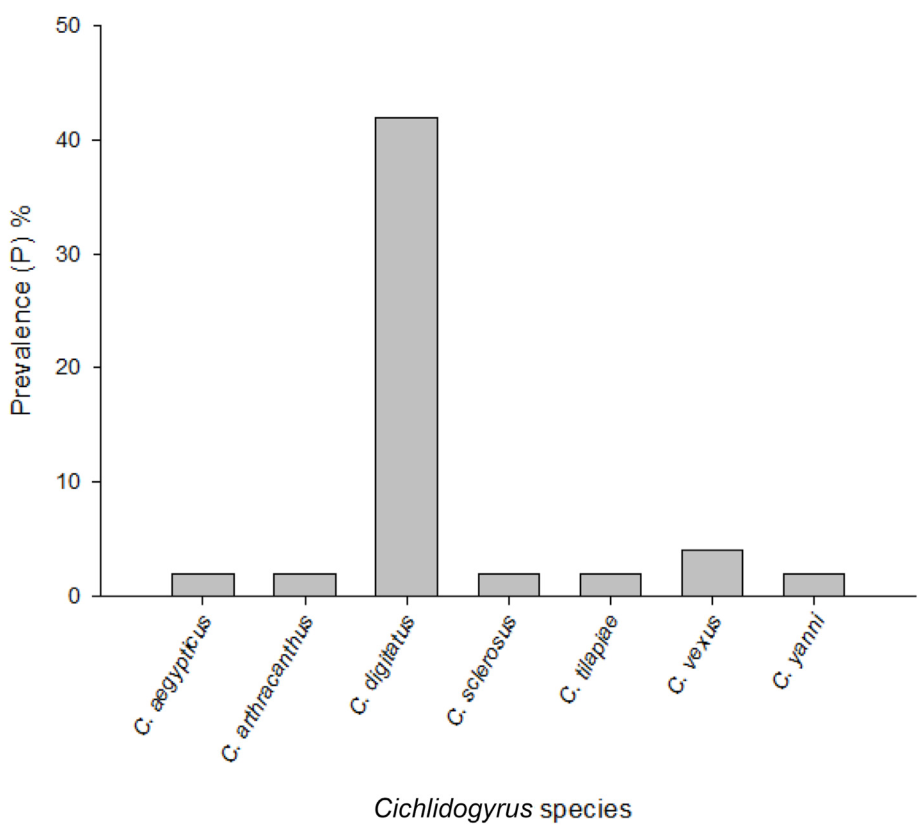

Fig. 7. Prevalence (P) % of the Cichlidogyrus species in Coptodon zillii from Lake Naivasha, Kenya.

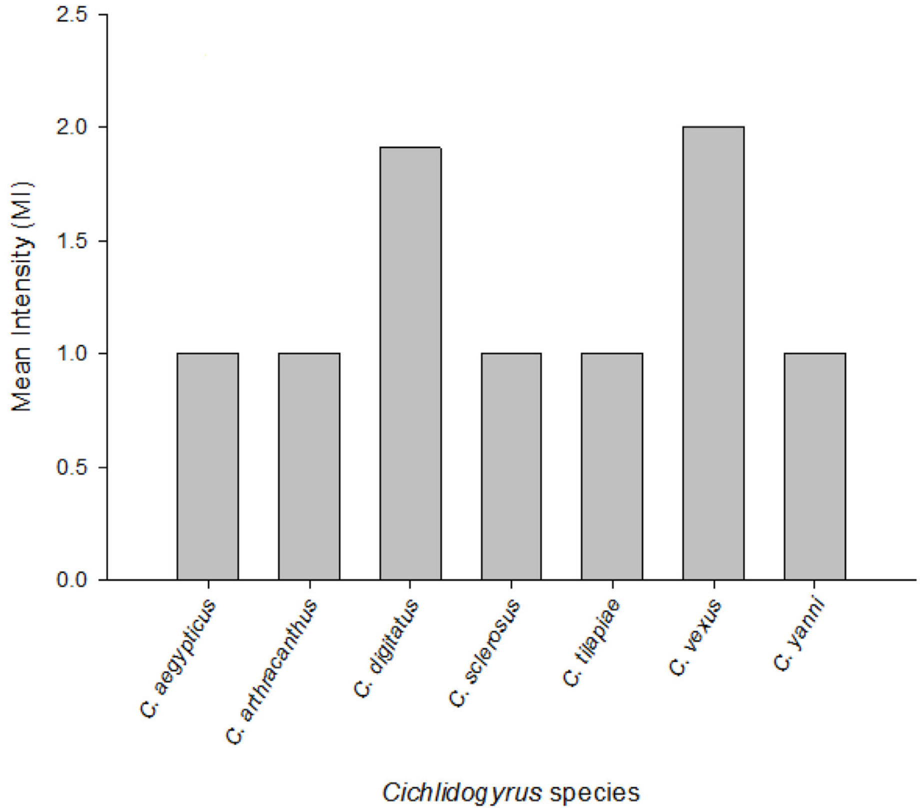

Fig. 8. Mean intensities (MI) of the Cichlidogyrus *species in* Coptodon zillii *from Lake Naivasha, Kenya.*

comparable with Ibrahim [8] who reported a Brillouin index of 2.050. The Berger-Parker index value was 0.750 (Table 1) which is also comparable with what Ibrahim [8] who reported 0.410. The slight differences in these indices in the two studies may be attributed to different sample sizes, seasonality and geographical locations.

3.3. Discussion

The finding of *C. digitatus, C. yanni, C. aegypticus, C. arthracanthus* and *C. vexus* in this study presents the first biogeographical record in Lake Naivasha and from the republic of Kenya. The *C. digitatus* was originally described by Dossou [33] in Benin based on the specimens from the gills of the type-host and later by Pariselle and Euzet [34]; Pouyaud *et al.* [35] from Benin, Ivory Coast and Guinea on the same type-host. The species has also been reported from various cichlid fishes: *C. dageti*, *C. guineensis*, *C. louka*, *C. brevimanus* and *C. walteri* from Senegal, Mali, Ivory Coast, Gambia and Guinea in Africa by Pariselle and Euzet [34] and Pouyaud *et al.* [35]. The latest record from Africa is by Blahoua *et al.* [36] in a man-made Lake Ayame I, in Ivory Coast from the type-host.

The *C. aegypticus* was originally described by Ergens [37] based on the specimens from the gills of type-host in River Nile Egypt, later from by Dossou [33] in Benin; Burkina Faso and in Ivory Coast by Pariselle and Euzet [34]; Pouyaud *et al.* [35]. The species has so far been reported from other fish hosts from Egypt and Ivory Coast in Africa: *C. dageti*, *S. galilaeus*; *O. niloticus; T. busumana*; *C. dageti*; *C. guineensis* and *C. walteri* [34,35,38]. The latest records from Africa are by Ibrahim [8] from Lake Manzalah, Egypt and Blahoua *et al.* [36] in man-made Lake Ayame I, Ivory Coast from the type-host.

The *C. arthracanthus* was originally described by Paperna [39] based on the specimens from the gills of type-host in Dor and near Sea of Galilee, Israel and later in Ghana [40—42], Uganda [34,43] and Egypt [35,37]. The species has also been reported from other host fishes from Israel in the Middle East: *T. simonis*; *T. sacra* and Egypt: *S. galilaeus; O. niloticus*; *T. busumana*; *C. dageti*; *C. guineensis* and *C. walteri* [34,35,38] in Africa. The latest record from the type-host is by Ibrahim [8] from Lake Manzalah, Egypt, Africa.

The *C. vexus* was originally described by Pariselle and Euzet [27,34,35] based on the specimens from the gills of *Tilapia guineensis* in Bandama River,

Table 2. Comparison between the current study and other studies of the Cichlidogyrus *species on* Coptodon zillii *in Africa.*

Cichlidogyrus species	Authors, Year and Country							
	Ergens [37] R. Nile, Egypt		Paperna [44] West Africa		Ibrahim [8] Lake Manzalah, Egypt		Present study Lake Naivasha, Kenya	
	P (%)	MI	P (%)	MI	P (%)	MI	P (%)	MI
C. aegypticus	NR	NR	NR	NR	33.82	12.29	2	1.00
C. arthracanthus	NR	NR	–	–	47.94	15.50	2	1.00
C. digitatus	–	–	NR	NR	–	–	42	1.91
C. yanni	–	–	NR	NR	–	–	2	1.00
C. sclerosus	–	–	–	–	9.12	5.51	2	1.00
C. tilapiae	NR	NR	–	–	–	4.97	2	1.00
C. vexus	–	–	NR	–		–	4	2.00
Prevalent taxon	NR		NR		*C. arthracanthus*		*C. digitatus*	

NR Studied but not recorded, - Not Studied.

Ebrié Lagoon, Ivory Coast in Africa. The latest record from Africa is by Blahoua *et al.* [36] in man-made Lake Ayame I, Ivory Coast from the type-host.

The present study recorded prevalnce and mean intensity ranges for various *Cichlidogyrus* species (Table 2) which were comparatively lower than the values reported by Otachi *et al.* [13]. This variation may be attributed to segregation of the species of this genus in the current work, which was not the case in Otachi *et al.* [13]. The species richness of the seven species of the genus *Cichlidogyrus* on *C. zillii*: *C. digitatus*, *C. yanni*, *C. vexus*, *C. arthracanthus*, *C. aegypticus*, *C. sclerosus*, and *C. tilapiae* is more than what has been reported in previous studies (Table 2). Ergens [37] found three monopisthocotylea species in 15 *C. zillii* in River Nile Cairo Egypt, Paperna [44] found five monopisthocotyleans on the same host in West Africa, Ibrahim [8] recovered more monogeneans from the same host in Lake Manzalah, Egypt with four species being similar to those found in this study, while Blahoua *et al.* [36] found four monopisthocotylean species in the same host in man-made Lake Ayame I, Ivory Coast (Table 2). The number of *Cichlidogyrus* species observed in a single host from Lake Naivasha shows the exploitation of a host fish by several species of monopisthocotylea (polyparasitism) which has been reported by various authors in other cichlids. For instance, Blahoua *et al.* [45] reported the presence of *Scutogyrus* and three species of *Cichlidogyrus* in *Sarotherodon melanotheron*. Ibrahim [8] also showed that eight monopisthocotylean species colonized the gills of *C. zillii* in L. Manzalah Egypt (Table 2).

Moreover, the colonization of hosts by several congeneric species was also reported by Boungou *et al.* [46] and Bittencourt *et al.* [47]. This polyparasitism could be explained by the fact that in the natural environments, the parasitic densities are generally low and therefore, niches are always available on the gill biotope thereby facilitating simultaneous colonization of the same host by several species of monopisthocotyla [48–50]. Indeed, most of the hosts have few if any parasites, while a small number of hosts are infected with many parasites [51]. This pattern is expected in most animals in nature, as observed in the present study and also has been reported by Ibrahim [8]. For example, *C. arthracanthus*, *C. aegypticus*, *C. ergensi*, *C. sclerosus, C. tilapiae, C. halli typicus, C. tiberianus* and *Gyrodactylus cichlidarum* gill parasites have been reported from Lake Manzalah, Egypt. According to Combes [52], an aggregative distribution may indicate heterogeneity in the relationship between the host and the parasite populations. The probability for a parasite to meet its host and its chances of surviving in the latter may vary from one host to another. In addition, Kennedy [53] stated that aggregative distribution increases the opportunities for parasites to meet a partner to reproduce. The occurrence of many monopisthocotylea parasites on the same host can also be a result of changes in abiotic factors such as changes in the concentration of suspended solids, conductivity and water transparency [54].

4. Conclusions

This study demonstrates that gill parasitizing monopisthocotyleans of the genus *Cichlidogyrus* of *C. zillii* exhibit polyparasitism in natural water systems. The five monogenean species (*C. digitatus*, *C. yanni*, *C. vexus*, *C. arthracanthus* and *C. aegypticus*) recorded in this study form the first biogeographical record in Lake Naivasha, Kenya on *C. zillii.* However, the *C. sclerosus* and *C. tilapiae* have been previously recorded from the *O. leucostictus* and *O. niloticus* from the same lake. The *C. digitatus* had the highest prevalence while the *C. vexus* had the highest mean intensity. By segregation of the *Cichlidogyrus* species, this study provides baseline infection indices important for future monitoring of this monopisthocotyleans of this genus in cichlids. Further investigation on the pathological effects of this *Cichlidogyrus* spp. on *C. zillii* needs to be considered.

Ethics information

This study received a research permit from the National Commission for Science and Technology Innovation (NACOSTI) reference No. NACOSTI/P/16/43570/8006. No ethical clearance was required for this study because it was carried out under the routine surveys of Kenya Marine and Fisheries Research Institute (KMFRI) a body mandated to conduct research in fisheries, marine and freshwater ecosystems in Kenya.

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AI usage declaration

None.

Author contributions

The author did all the work of conceptualization, sampling, data collection, methodology, resources, formal analysis, data curation, writing original, final draft and funding acquistion.

Conflict of interest

The author declares no conflict of interest.

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