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ORIGINAL PAPER

Gill monogeneans of *Oreochromis niloticus* (Linnaeus, 1758) and *Oreochromis leucostictus* (Trewavas, 1933) in Lake Naivasha, Kenya

Nehemiah Mogoi Rindoria[1] · **Lewis Kamau Mungai**[1] · **Andrew Wamalwa Yasindi**[1] · **Elick Onyango Otachi**[1]

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Abstract An investigation of gill monogeneans from the Nile tilapia *Oreochromis niloticus* and the blue spotted tilapia *Oreochromis leucostictus* (50 individuals per species) was done between the months of November 2014 to February 2015 in Lake Naivasha, Kenya. Standard parasitological procedures were used to examine fish gills for the presence of monogeneans. The observed monogeneans were collected, preliminarily identified using identification keys, quantified and fixed in 4 % formalin for morphological studies and absolute ethanol for molecular studies. Four parasite species comprising of three species of the genus *Cichlidogyrus* and one species of the genus *Scutogyrus* were recovered. *Cichlidogyrus sclerosus* and *Cichlidogyrus tilapiae* infested both fish species but the *C. sclerosus* was most prevalent in *O. leucostictus* (Prevalence (P) = 100 %, Mean intensity (MI) = 3.4) and *C. tilapiae* in *O. niloticus* (P = 8 %, MI = 4). *Cichlidogyrus tilapiae* had a P = 12 % and MI = 5.0 and a P = 6 % and MI = 3.0 in *O. niloticus* and *O. leucostictus*, respectively. *Cichlidogyrus halli* (P = 4 %, MI = 15.5) and *Scutogyrus gravivaginus* (P = 2 %, MI = 1.0) were only found in *O. leucostictus*. This is the first time that these monogeneans have been identified from Lake Naivasha, Kenya, presenting new geographical records. It was concluded that Ancyrocephalids (*Cichilidogyrus* spp.) dominated the two cichlid fish species in Lake Naivasha, Kenya.

Keywords Monogenean · *Cichlidogyrus* · *Scutogyrus* · Lake Naivasha · Tilapia

✉ Nehemiah Mogoi Rindoria
mrindoria84@yahoo.com

[1] Department of Biological Sciences, Egerton University, P.O. Box 536, Egerton, Kenya

Introduction

Fisheries contribute 0.5 % to the GDP of Kenya (KNBS 2012) and thus play an important role in the national economy. The fisheries of Lake Naivasha depend on several introduced fish (Gherardi et al. 2011). Fish parasites have been recognized as one of the detrimental and limiting factors in the development of capture fisheries and aquaculture. Several studies on parasites of fish have been undertaken in Lake Naivasha (Malvestuto and Ogambo-Ongoma 1978; Aloo 1999, 2002; Aloo and Dezfuli 1997; Amin and Dezfuli 1995; Otachi et al. 2014). However, in all the earlier studies, no ectoparasites were reported with the exception of the study by Otachi et al. (2014). Therefore, research on monogeneans parasitizing fish from Lake Naivasha, Kenya is scanty. Otachi et al. (2014) showed that monogenean trematodes form the bulk of fish parasites in this lake with prevalences of between 25.5 and 99.3 % in common carp *Cyprinus carpio* (Linnaeus, 1758), 64.5 % in Red belly tilapia *Tilapia zillii* (Gervais, 1848), 91.1 % in Blue spotted tilapia *Oreochromis leucostictus* (Trewavas, 1933), and 83.6 % in straightfin barb *Barbus paludinosus* (Peters, 1852). However, as noted by Otachi et al. (2014), the putative identity of the monogeneans observed thus far remains a challenge. The aim of this study was to identify the monogeneans infecting cichlid hosts in Lake Naivasha, Kenya.

Materials and methods

Study site

Fish were caught from the main Lake Naivasha (Fig. 1). This is the second largest freshwater lake in Kenya after the Kenya portion of Lake Victoria (Mavuti and Harper 2005). The lake

Fig. 1 A map of Kenya showing the location of study site (Source: Topographical map of Kenya scale 1:50,000) (Survey of Kenya)

lies at 00°45′ S and 36°20′ E in a closed basin at an altitude 1890 m above sea level, within the Eastern Rift Valley of Kenya. It is a freshwater lake in the Rift Valley without a surface outlet but with a substantial exchange with groundwater (Gaudet and Melack 1981). It has an approximate surface area of 160 km^2, a volume of 4.6 km^3 (Campbell et al. 2003), and an average depth of 6 m with the deepest area being 7 m (Hickley et al. 2008). These values vary with extreme weather conditions.

Fish collection, parasite recovery, and measurement of sclerotized parts

One hundred specimens of the two cichlids (50 of each, Nile tilapia *Oreochromis niloticus* and blue spotted tilapia *O. leucostictus*) were collected using a fleet of gill nets with mesh sizes 2, 2.5, 3, 3.5, 4, and 4.5 in. between November 2014 and February 2015. The fish were transported alive in a fish tank with lake water to the laboratory of the Department of Biological Sciences, Egerton University, Njoro, where they were killed by cervical dislocation (Schäperclaus 1990). In the laboratory, the fish were dissected and the gills were removed and examined with a dissecting microscope and a motic BA210 compound microscope. The monogeneans were detached from the gills using a pair of fine forceps. Some of the monogeneans were individually transferred to a drop of ammonium picrate- glycerine (Malmberg 1957) in a glass slide for observations of the sclerotized structures (Ergens 1969). The preparation was covered with a cover slip and sealed with a transparent nail hardener for examination of their internal anatomy. Other monogeneans were flattened and fixed in 4 % formalin and some were preserved in absolute ethanol. The sclerotized structures such as the haptor and the copulatory complex were drawn using corelDRAW Graphics Suite 12 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. All measurements are given in micrometers as the mean ± the standard deviation followed by the range in parentheses, as proposed by Gussev (1962). Monogenean identification was done using the identification keys by Pariselle and Euzet (1995, 2009). The method of numbering of the haptorial pieces was that adopted at ICOPA IV (Euzet and Prost 1981); using the terminology proposed by Pariselle and Euzet (1995): uncinulus for the marginal hooklets; gripus for the large median hooks. The important 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 (1997). The prevalence (P) and mean intensities (MI) were determined according to Bush et al. (1997). The measures of monogeneans community structure such as the Shannon–Wiener index, Margalef richness index and Berger–Parker dominance index as proposed by Magurran (1988) were determined using the online Biodiversity calculator (Danoff-Burg and Xu 2005).

Results

One species of the genus *Scutogyrus* (*Scutogyrus gravivaginus* Paperna & Thurston, 1969) and three species of *Cichlidogyrus* (*C. halli* Price & kirk, 1967, *C. tilapiae* Paperna 1960, *Cichlidogyrus sclerosus* Parpena & Thurston, 1969) were found in the gills of *O. leucostictus* (Table 1). The gills of *O. niloticus* were found infested with two species of the genus *Cichlidogyrus* (*C. tilapiae* and *C. sclerosus*). The most dominant taxa were *C. sclerosus* and *C. tilapiae* in *O. leucostictus* and *O. niloticus* with Berger–Parker index of dominance of 0.7296 and 0.5714, respectively (Table 2).

S. gravivaginus (Paperna & Thurston, 1969)

Description (Fig. 2)

Only 1 specimen was recovered and measured. Adult: 576 long, 150 wide. Two pairs of eyes with lens on the first pair. Haptor with two pairs of hamuli and seven pairs of uncinuli. Gripus: a = 27, b = 19, c = 8, d = 9, e = 5. Dorsal transverse bar: x = 33, y = 12, h = 57, w = 7. Ventral transverse bar: x = 37, w = 4. Uncinuli: u = 32. Copulatory organ of this parasite is larger with a basal portion: AP = 56, Pe = 70, He = 27. Vagina is highly sclerotized L = 37, l = 9. The measurement in this parasite conforms to descriptions in Paperna and Thurston (1969), Douëllou (1993) and Matla (2012) which confirms its identification.

Type-host: *O. leucostictus* Trewavas, 1933, (Perciformes: Cichlidae)

Table 1 Prevalence (P) and Mean intensity (MI) of the three species of *Cichlidogyrus* and one species of *Scutogyrus* on the two Cichlids: *O. leucostictus* and *O. niloticus* from Lake Naivasha between November 2014 to February 2015

Monogenean species	*O. leucostictus* (n = 50)		*O. niloticus* (n = 50)	
	P (%)	MI	P (%)	MI
C. sclerosus	100	3.4	8	4.0
C. tilapiae	6	3.0	12	5.0
C.halli	4	15.5	ND	ND
S. gravivaginus	2	1.0	ND	ND

ND not detected

Type-locality: Lake Naivasha, Kenya, 00°45′ S, 36°20′ E

Site of infection: Gills.

Material studied: 50 individuals.

Deposition of types: Preserved at Department of Biological Sciences in Egerton University, Njoro Kenya.

Remarks This is the first time *S. gravivaginus* is reported in Lake Naivasha, Kenya. The parasite was first described as *Cichlidogyrus longicornis gravivaginus* by Paperna and Thurston (1969) from the gills of *O. leucostictus* in Lake Albert, Uganda. It was described with other subspecies *Cichlidogyrus longicornis longicornis* from the gills of *O. niloticus*. The parasite was elevated to the species level as *C. gravivaginus* according to Douëllou (1993) in his redescriped specimens from the gills of *Oreochromis mortimeri* in Lake Kariba, Zimbabwe. The copulatory organ of this parasite is larger with a basal portion of a heavily sclerotized vagina with a rounded part and an elongated part ending with three finger-like extensions. The measurements in these parasite conforms to descriptions in Paperna and Thurston (1969); Douëllou (1993) and Matla (2012) which confirms its identification.

C. sclerosus (Paperna & Thurston, 1969)

Description (Fig. 3)

(10 specimens measured): The body is elongate, Adult: 445 ± 76.1 (368–546) long, 215 ± 43.5 (147–286) wide. Two pairs of eyes with lens on the first pair. Haptor is rounded with two pairs of hamuli and seven pairs of uncinuli. Gripus: a = 27 ± 4.1 (21–34), b = 22 ± 1.9 (19–25), c = 7 ± 2.2 (5–11), d = 12 ± 1.0 (10–13), e = 12 ± 1.6 (11–16). Dorsal transverse bar massive, X-shaped, branches wide, appendages pyriform with rounded ends: x = 36 ± 6.3 (24–43), y = 11 ± 1.0 (10–12), h = 17 ± 2.4 (13–22), w = 8 ± 1.2 (6–9). Ventral transverse bar V-shaped: x = 29 ± 3.6 (24–35), w = 6 ± 1.0 (4–7), with rounded extremities. The dorsal and ventral hamuli are of same shape and of similar size. Uncinuli: u = 16 ± 4.3 (11–27). Male copulatory complex is large, with serrated plate, thin

Table 2 Comparison of the diversity characteristics of the monogenean communities of the two cichlids: *O. leucostictus* and *O. niloticus* from Lake Naivasha between November 2014 to February 2015

Total component communities	*O. leucostictus* ($n=50$)	*O. niloticus* ($n=50$)
Total number of species	4	2
Shannon–Wiener index	0.7901	0.2966
Berger–Parker index	0.7296	0.5714
Margalef richness	0.5504	0.5139
Dominant species	*C. sclerosus*	*C. tilapiae*

copulatory tube arched, with tapered end: Pe = 61 ± 9.9 (43–71), He = 9 ± 1.5 (7–12).

Type-host: *O. leucostictus* Trewavas, 1933, and *O. niloticus* Linnaeus, 1758 (Perciformes: Cichlidae)

Type-locality: Lake Naivasha, Kenya, 00°45′ S, 36°20′ E

Site of infection: Gills.

Material studied: 50 individuals.

Deposition of types: Preserved at Department of Biological Sciences in Egerton University, Njoro Kenya.

Remarks The finding of *C. sclerosus* in this study represents the first record from Lake Naivasha, Kenya. This parasite was originally described by Paperna and Thurston (1969) based on the specimens from the gills of *O. niloticus niloticus* (as *Tilapia nilotica*), *Oreochromis mossambicus* (as *Tilapia mossambica*), *O. leucostictus* (as *Tilapia leucosticta*), *Tilapia zillii,* and *Haplochromis sp*. in Uganda, Africa. The species has so far been reported from various cichlid fishes from Israel in the Middle East, from Uganda, Egypt, South Africa, Botswana, and Zimbabwe in Africa; from Thailand Singapore, Hong Kong, Philippines, and Japan in Asia; and from the American countries of Mexico, Cuba, and Colombia (Douëllou 1993; Jiménez et al. 2001; Pouyaud et al. 2006; Kohn et al. 2006; Mendora-Franco et al. 2006; Lerssutthichawal 2008; Boungou et al. 2008; Pariselle and Euzet 2009; Le Roux and Avenant-Oldewage 2010; Madanire-Moyo et al. 2011; Akoll et al. 2012; Maneepitaksanti and Nagasawa 2012; Maneepitaksanti et al. 2014).

***Cichlidogyrus halli* (Price & Kirk, 1967)**

Description (Fig. 4)

(Only two specimens were recovered). Elongated body, 405 ± 34.7 (405–454) long and 223 ± 14.1 (203–223) wide. One pair of eyes with lens, haptor ellipsoid, with two pair of hamuli, dorsal hamuli is smaller $a = 23 \pm 3.7$ (23–29) $b = 18 \pm 5.7$ (18–26), $c = 3 \pm 0.6$ (3–4), $d = 13 \pm 2.6$ (9–13), $e = 16 \pm 3$ (12–16). Ventral transverse bar V-shaped, x=30 ± 1.8 (28–30), $w = 9 \pm 0.1$ (8.3-8.5). Dorsal transverse bar large and massive, $x = 19 \pm 0.2$ (18.6-18.9), y =11 ± 0.4 (10–11), $w = 9 \pm 1.4$ (9–11), auricles wide apart, $h = 22 \pm 1.4$ (20–22), seven pairs of uncinuli are long $U = 12 \pm 0.7$ (12–13). Copulatory tube is large and S-shaped, Pe = 40 ± 2 (37–40) long with irregular shape, accessory piece is lancet-shaped and shorter, He = 12 ± 3.4 (12–17)

Type-host: *O. leucostictus* Trewavas, 1933, (Perciformes: Cichlidae)

Type-locality: Lake Naivasha, Kenya, 00°45'S, 36°20'E

Site of infection: Gills.

Material studied: 50 individuals.

Deposition of types: Preserved at Department of Biological Sciences in Egerton University, Njoro Kenya.

Remarks *C. halli* is reported in this study for the first time in Lake Naivasha, Kenya. This species was first described as *Cleidodiscus halli* Price and Kirk (1967) from the gills of *Oreochromis shiranus shiranus* (as *Tilapia s. shirana*) in Malawi-Africa. It has been recorded from various cichlid fishes in

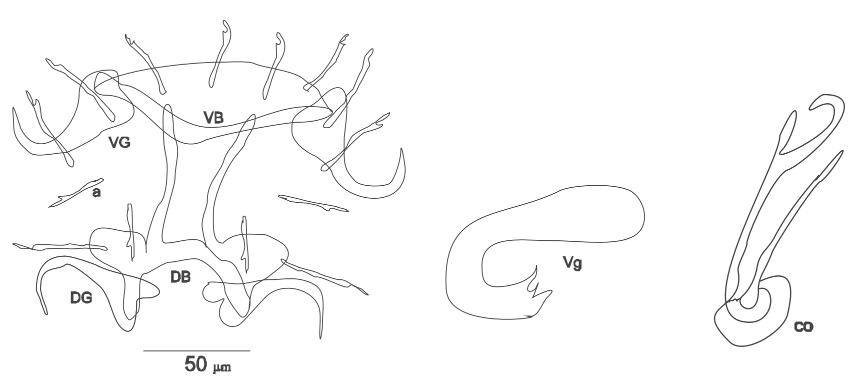

Fig. 2 *Scutogyrus gravivaginus* Paperna and Thurston 1969: Haptorial features and copulatory organ. *a* uncinuli (marginal hooks), *CO* copulatory organ, *DB* dorsal bar, *DG* dorsal gripus, *Vg* Vagina, *VG* ventral gripus

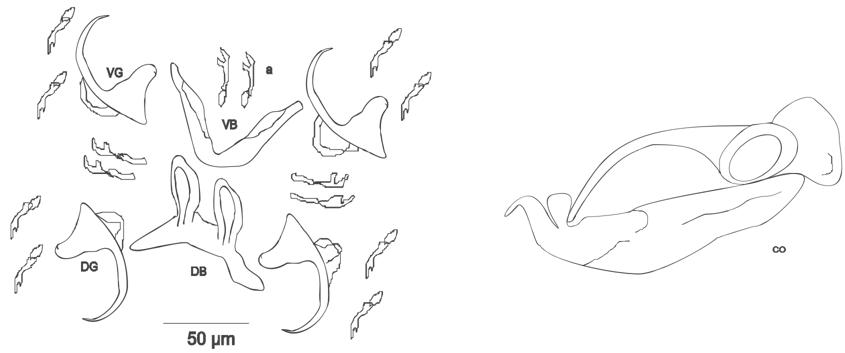

Fig. 3 *Cichlidogyrus sclerosus* Paperna and Thurston 1969: Haptoral structures and copulatory organ. *a* uncinuli (marginal hooks), *CO* copulatory organ, *DB* dorsal bar, *DG* dorsal gripus, *VG* ventral gripus

African countries such as Ghana, Egypt Malawi, Guinea, Senegal, Ivory Coast, Burkina Faso, Uganda, South Africa, Sierra Leone, Benin, and Zimbabwe. It has been also recorded from cichlid fish from Japan in Asia (Douëllou 1993; Jiménez et al. 2001; Pouyaud et al. 2006; Kohn et al. 2006; Mendora-Franco et al. 2006; Lerssutthichawal 2008; Boungou et al. 2008; Pariselle and Euzet 2009; Le Roux and Avenant-Oldewage 2010; Madanire-Moyo et al. 2011; Akoll et al. 2012; Maneepitaksanti and Nagasawa 2012; Maneepitaksanti et al. 2014). The species is relatively large compared other *Cichlodogyrus spp.* found in the lake. It has two eyes. The copulatory organ is simple and long with S-shaped copulatory tube having an irregular basal portion. The accessory piece ends with a triangular extremity. It has seven pairs of uncinuli. The sclerotized parts and their measurements agree with that Price and Kirk (1967); Douëllou (1993) and Matla (2012) which confirms the species' identification.

Cichlidogyrus tilapiae (Paperna 1960)

Description (Fig. 5)

(10 specimens measured). The body is slender tapering at the posterior end. Adult: 392 ± 62.8 (353–538) long, 126 ± 28.6 (82–187) wide. Two pairs of eyes with lens on the first pair. Haptor ellipsoid with two pairs of hamuli and seven pairs of uncinuli. Gripus: $a = 34 \pm 5.9$ (27–42), $b = 25 \pm 2.7$ (22–30), $c = 5 \pm 1.5$ (3–8), $d = 14 \pm 5.5$ (7–23), $e = 8 \pm 1.5$ (5–9). Dorsal transverse bar: $x = 22 \pm 5.1$ (13–27), $y = 9 \pm 1.3$ (7–12), $h = 28 \pm 3.6$ (23–34), $w = 7 \pm 1.0$ (6–9). Ventral transverse bar: $x = 28 \pm 3.6$ (23–34), $w = 5 \pm 0.9$ (4–6). Uncinuli: $u = 15 \pm 1.8$ (14–18). Male copulatory complex with a short, simple, straight copulatory tube that is wider at the base: Pe = 29 ± 3.0 (25–34), He = 6 ± 1.2 (4–7). Accessory piece is straight with a sharp hook at the terminal end: AP = 29 ± 3.5 (25–35). Vagina was not observed.

Type-host: *O. leucostictus* Trewavas, 1933, and *O. niloticus* Linnaeus, 1758 (Perciformes: Cichlidae)

Type-locality: Lake Naivasha, Kenya, 00°45′ S, 36°20′ E

Site of infection: Gills.

Material studied: 50 individuals.

Deposition of types: Preserved at Department of Biological Sciences in Egerton University, Njoro Kenya.

Remarks The collection of *C. tilapiae* in this study constitutes the first record from Lake Naivasha, Kenya. This parasite was first described by Paperna (1960) using specimens from the gills of *O. niloticus niloticus* (as *T. nilotica*), *Sarotheroderon galilaeus galilaeus* (as *Tilapia galilaea*), *Tristramella sacra,* and *Trastramella simonis simonis* (as *Tilapia simonis*) in Israel. The parasite has been reported from various cichlid fishes from Israel in Middle East; from Uganda, Tanzania, Egypt, Ghana, South Africa, Burkina Faso, Ivory Coast, and Zimbabwe in Africa; from Bangladesh, Thailand, Philippines, and Japan in Asia; and from American coutries of Mexico, Cuba, and Colombia. (Douëllou 1993; Jiménez et al. 2001; Pouyaud et al. 2006; Kohn et al. 2006; Mendora-Franco et al. 2006; Lerssutthichawal 2008; Boungou et al. 2008; Pariselle and Euzet 2009; Le Roux and Avenant-Oldewage 2010; Madanire-Moyo et al. 2011; Akoll et al. 2012; Maneepitaksanti and Nagasawa 2012; Maneepitaksanti et al. 2014).

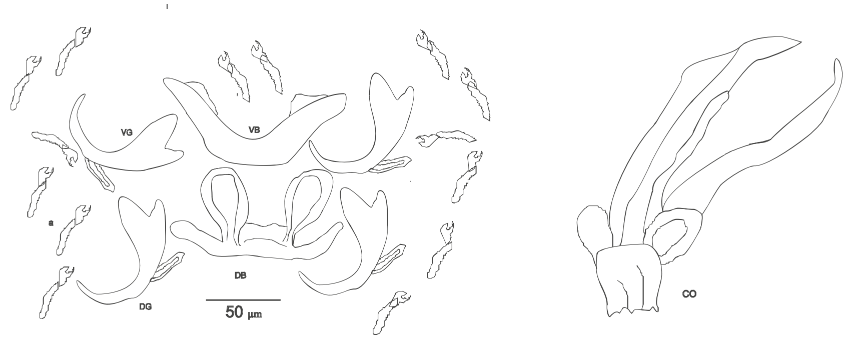

Fig. 4 *Cichlidogyrus halli* Price and Kirk 1967: Haptoral structures and copulatory organ. *a* uncinuli (marginal hooks), *CO* copulatory organ, *DB* dorsal bar, *DG* dorsal gripus, *VG* ventral gripus

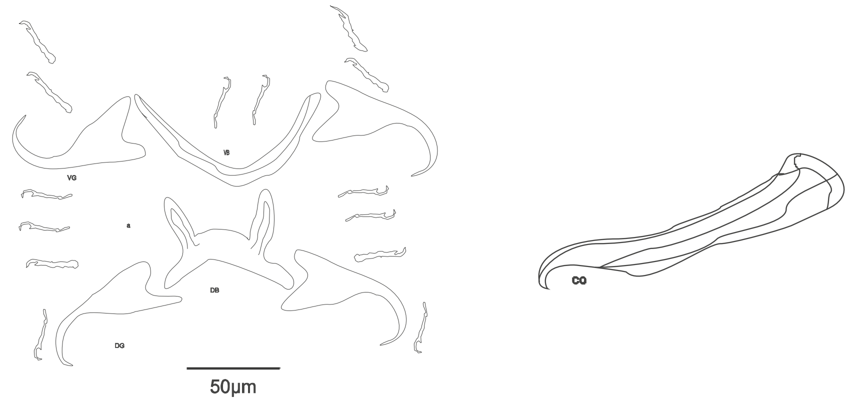

Fig. 5 *Cichlidogyrus tilapiae* Paperna 1960. *a* uncinuli (marginal hooks), *CO* copulatory organ, *DB* dorsal bar, *DG* dorsal gripus, *VG* ventral gripus

Discussion

The morphology and measurements of the four monogeneans from the gills of the two cichlid fishes from L. Naivasha, Kenya, corresponded to those of *C. gravivaginus* Paperna and Thurston (1969), *C. halli* Price and Kirk (1967), *C. tilapiae* Paperna (1960) and *C. sclerosus* Paperna and Thurston (1969). The findings of this study of *C. tilapiae* ($P = 12$ %, MI = 5.0) and *C. sclerosus* in *O. niloticus* ($P = 8$ %, MI = 4.0) are comparable to other studies on *O. niloticus* in other parts of the world (Boungou et al. 2008; Akoll et al. 2012; Maneepitaksanti and Nagasawa 2012; Maneepitaksanti et al. 2014 among others). For example, Akoll et al. (2012) study in Uganda, found the same *Cichlidogyrus* species as in our study, with an almost equal mean intensities but not the prevalences ($P = 50$ %, MI = 6.6). However, Our study found lower prevalences than in the study by Akoll et al. (2012). This could be due to the fact that in our study we separated the data for the two species, while it was presented as combined for the two species in the Akoll et al. (2012) study. Differences could also have resulted from the different sample sizes studied: ($n = 140$) as compared to our study (n = 50), and the sampling environments. For example, in our study we obtained fish from the wild, while in the study by Akoll et al. (2012) several water bodies were sampled such as a stream, reservoir, dam, and including aquacultured-caged fish and all data were pooled together. The low mean intensity (4.0 and 5.0) recorded in our study can also be explained by the fact that *O. niloticus* has been found to have a strong immune resistance against further invasion of ectoparasites (Sandoval-Gio et al. 2008). This study recorded higher mean intensities of *C. tilapiae* compared to the study of Tombi et al. (2014) from Melen fish station in Yaounde, Cameroon who found it on the gills of *O. niloticus* (MI = 1.38 left side, 1.35 right side). Contrastingly, other studies have found *C. halli* and *Scutogyrus spp.* in *O. niloticus* but we only found them in *O. leucostictus* (Boungou et al. 2008; Maneepitaksanti and Nagasawa 2012; Tombi et al. 2014). Lambert (1997) hypothesized that the introduction of an animal species in a new environment means the introduction of a host- parasite system, while the invasion theory explains the absence of certain parasites upon the introduction of a host to a new environment (temporal release) (Keane and Crawley 2002; Torchin et al. 2003). Therefore, the absence of *C. halli* and *S. gravivaginus* in *O. niloticus* in Lake Naivasha could possibly indicate that the *O. niloticus* reintroduced into the lake were not infected by the two parasites species and that the number of lateral transfers of the parasites which are usually observed after the introduction of new hosts in the new environment, are minimal. The *O. leucostictus* was introduced in 1956 into Lake Naivasha (Gherardi et al. 2011) and has had enough time to acquire diverse parasite taxa unlike the *O. niloticus* which was recently reintroduced (2011) into the lake. On the other hand this result could also suggest the difficulty for these parasites species to survive in Lake Naivasha. Our findings that *C. sclerosus* is most dominant in *O. leucostictus* while *C. tilapiae* is the most dominant in *O. niloticus* (Berger–Parker index of dominance 0.7296 and 0.5714, respectively) differs from those of Maneepitaksanti and Nagasawa (2012) who found that *C. sclerosus* was the most dominant species on *O. niloticus* and *C. tilapiae* the least dominant. The high prevalence (100 %) of *C. sclerosus* in *O. leucostictus* signals that Lake Naivasha provides good conditions for the diffusion of the parasite. Physical factors such as high water temperatures (23.4 °C) and the biomass of the *O. leucostictus* in Lake Naivasha may induce the fecundity of this parasite (Woo, 1995). The variability of parasite richness in *O. leucostictus* and *O niloticus* (Margalef richness 0.5504 and 0.5139 and diversity: Shannon–Weiner index 0.7901 and 0.2966 respectively) can be associated to factors related to: water quality–eutrophication (Galli et al. 2001), host (Morand et al. 1999), ecology (Zharikova 2000), and the phylogeny of the host and parasites (Bush et al. 1997; Sasal et al. 1997). This study is a continuation of the discovery of ectoparasites from Lake Naivasha (Otachi et al. 2014), which had never been recorded in the tropical lake (Aloo 2002) and attributed to sensitivity of ectoparasites to poor water quality (Dubinin 1958; Aloo 2002). This is the first time that these monogeneans have been identified from Lake Naivasha, Kenya, presenting new geographical records. It was concluded that Ancyrocephalids (*Cichilidogyrus* spp.) dominated the two cichlid fish species in Lake Naivasha, Kenya.

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Compliance with Ethical Standards

Conflict of interests The authors declare that there are no competing interests.

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