



Monopisthocotyla parasites of the gills of *Oreochromis niloticus* (Osteichthyes: Cichlidae) collected in the Department of Amazonas, Peru, with the description of a new species of *Gussevia* Kohn & Paperna

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Abstract The intensification of *Oreochromis niloticus* (Linnaeus) aquaculture in the Peruvian Amazon has increased the need for detailed knowledge of its parasite fauna, particularly monopisthocotyls, which can severely impact gill function and fish health. This study aimed to characterize the community of monopisthocotyls infecting the gills of *O. niloticus* from a natural water body in Amazonas, Peru, and to describe a new species of *Gussevia* Kohn & Paperna, 1964. Forty tilapias were sampled in June 2024 from the Mashuyacu River (Amazonas, Peru). Gills were removed and processed using standard protocols for monopisthocotyls, staining and mounting. Sclerotized structures were examined under phase-contrast microscopy, measured, and illustrated, and parasitological indices were calculated. Four previously known species were identified: *Cichlidogyrus tilapiae*

Paperna, 1960, *C. sclerosus* Paperna & Thurston, 1969, *C. thurstonae* Ergens, 1981 and *Scutogyrus longicornis* (Paperna & Thurston, 1969). In addition, a new monopisthocotyl is described based on the morphology of its copulatory complex and haptoral sclerites. *Gussevia peruensis* n. sp. can be readily distinguished from these congeners by the unique configuration of its accessory piece, which is medially widened and terminates distally in a rounded, laterally directed tip with a comma-shaped branching. The haptoral structures further support the distinctiveness of the new species, particularly the combination of a thin, medially curved dorsal bar and dissimilar anchors with moderately developed roots. Although just one species of the host was parasitized by *G. peruensis* n. sp. showed low prevalence (2.5%; 1/40), the infected fish harbored 63 specimens (mean intensity = 63; mean abundance = 1.57). This represents the first record of the Neotropical genus *Gussevia* on an African cichlid and the first occurrence of this genus in tilapia in Peru, strongly suggesting a host-switching event from native South American cichlids to an introduced host. Our findings expand the known diversity of monopisthocotyls associated with *O. niloticus* in the Peruvian Amazon and highlight the potential for native parasites to integrate into parasite assemblages of farmed, non-native fishes.

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Introduction

Oreochromis niloticus (Linnaeus) is an African cichlid that has been widely introduced into tropical and subtropical regions outside its native distribution, including the Neotropical Region. As in other members of the family Cichlidae, this species harbors a diverse parasite fauna, with gill-infecting monopisthocotyls of the Ancyrocephalidae being particularly prominent. These ectoparasitic platyhelminths are characterized by high host specificity and by the taxonomic significance of their sclerotized structures (Paperna, 1960; Ergens, 1981; Pariselle & Euzet, 2009).

Monopisthocotyls associated with cichlids have been the subject of extensive systematic studies due to the morphological variability of their male copulatory complex and haptoral sclerites, which constitute the primary diagnostic characters at both the species and generic levels (Kohn & Paperna, 1964; Kritsky et al., 1986). In *O. niloticus*, most described species belong to the genera *Cichlidogyrus* Paperna, 1960 and *Scutogyrus* Pariselle & Euzet, 1995, both of which were originally established from African cichlid hosts (Paperna, 1960; Pariselle et al., 2003).

In Peru, studies on monopisthocotyls associated with *O. niloticus* remain scarce; however, available research consistently indicates the predominance of species of *Cichlidogyrus*, mainly parasitizing the gill tissues, with occasional records of *Gyrodactylus* spp. infecting the skin and fins (Table 1). These records suggest that the monopisthocotylan fauna associated with *O. niloticus* in Peru is still incompletely known and highlight the need for further taxonomic surveys in natural and semi-natural environments.

In contrast, the genus *Gussevia* Kohn & Paperna, 1964 has historically been regarded as a strictly Neotropical taxon, parasitizing exclusively native South American cichlids. Species of *Gussevia* are distinguished by combinations of characters of the male copulatory complex and by the morphology of the haptor, which have allowed their delimitation from other monopisthocotyls associated with cichlids (Kohn & Paperna, 1964; Kritsky et al., 1989). To date, all valid species of *Gussevia* have been recorded only from Neotropical cichlids, with no confirmed reports from introduced African hosts.

Despite the wide distribution of *O. niloticus* in the Peruvian Amazon, knowledge of the taxonomic composition and systematic affinities of its monopisthocotyls in natural environments remains fragmentary. In this context, the present study aimed to characterize the monopisthocotylan fauna infecting the gills of *O. niloticus* from a natural water body in the department of Amazonas, Peru, and to describe a new species of the genus *Gussevia*. The discovery of *Gussevia peruensis* n. sp. in an African cichlid represents the first record of this genus parasitizing a non-Neotropical host, providing new evidence of host-range plasticity and contributing to a better understanding of the systematic boundaries of monopisthocotyls associated with cichlids.

Materials and methods

Forty individuals of *O. niloticus* were collected from the River Mashuyacu, Department of Amazonas-Peru (6°35'11.6"S 77°13'59.0"W). Samples were collected in June 2024 under the license for collection of biological material: Resolution

Table 1 Monopisthocotyala species in *Oreochromis niloticus* (Linnaeus) from natural environments and fishponds in the Peruvian Amazon

Parasite species	Fish-host	Localization	Type of environment	Localization	Reference
<i>Cichlidogyrus sclerosus</i> , <i>Cichlidogyrus thurstonae</i> and <i>Cichlidogyrus</i> sp.	<i>Oreochromis niloticus</i>	Gill archers	Freshwater	San Martin	Cabrera et al. (2019)
<i>Gyrodactylus</i> sp.	<i>Oreochromis niloticus</i>	Skin and fins	Freshwater	San Martin	Cabrera et al. (2019)
<i>Cichlidogyrus tilapiae</i>	<i>Oreochromis niloticus</i>	Gill archers	Freshwater	Loreto	Ocmín et al. (2022)
<i>Cichlidogyrus</i> sp.	<i>Oreochromis niloticus</i>	Gill archers	Freshwater	San Martin	Puicón et al. (2023)
<i>Cichlidogyrus sclerosus</i>	<i>Oreochromis niloticus</i>	Gill archers	Freshwater	San Martín	Santillán et al. (2024)
<i>Cichlidogyrus</i> sp.	<i>Oreochromis niloticus</i>	Gill archers	Freshwater	San Martin	Calderón et al. (2024)

No132-2014-GRL-DIREPRO; Resolution No21-2016 GRL-DIREPRO; and PTH-068-16-PECSAN-IPES. Gill arches were immediately removed and placed in vials containing heated water (approximately 68 °C). Each vial was vigorously shaken, and 96% ethanol was added. Samples were sent to the “Laboratorio de Parasitología y Sanidad Acuicola” from Instituto de Investigaciones de la Amazonía Peruana” for analyses. In the laboratory, the content of each vial was examined using a dissecting microscope and parasites were removed from the gills or sediment using dissection needles. Some monopisthocotyls were stained with Gomori’s trichrome (Boeger and Vianna, 2006) and mounted in Canada Balsam to determine internal soft structures, while others were cleared in Hoyer’s medium for the study of sclerotized structures (Boeger and Vianna, 2006).

Sclerotized structures of all parasites were photographed with a digital camera (LEICA ICC50W) connected to a phase contrast microscope (LEICA DM750), and the images were used to obtain the measurements of the male copulatory organ (MCO) and haptor sclerites (Kritsky, 1974). Measurements are expressed as the range followed by the mean and number (n) of structures measured in parentheses. Measurements, all in micrometers, were made using the LAS EZ software from LEICA and following the procedures of Morey et al. (2024). Lengths of curved or bent structures (anchors, bars, and accessory piece) represent the straight-line distances between extreme ends. Drawings were prepared with the aid of a drawing tube and microprojector. Illustrations were prepared using Adobe Illustrator 2024 for Microsoft Windows.

The type specimens were deposited in the Helminthological Collection of the Museum of Natural History at the San Marcos University (MUSM)

Peru, and in the collection of the Laboratorio de Parasitología y Sanidad Acuicola of the Instituto de Investigaciones de la Amazonía Peruana (LAPYSA). To comply with the regulations set out in article 8.5 of the amended 2012 version of the International Code of Zoological Nomenclature (ICZN) (ICZN, 2012), details of the new taxon have been submitted to ZooBank (i.e., generic name, specific name). The Life Science Identifier (LSID) is reported in the taxonomic summary. Parasitological indices were calculated according to Bush et al. (1997).

Ethic aspects: statement on ethical approval from an ethics committee and license for working with fish species were followed according to the resolutions: Resolution No132-2014-GRL-DIREPRO; Resolution No21-2016 GRL-DIREPRO; and PTH-068-16-PECSANIPES.

Results

Three species of *Cichlidogyrus* were identified: *C. tilapiae*, *C. sclerosus*, and *C. thurstone*, as well as one species of *Scutogyrus*: *S. longicornis* and a new species of *Gussevia*: *Gussevia peruensis* n. sp. Parasitological indices are shown in Table 2.

Class Monopisthocotyla Brabec, Salomaki, Kolisko, Scholz & Kuchta, 2023

Order Dactylogyridea Bychowsky, 1937

Dactylogyridae Bychowsky, 1937

***Cichlidogyrus* Paperna, 1960**

Table 2 Parasitological indices of the species of Monopisthocotyla from *Oreochromis niloticus* (Linnaeus) collected in Amazonas-Peru

Species	AF	PF	P%	TNP	mI	mA
<i>Cichlidogyrus tilapiae</i>	40	18	45	165	9.16	4.12
<i>Cichlidogyrus thurstone</i>	40	8	20	20	2.5	0.5
<i>Cichlidogyrus sclerosus</i>	40	8	20	32	2.5	0.8
<i>Scutogyrus longicornis</i>	40	10	25	30	3	0.75
<i>Gussevia peruensis</i> n. sp.	40	1	2.5	63	63	1.57

AF = analyzed fish, PF = parasitized fish, P% = prevalence, TNP = total number of parasites, mI = mean intensity of infestation, mA = mean abundance of infestation

Cichlidogyrus tilapiae (Figure 1). Body robust. Trilobed head, with a pair of small eyes close together. The copulatory complex consists of the MCO, which is tubular, thin, with a widened base; and the accessory piece, which is articulated to the base of the MCO by a thin ligament. The accessory piece is hood-shaped. The egg is oval-shaped, with a double membrane around it. The haptor has an expanded V-shaped ventral bar and a dorsal bar with anterior expansions, giving it the appearance of “rabbit ears.” The anchors are short. The hooks are small, equal in shape and size. This species has abundant vitelline, dense throughout the body from approximately the height of the pharynx to the beginning of the haptor.

Cichlidogyrus sclerosus (Figure 2). Body robust. Trilobed head with poorly developed lobes; two pairs of eyes, the anterior pair being smaller than the posterior pair; and a copulatory complex consisting of a thin, tubular MCO with an expanded base, the tube tapering at its distal end. The accessory piece is

articulated at the base of the MCO, presenting a fairly pronounced “beard”-shaped layer that expands from its middle to its end, with a pointed tip at the distal end. The haptor has an expanded V-shaped ventral bar; the dorsal bar has an elongated base with projections on both sides that resemble “rabbit ears.” The anchors are similar in shape and size, with short, robust roots. The hooks are small and similar in shape and size. Vitelline distributed up to approximately the end of the germarium.

Cichlidogyrus thurstonae (Figure 3). Body elongated. Trilobed head with poorly developed lobes and a pair of medium-sized eyes. The copulatory complex consists of the MCO, a tube with an expanded “shoe-shaped” base. The tube tapers as it reaches its distal end. The accessory piece is articulated with the base of the MCO and is irregular in shape with intersecting expansions in both its middle and distal parts. The haptor has an expanded V-shaped ventral bar; the dorsal bar is elongated, with projections directed anteriorly in the shape of “rabbit ears.” The anchors have well-developed and pronounced roots. The hooks are large, with two subunits. The vagina is a thick, short tube with a spherical distal part. The haptor is characterized by a ventral bar shaped like a fairly expanded “V”; the dorsal bar is elongated, with “rabbit ear”-shaped projections directed anteriorly and quite elongated; the dorsal bar has lateral expansions shaped like shoulder blades. The anchors are robust and short; the ventral anchor has poorly developed roots and the dorsal anchor has more pronounced roots, with the superficial root being thicker and longer than the deep root, which is short. The hooks have a thin thumb, blade, and tip. A species of *Scutogyrus* was reported (Fig. 4).

Class Monopisthocotyla Brabec, Salomaki, Kolísko, Scholz & Kuchta, 2023

Order Dactylogyridea Bychowsky, 1937

Dactylogyridae Bychowsky, 1937

***Gussevia* Kohn & Paperna, 1964**

***Gussevia peruensis* n. sp. (Figure 5)**

Body elongate, fusiform, 376–532 (492; n = 10) long; greatest width 105–180 (150; n = 10) usually at level of testes. Rounded head presenting three

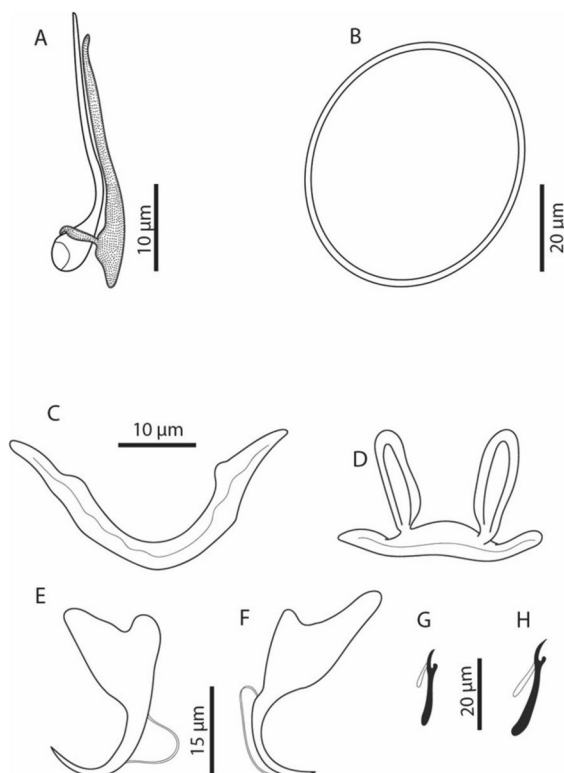
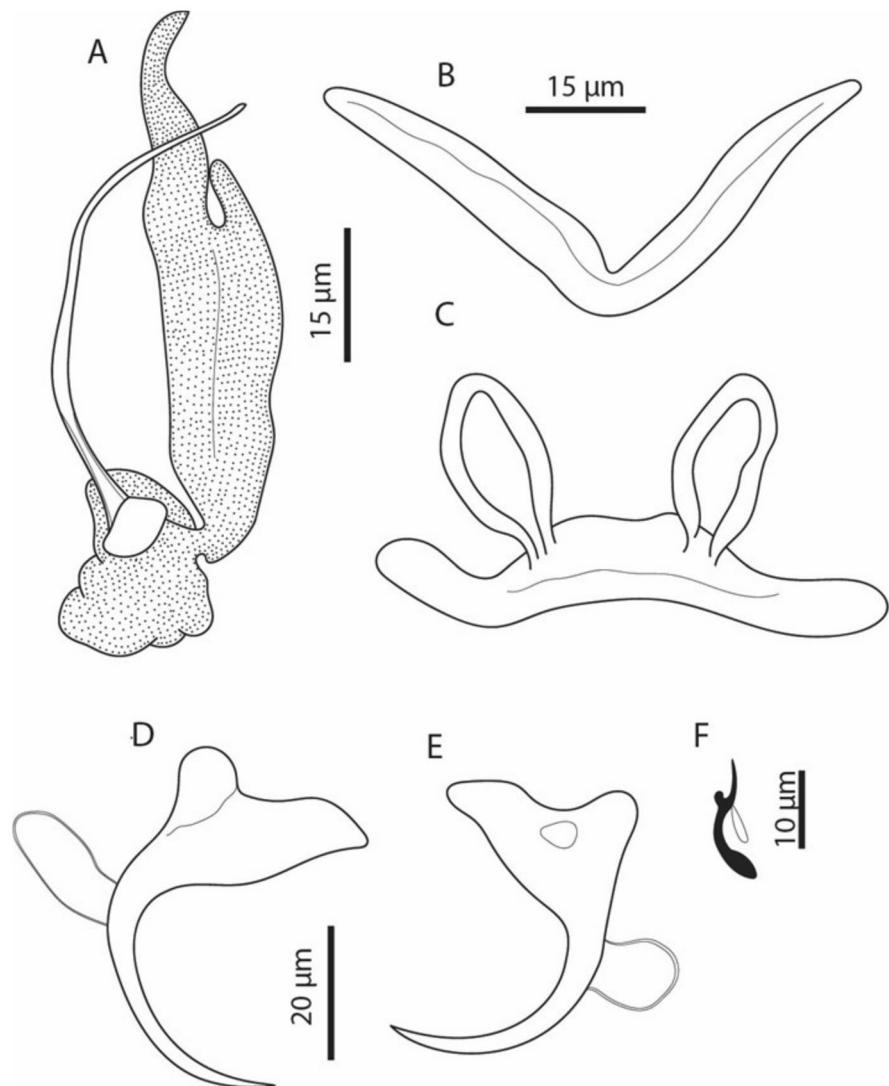


Fig. 1 *Cichlidogyrus tilapiae* Paperna, 1960 from the gills of *Oreochromis niloticus* (Linnaeus). A. Copulatory complex. B. Egg. C. Ventral bar. D. Dorsal bar. E. Ventral anchor. F. Dorsal anchor. G. Hook pair I. H. Hook pair IV.

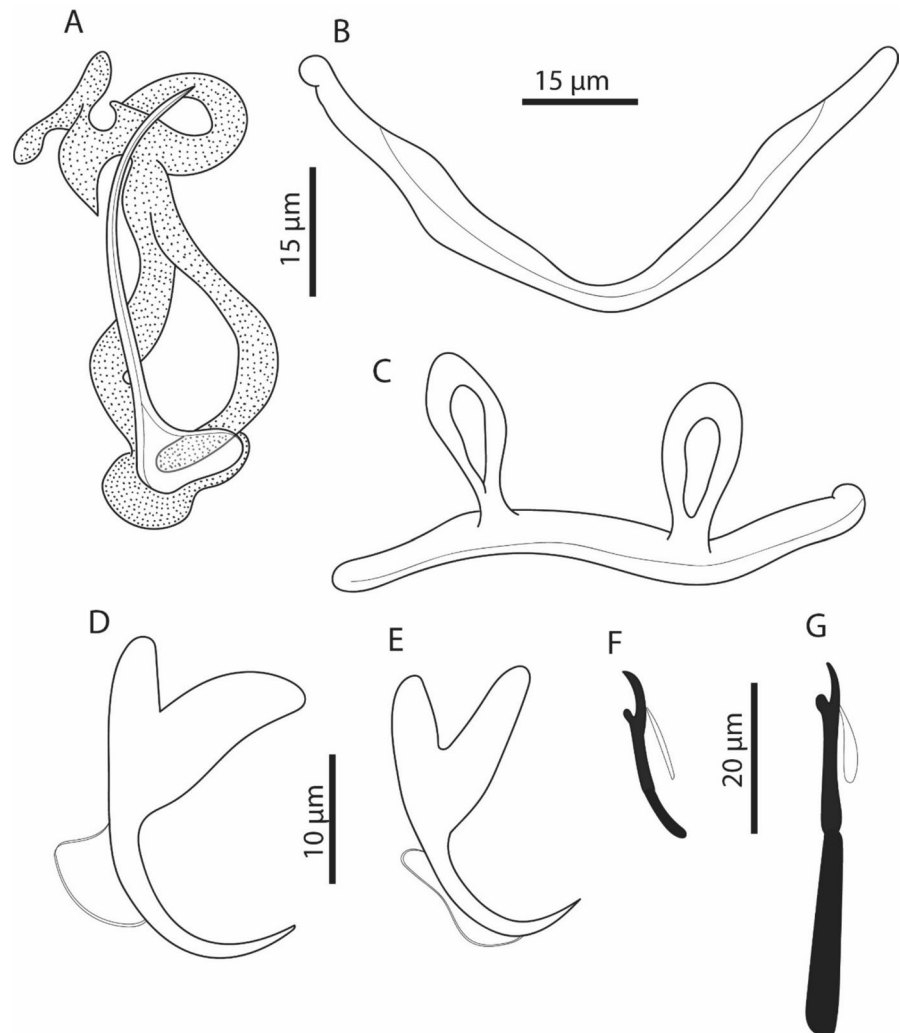
Fig. 2 *Cichlidogyrus sclerosus* Paperna & Thurston, 1969 from the gills of *Oreochromis niloticus* (Linnaeus). A. Copulatory complex. B. Ventral bar. C. Dorsal bar. D. Ventral anchor. E. Dorsal anchor. F. Hook Pair I.



bilateral pairs of conspicuous head organs. Eyes present, being the anterior one smaller than posterior. Pharynx spherical, well developed, 34–52 (46; $n = 10$) in diameter. Tetra-lobed haptor 54–72 (68; $n = 10$) long; 86–122 (100; $n = 10$) wide. Male copulatory organ (MCO) 22–44 (32; $n = 10$) long, a thin tubular, J-shaped, with a slight curvature in its proximal part, presenting an expanded oval-shaped base. Accessory piece 24–41 (31; $n = 10$) articulated at the base of the MCO. The accessory piece presented as an elongated, and robust structure that runs predominantly parallel to the MCO. Proximally, it originates near the base of the organ with a distinct, recurved spur or "heel-like" projection that appears to wrap around

the initial curve of the MCO. It presents a thin layer that widens in the middle, moving distally, the accessory piece transitions into a long, relatively straight main shaft. At its distal end, it expands into a prominent, C-shaped or sickle-like hook that curves inward. Dextral vagina as a short and thick tube with slightly sclerotized walls, laying into the seminal receptacle, which is round. Testis elongated, 55–85 (80; $n = 4$) long, 25–40 (35; $n = 4$) wide. Ovary ovate, 42–78 (62; $n = 4$) long, 22–36 (30; $n = 4$) wide; vas deferent passing behind left caecum; seminal vesicle sac-shaped. Prostatic reservoir, oviduct, oötype, uterus and eggs not observed. Vitellaria distributed extensively throughout the body, beginning just posterior

Fig. 3 *Cichlidogyrus thurstonae* Ergens, 1981 from the gills of *Oreochromis niloticus* (Linnaeus). A. Copulatory complex. B. Ventral bar. C. Dorsal bar. D. Ventral anchor. E. Dorsal anchor. F. Hook Pair I. G. Hook pair VI.



to the pharynx and extending nearly to the haptor. Ventral bar 37–51 (43; $n = 10$) long, 3–5 (4; $n = 10$) wide, thickened at the midpoint, tapering slightly toward the lateral extremities; dorsal bar 43–51 (46; $n = 10$) long, 4–8 (6; $n = 10$) wide, thin and curved in the middle. Anchors dissimilar in shape and size. Ventral anchor 17–22 (20; $n = 10$) long, 15–17 (15; $n = 10$) wide, with a well-developed, elongated superficial root and a poorly developed deep root, with a curved shaft and elongated tip. Dorsal anchor 17–23 (22; $n = 10$), 10–16 (14; $n = 10$) wide, with an elongated, laterally oriented superficial root, short deep root, with short shaft and tip. Dorsal anchor with a widened anchor filament that is clearly visible in

relation to the ventral anchor filament. Hooks, 11–18 (14; $n = 10$) long, similar in shape and size, each with erected thumb, straight shank, with slightly expanded base and short point; filamentous hook (FH) about shank length (Figure 6).

Taxonomic summary

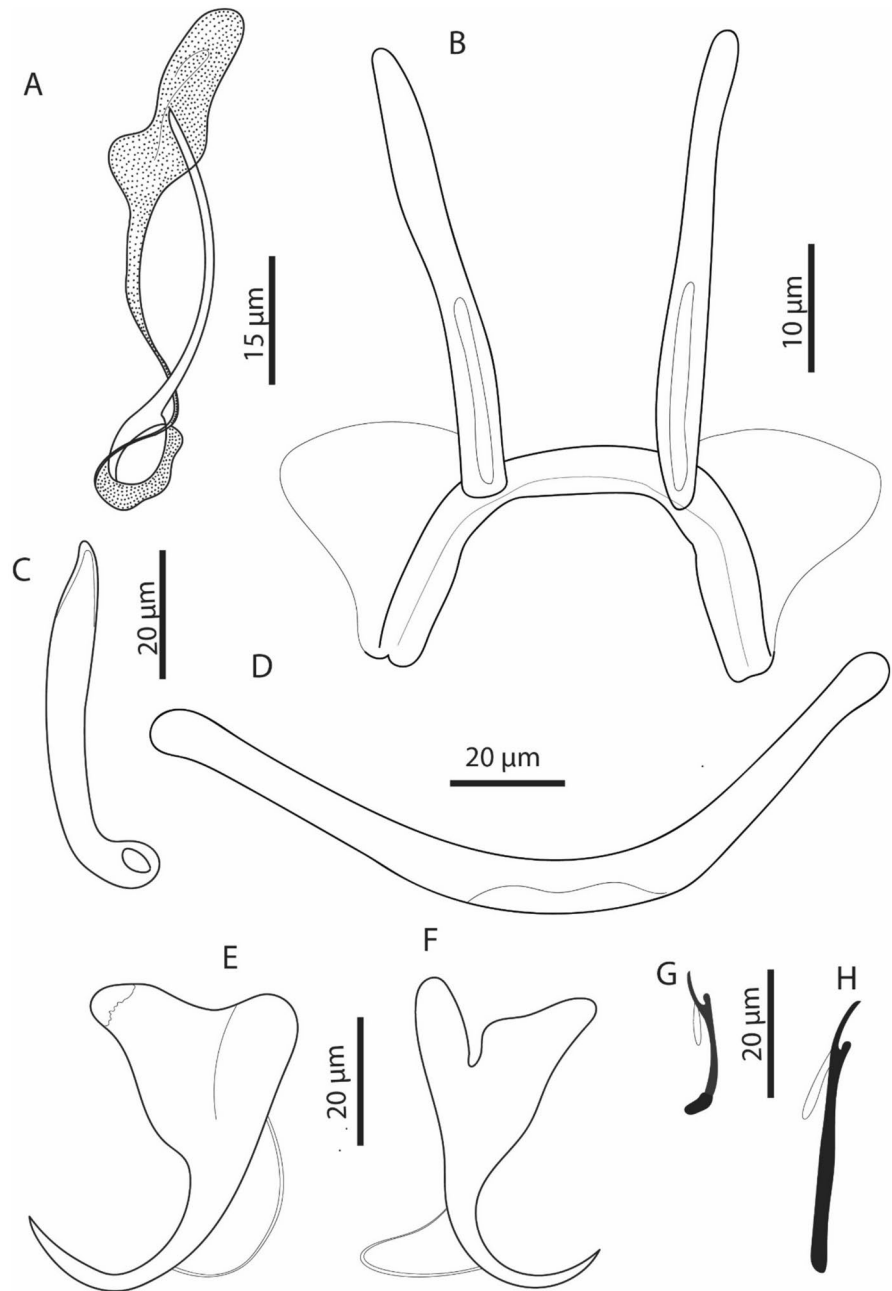
Type-host: *Oreochromis niloticus* (Linnaeus) (Cichliformes: Cichlidae)

Site in host: Gill filaments.

Type-locality: River Mashuyacu, Department of Amazonas, Peru (6°35'11.6"S 77°13'59.0"W).

Type-material: Holotype (MUSM 5385), four paratypes (MUSM 5386 a-d) and (LAPYSA M-22 a-d)

Fig. 4 *Scutogyrus longicornis* (Paperna & Thurston, 1969) from the gills of *Oreochromis niloticus* (Linnaeus). A. Copulatory complex. B. Dorsal bar. C. Vagina. D. Ventral bar. E. Ventral anchor. F. Dorsal anchor. G. Hook Pair I. H. Hook pair VI



ZooBank registration: The Life Science Identifier (LSID) for *Gussevia peruensis* n. sp. is urn:lsid:zoobank.org:pub:D877E110-4062-499C-8BE4-772C4E2DA4E0

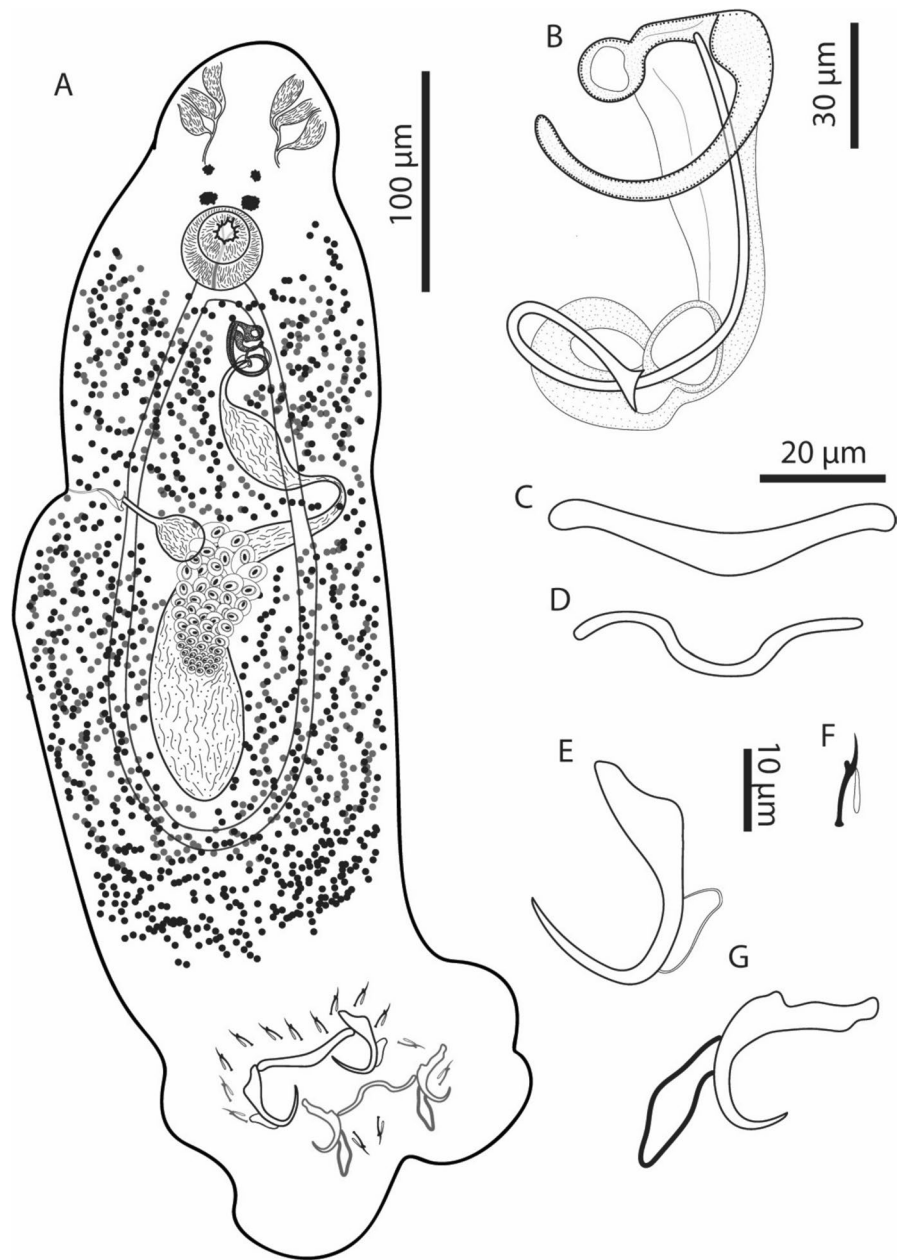
Parasitological indices: prevalence 3% (1/40), total number of parasites 63, range of intensity 63, mean

intensity of infestation 63; mean abundance of infestation 1.57

Etimology: The specific name *peruensis* is a geographical designation referring to Peru, the country where the host fish was collected and the type specimens were discovered.

Remarks

Fig. 5 *Gussevia peruensis* n. sp. from the gills of *Oreochromis niloticus* (Linnaeus). A. Whole specimen ventral view. B. Copulatory complex. C. Ventral bar. D. Dorsal bar. E. Ventral anchor. F. Hook pair I. G. Dorsal anchor.



Gussevia peruensis n. sp. is assigned to *Gussevia* Kohn & Paperna, 1964 based on the combination of diagnostic characters typical of the genus, including a tubular male copulatory organ with an articulated accessory piece, a dextral vagina, haptor tetralobated, dorsal anchor modified, with anchor filament being more prominent and visible than the ventral anchor filament (Kohn & Paperna, 1964; Cohen et al., 2013). Morphologically, the new species most

closely resembles *G. undulata*, *G. tucunarensis* and *G. longihaptor*, all described from Neotropical cichlids of the genus *Cichla*. However, *G. peruensis* n. sp. can be readily distinguished from these congeners by the unique morphology of its accessory piece, which is medially widened and terminates distally in a rounded, laterally directed tip with a comma-shaped branching, a feature not reported in other species of the genus. In addition, the male copulatory organ

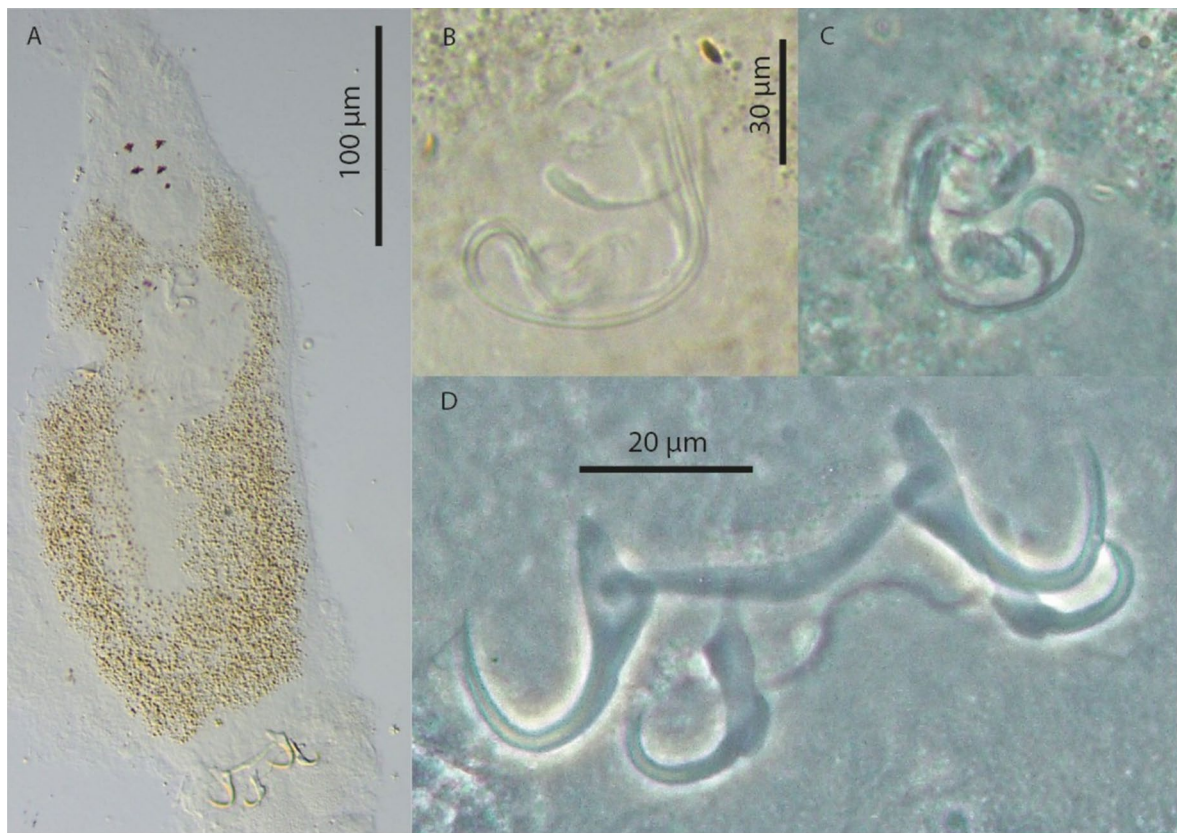


Fig. 6 Photomicrography of *Gussevia peruensis* **n. sp.** from the gills of *Oreochromis niloticus* (Linnaeus). A. Whole specimen ventral view. B, C. Copulatory complex. D. Haptor.

of *G. peruensis* **n. sp.** is comparatively shorter and J-shaped, with a moderately expanded oval base, differing from the longer and slenderer MCO observed in *G. longihaptor* and from the more robust copulatory complexes described in *G. undulata* and *G. tucunarensis*. The haptoral structures further support the distinctiveness of the new species, particularly the combination of a thin, medially curved dorsal bar and dissimilar anchors, which contrast with the more robust or elongate haptoral elements of its closest congeners.

Discussion

Tilapias (*Oreochromis* spp.), despite their African origin, have developed diverse parasite assemblages in regions where they have been introduced, particularly in South America. Among ectoparasites,

monopisthocotyls represent one of the most relevant parasite groups due to their direct life cycle, high host specificity, and close association with gill microhabitats (Thoney & Hargis, 1991; Pariselle & Euzet, 2009). In South America, numerous studies have documented monogenean infections in wild tilapias, with parasite communities typically dominated by species of *Cichlidogyrus*, a genus historically associated with African cichlids and widely regarded as co-introduced with their hosts (Paperna, 1960; Pariselle & Euzet, 2009; Mendoza-Franco et al., 2018).

In addition to these African-origin parasites, accumulating evidence indicates that introduced tilapias may acquire native neotropical parasites following establishment. A classic example is the study by Kritsky and Thatcher (1974), who reported *Anacanthorus colombianus* Kritsky & Thatcher, 1974 infecting *Tilapia mossambica* (Peters) in Colombia. This record was of particular systematic relevance

because the genus *Anacanthorus* had previously been known exclusively from South American freshwater fishes, only Characiformes, with this exception, and its occurrence in tilapia was interpreted as a host-switching event. This study provided early empirical evidence that neotropical monopisthocotylans can colonize introduced African cichlids when suitable ecological opportunities arise.

In Peru, information on monopisthocotyls associated with *Oreochromis niloticus* remains limited; however, available records indicate a pattern consistent with that reported elsewhere in South America. Recurrent infections by *Cichlidogyrus sclerosus*, *C. tilapiae* and *C. thurstonae*, as well as occasional records of *Gyrodactylus* sp. (Cabrera et al., 2019; Ocmín et al., 2022; Puicón et al., 2023; Santillán et al., 2024 and Calderón et al., 2024), suggest that the monopisthocotylan fauna of *O. niloticus* is dominated by co-introduced African taxa. Nevertheless, the occurrence of Neotropical monopisthocotyls in tilapia indicates that this host can become integrated into local parasite assemblages.

The most significant finding of the present study is the first record of the genus *Gussevia* Kohn & Paperna, 1964 parasitizing *O. niloticus*. This finding is particularly important from a systematic and biogeographical perspective, as *Gussevia* has long been regarded as a strictly Neotropical genus, historically restricted to native South American cichlids, especially within Amazonian river systems, with no previous records from African cichlids (Kohn & Paperna, 1964; Kritsky et al., 1986; Boeger & Kritsky, 2001; Delgado, 2012). The presence of *Gussevia peruensis* n. sp. in an African cichlid considerably expands the known host range of the genus and documents a novel host–parasite association.

The occurrence of *G. peruensis* n. sp. in *O. niloticus* can be explained by the high ecological and morphological compatibility between African and Neotropical cichlids at the gill level, which may facilitate the establishment of monopisthocotyls following host-contact events. Monopisthocotyls are highly dependent on the architecture of the haptor and the microstructure of the gills, and relatively subtle similarities may be sufficient to allow successful colonization of a new host (Kritsky et al., 1986; Šimková et al., 2014). In the present study, *G. peruensis* n. sp. exhibited no detectable morphological divergence in

diagnostic characters of the male copulatory complex or haptoral sclerites when compared with congeners described from Neotropical cichlids, suggesting either a recent colonization event or strong morphological conservatism within the genus.

Such patterns of morphological stability following host-switching have been previously documented in monopisthocotyls, notably in the case of *Anacanthorus colombianus* infecting African cichlids, where no host-associated morphological differentiation was observed (Kritsky & Thatcher, 1974). However, evolutionary studies indicate that persistence on an alternative host over extended timescales may lead to morphological divergence and eventual speciation, particularly when selective pressures act on attachment and reproductive structures (Desdèvises et al., 2002; Poulin, 2007). In this context, the occurrence of *G. peruensis* n. sp. in *O. niloticus* may represent an early stage in the establishment of a novel host–parasite association.

Clear parallels can therefore be drawn between the present findings and the classical case reported by Kritsky and Thatcher (1974), in which a South American monopisthocotyl successfully infected an African cichlid without detectable morphological divergence from specimens collected from its native host. Similarly, the detection of *G. peruensis* n. sp. in *O. niloticus* suggests that morphological compatibility of gill structures among cichlids, combined with phylogenetic proximity at higher taxonomic levels, may facilitate parasite establishment across geographically distinct lineages.

Overall, the present study significantly expands current knowledge of the diversity, host range and systematic boundaries of monopisthocotyls associated with *O. niloticus* in Peru and documents, for the first time, the presence of the genus *Gussevia* in an African cichlid. This novel host–parasite association contributes to a better understanding of monopisthocotylan systematics, biogeography and host plasticity, and highlights the importance of examining introduced hosts to uncover previously unrecognized parasite diversity and early stages of host-associated diversification.

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Author contributions The study was designed by GAMM, HADP, VPNG; Collection of parasites was performed by VPNG, HADV, AMLF; Laboratory tests were performed by GAMM, HADP, VPNG, CPPP, AMLF. The manuscript was written by GAMM, CATR, VPNG and subsequently revised by all other authors.

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Data availability The data that support the findings of this study are available from the corresponding author upon reasonable request. No datasets were generated or analyzed during the current study

Declarations

Conflict of interest The authors declare no competing interests.

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