

RESEARCH ARTICLE

Three new *Dactylogyrus* species (Monogenea: Dactylogyridae) and redescription of one other, gill parasites of five *Labeo* spp. (Cypriniformes: Cyprinidae) from the Sanaga basin (Cameroon, Central Africa)

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ABSTRACT. Three new and one already known species of *Dactylogyrus* Diesing, 1850 are described from five species of *Labeo* (Cyprinidae) sampled in the middle section of the Sanaga hydrosystem (Centre Region-Cameroon): *Dactylogyrus sanagaensis* sp. nov. from *Labeo sanagaensis* Tshibwabwa, 1997, *L. nunensis* Pellegrin, 1929, *L. camerunensis* Trewavas, 1974 and *L. annectens* Boulenger, 1903; *Dactylogyrus nachtigalensis* sp. nov. and *D. yassensis* Musilová, Řehulková & Gelnar, 2009 from *Labeo batesii* Boulenger, 1911; and *Dactylogyrus djimensis* sp. nov. from *Labeo camerunensis*. *Dactylogyrus sanagaensis* sp. nov. is close to *D. longiphalloides*, *D. longiphallus*, *D. leonis*, *D. marocanus*, and *D. dembae*, however it can be easily distinguished from these species by the size of MCO. *Dactylogyrus nachtigalensis* sp. nov. is similar to *D. dembae* and *D. sanagaensis* sp. nov. but this new species can be mainly differentiated by the length of penis. *Dactylogyrus djimensis* sp. nov. mostly similar to *D. omega* can be differentiated from it by the penis diameter. *Dactylogyrus yassensis* collected from Cameroon doesn't significantly differ morphometrically from the original description, thus extends the distribution of this species to Sanaga basin. Monogenean species collected from *Labeo* spp. in the middle section of the Sanaga hydrosystem were classified into two morphological groups: the 'pseudanchoratus-like group' and the 'cyclocirrus-like group' newly defined herein. Phylogenetic relationships are suggested among *Dactylogyrus* species.

KEYS WORDS. *Dactylogyrus nachtigalensis* sp. nov., *Dactylogyrus sanagaensis* sp. nov., *Dactylogyrus djimensis* sp. nov., *Dactylogyrus yassensis*, taxonomy.

INTRODUCTION

While both Cyprinidae and Cichlidae are more represented in the African freshwater ichthyofauna (Lévêque et al. 2008), cyprinids belonging to the genus *Labeo* Cuvier, 1816 are widely distributed throughout Africa and South-East Asia (De Weirdt et al. 2007). About 88 species of *Labeo* are described in Africa, which can be divided into two distinct groups based on the presence of papillate or plicate lips. Members of the latter group are only represented in Lower Guinea by six valid species and an undescribed one (Tshibwabwa 1997). They are all present in

Cameroon (Bitja Nyom et al. 2020) that is a crossroads of many hydrographic basins (Niger, Congo, Cross and Atlantic) (Olivry 1986): *Labeo sanagaensis* Tshibwabwa, 1997, *L. batesii* Boulenger, 1911, *L. nunensis* Pellegrin, 1929, *L. camerunensis* Trewavas, 1974, *L. annectens* Boulenger, 1903, *L. lukulae* Boulenger, 1902, and *Labeo* sp. All of them are found in the Sanaga hydrosystem. Despite the diversity of *Labeo* spp. in this basin, no data on their parasitic biodiversity is available.

Monogeneans are hosts specific and may provide information on their hosts biogeography and/or phylogeny (Guégan et al. 1988, 1989, Boeger et al. 2003, Pérez-Ponce & Choudhury

2005, Šimková et al. 2007, Pariselle et al. 2011). To date, more than 900 nominal species of *Dactylogyrus* Diesing, 1850 have been described in the world (Gibson et al. 1996) mainly on cyprinids. A total of 100 species have been listed on African cyprinids belonging to six genera: *Enteromius* Cope, 1867, *Labeobarbus* Rüppell, 1836, *Labeo*, *Luciobarbus* Heckel, 1843, *Carasobarbus* Karaman, 1971, and recently on *Pterocapoeta* Günther, 1902 (Raphahlelo et al. 2020). According to Paperna (1979), *Dactylogyrus* spp. in Africa could be divided into three distinctive groups (pseudanchoratus-like group, afrobarbae-like group and varicorhini-like group) based in one hand on the morphology of sclerotized parts of the haptor, and on the other hand on the structure of copulatory organs: pseudanchoratus-like group characterized by anchors with long inner root and very short or even vestigial outer root, a tubiform cirrus (penis) slightly curved or coiled if longer (Paperna 1979); afrobarbae-like group characterized by anchors with long inner root and short or vestigial outer root, tubiform cirrus (penis), long and coiled once or twice, with distal portion embraced by the accessory piece; varicorhini-like group characterized by two bars one large and wide with extreme median constriction, cirrus (penis) long coiled tube (Paperna 1979). El-Gharbi et al. (1994), then Rahmouni et al. (2017) identified four types of haptors in the North African region: varicorhini-like group, pseudanchoratus-like group, carpathicus-like group characterized by the presence of a cross-shaped ventral bar, and the guirensis-like group specific to the Guir basin and mainly characterized by a single cross-shaped bar with curved ends, anchors with very long guard and tip. These last two groups were only found in this part of the continent where afrobarbae-like group seems to be absent. In Africa, only few data concern Monogenea parasitizing *Labeo* spp. (Paperna 1969, 1973, 1979, Guégan and Lambert 1991, Gibson et al. 1996,

Musilová et al. 2009, Pravdová et al. 2018). In Cameroon, no data on monogeneans from *Labeo* was found; Birgi and Euzet (1983) described for the first time a dactylogyrid (*Dactylogyrus batesii* Birgi & Euzet, 1983) from a Cyprinodontidae of the genus *Aphyosemion* Myers, 1924. Afterwards fourteen monogenean species were described from species belonging to *Barbus* Cuvier & Cloquet, 1816 (syn. *Enteromius* Cope, 1867) in the Nyong basin (Birgi 1987, Birgi and Lambert 1987).

The aim of this work was to bring better knowledge on the biodiversity of Monogenean parasites of *Labeo* spp. in the middle section of the Sanaga hydrosystem.

MATERIAL AND METHODS

Fish specimens (30 *Labeo batesii*, 21 *L. sanagaensis*, 19 *L. nunensis*, 15 *L. camerunensis*, 3 *L. amnectens*) were sampled from January 2018 to March 2019 in the middle section of the Sanaga basin (Fig. 1) using gill nets. Immediately after fishing, they were kept in a portable deep freezer (Engel) then transported to the laboratory for further examination. After thawing, the gill arches were detached and placed in a Petri dish with tap water. Monogeneans were detached from the gill filaments under a stereomicroscope (M8 Wild Heerbrugg) using an entomological needle, then mounted between slide and cover slip in a drop of ammonium picrate-glycerine (Malmberg 1957) according to Bassock Bayiha et al. (2016). After 24 hours, slides were sealed with Glyceel (Bates 1997). Morphological study of the sclerotized parts of the haptor and the copulatory organs (i.e., male copulatory organ and vagina) was made with a Leica DM 2500 microscope and the LAS 3.8 software. Measurements, with some modifications, are those defined by Gussev (1962) (Fig. 2). They are given in micrometers and expressed as follows: mean (range, number of

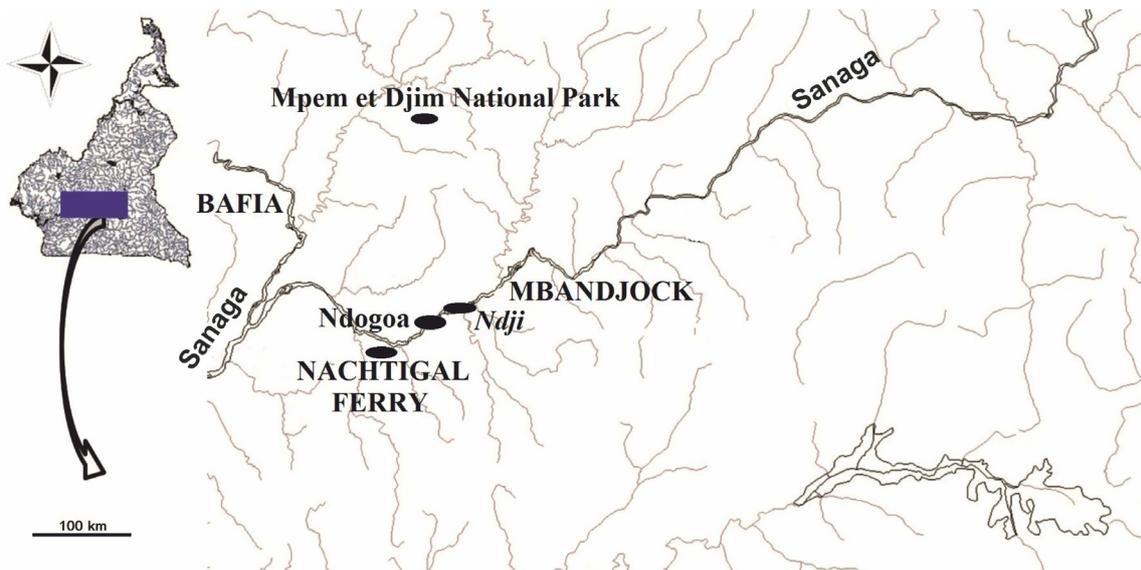


Figure 1. Map of the middle section of the Sanaga hydrosystem indicating sampling localities.

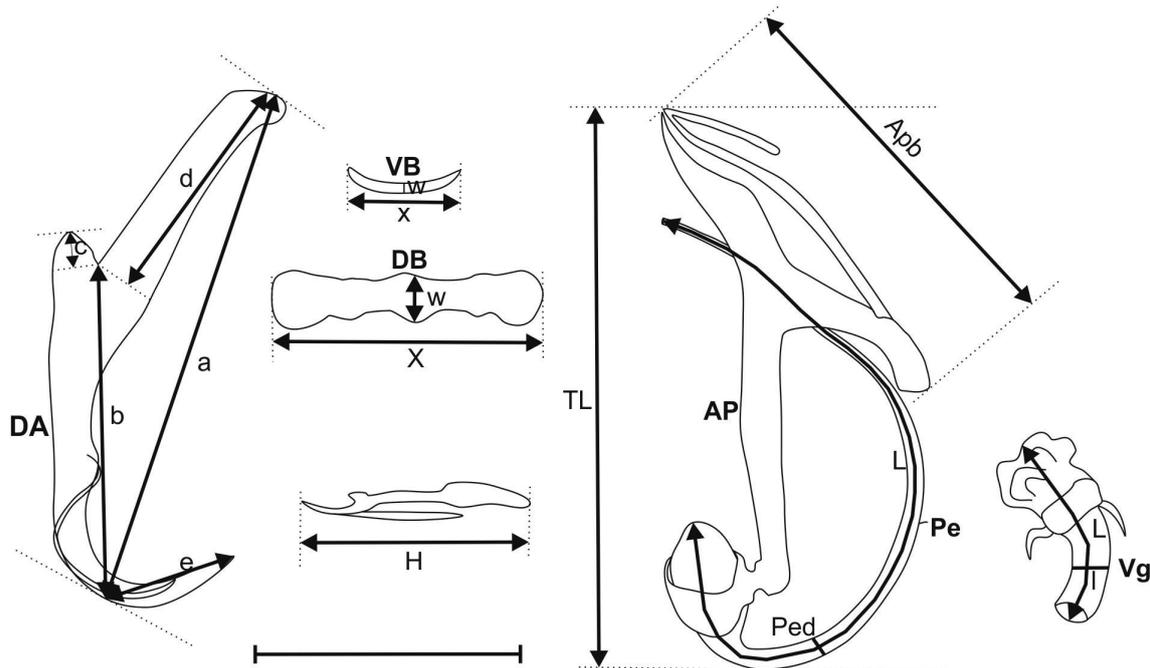


Figure 2. Measurements taken on sclerotized parts according to Gussev (1962). Anchor: (a) total length, (b) length to notch, (c) outer root length, (d) inner root length, (e) point length; (DB) Dorsal bar and (VB) ventral bar: (x) length, (w) width; (H) hook I to VII: length ("larval hook" + shank = proximal + distal subunit); Male copulatory organ (MCO): (TL) total length, (Pe) penis, (L) length, (APb) accessory piece base length; (Vg) vagina: (L) length, (l) width. Scale bar: 20 μ m.

measurements). Drawings were made with the camera lucida of a Leitz Diaplan microscope and refined through Coral Draw X4 Software (v. 14.0.0.70, Corel Inc.). Numbering the haptor pieces followed Llewellyn (1963) and the recommendation adopted at ICOPA IV (Euzet and Prost 1981). Mean intensity and prevalence are defined after Bush et al. (1997). Principal Component Analysis (PCA) of morphometric data was performed on 22 variables from 53 specimens using Statistica software version 6 (StatSoft Inc. 2012). Note that authors of new species are different from those of this paper according to Article 50.1 and Recommendation 50A of the International Code of Zoological Nomenclature (ICZN 1999). Type specimens were deposited in the Royal Museum for Central Africa (RMCA), Tervuren, Belgium.

TAXONOMY

Dactylogyrus sanagaensis Fankoua, Bassock Bayiha & Rahmouni, sp. nov.

Fig. 3

<http://zoobank.org/73C94FE9-77F5-4999-95CB-6A3F1F8B75C5>

Type host. *Labeo sanagaensis* Tshibwabwa, 1974.

Other hosts. *Labeo nunensis* Pellegrin, 1929; *Labeo camerunensis* Trewavas, 1974; *Labeo annectens* Boulenger, 1903.

Infection site. Gill lamellae.

Type locality. Nachtigal (04°20'50.1"N; 011°38'00.3"E).

Other localities. Ndokoa (04°23'56.64"N; 011°44'14.52"E), National Park of Mpem and Djim (05°6'37.23"N; 11°33'28.91"E).

Prevalence. 69.2% in *Labeo sanagaensis*, 60% in *L. nunensis*, 67.7% in *L. camerunensis*, 33.3% in *L. annectens*.

Mean intensity. 7.9 in *L. sanagaensis*, 15.5 in *L. nunensis*, 8.5 in *L. camerunensis*, 01 in *L. annectens*.

Material studied. 18 whole-mounted specimens in GAP.

Type specimens. Holotype RMCA_VERMES_43352, Paratype RMCA_VERMES_43353, Paratype RMCA_VERMES_43354, Paratype RMCA_VERMES_43355, Paratype RMCA_VERMES_43356, Paratype RMCA_VERMES_43357.

Etymology. Epithet *sanagaensis* refers to the River Sanaga in which specimens of the type host were sampled.

Description. The anatomy is that of the *Dactylogyrus*. Body length 335.8 (271.9–483.8; n = 18); width 68.3 (48.5–86.4; n = 18) at level of ovary. Cephalic glands present. Two pairs of eye-spots of variable size, anterior to pharynx. Haptor not well separated from rest of the body. Dorsal anchor (DA) with arched point, guard distinctively longer than shaft, and arched at the distal extremity. Ventral bar (VB) reduced, crescent moon-shaped. Dorsal bar (DB) straight and enlarged at the middle and at the two extremities. All the 14 hooks (07 pairs) with similar morphology but different sizes. One pair of needles (N) located near hooks pair V. Male copulatory organ (MCO) complex, J-shaped, tubular

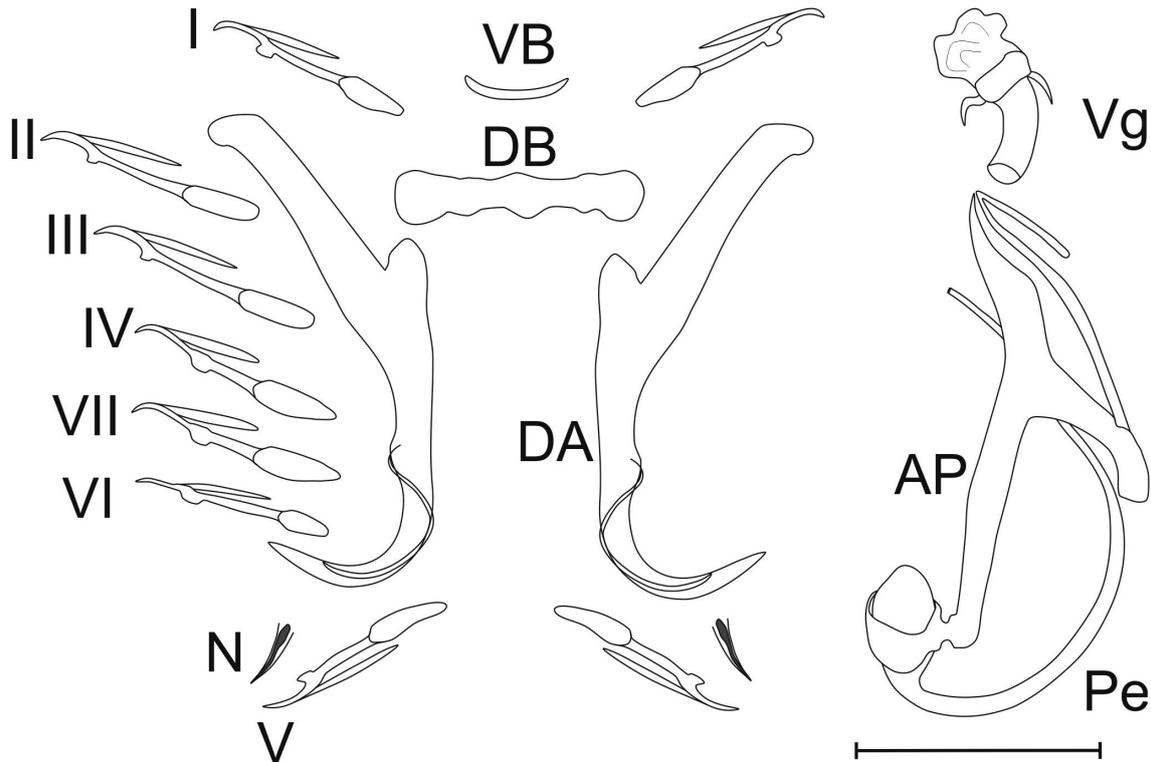


Figure 3. Drawing of sclerotized parts of *Dactylogyrus sanagaensis* sp. nov.: (DA) dorsal anchor, (DB) Dorsal bar, (VB) ventral bar, (Pe) penis, (AP) accessory piece, (Vg) vagina, (N) needle. Scale bar: 20 μ m.

penis starting by a basal bulb (one ovoid lobe). Accessory piece (AP) is T-shaped with two branch of equal size, one with a sharp extremity, the other with a rounded extremity; a thinner part attached to this extremity folded back near the sharp extremity. Vagina (Vg) is a short thick tube with a flame shaped structure at its distal extremity; the distal third of vagina is wrapped by a large ring with two short filaments on either side.

The measurements of haptor and copulatory sclerites are similar in both hosts and given in Table 1.

Remarks. *Dactylogyrus sanagaensis* sp. nov. resembles *D. leonis* Musilová, Řehulková & Gelnar, 2009 from *Labeo coubie* Rüppell, 1832, *D. longiphallus* Paperna, 1973 from *L. victorianus* Boulenger, 1901, *D. longiphalloides* Guégan & Lambert, 1991 from *Labeo allauadi*, Pellegrin, 1933, and *D. marocanus* El-Gharbi, Birgi & Lambert, 1994 from *Carasobarbus fritschii* Günther, 1901 and *D. dembae* Musilová, Řehulková & Gelnar, 2009 from *L. coubie* by the similar shaped haptor sclerites, the conspicuous subterminal notch on the outer root of the dorsal anchor, the same ‘pseudanchorus’ type of the male copulatory organ (J-shaped), accessory piece T-shaped, tubular vagina with a distal flame shaped structure, and a large ring with two short distal filaments. The main difference is the size of MCO: AP = 29–41 μ m vs 28–32 μ m; 31–40 μ m; 45–52 μ m; 38–57 μ m and 26–30 μ m respectively for *D. leonis*, *D. longiphallus*, *D. longiphalloides*, *D. ma-*

rocenus and *D. dembae*; Pe = 27–34 μ m vs 28–34 μ m; 38–45 μ m; 40–45 μ m; 41–61 μ m and 27–34 μ m respectively for *D. leonis*, *D. longiphallus*, *D. longiphalloides*, *D. marocanus* and *D. dembae*.

Dactylogyrus nachtigalensis Fankoua, Bassock
Bayiha & Rahmouni, sp. nov.

Fig. 4

<http://zoobank.org/01715191-F0D4-44A7-9F41-8E1532573603>

Type host. *Labeo batesii* Boulenger, 1911.

Infection site. Gill lamellae.

Type locality. Nachtigal (04°20'50.1"N; 011°38'00.3"E).

Other localities. Ndokoa (04°23'56.64"N; 011°44'14.52"E), National Park of Mpem and Djim (5° 6'37.23"N; 11°33'28.91"E), Assamba (04°24'33"N; 011°49'47.34"E).

Prevalence. 90%.

Mean intensity. 5.1.

Material studied. 12 whole mounted specimens in GAP.

Type specimens. Holotype RMCA_VERMES_43364, Paratype RMCA_VERMES_43365, Paratype RMCA_VERMES_43366, Paratype RMCA_VERMES_43367, RMCA_VERMES_4338 and RMCA_VERMES_43369.

Etymology. Epithet *nachtigalensis* refers to the type locality (Nachtigal).

Table 1. Measurements in micrometers of the sclerotized parts of three new species of *Dactylogyrus* and three others species already described.

Specific names	<i>D. sanagaensis</i> sp. nov.	<i>D. longiphalloides</i>	<i>D. noctigalensis</i> sp. nov.	<i>D. yassensis</i> , current study	<i>D. djimensis</i> sp. nov.	<i>D. omega</i>
Hosts	* <i>Labeo sanagaensis</i> , <i>L. nunensis</i> , <i>L. annectens</i> , <i>L. camerunensis</i>	* <i>Labeo alluaudi</i>	* <i>Labeo batesii</i>	* <i>Labeo batesii</i>	* <i>Labeo camerunensis</i>	* <i>Labeo rouaneti</i> , <i>L. parvus</i>
Body length	335.8 (271.9–483.8; n=18)	370 (250–460)	339.9 (194.4–402.9; n=12)	594.3 (491.9–758.7; n=7)	611.7 (455.2–821.6; n=16)	530 (360–830)
Body width	68.3 (48.5–86.4; n=18)	60 (40–80)	70.7 (42.5–86.8; n=12)	141 (100.7–206.4; n=7)	148.9 (111.9–245.3; n=16)	100 (70–120)
Dorsal anchor						
a	40.2 (36.9–44.7; n=18)	43 (40–45)	33.1 (31.6–34.1; n=12)	35.9 (33.8–38.1; n=7)	34.8 (32.7–36.3; n=16)	35 (32–36)
b	26.1 (22.8–29.9; n=18)	25 (24–28)	22.5 (21.6–23.3; n=12)	30 (27.9–33.9; n=7)	28.9 (25.9–31.5; n=16)	28 (26–30)
c	2.2 (1.7–3; n=18)	1–3	2.1 (1.6–2.7; n=12)	5.4 (4–6.3; n=7)	4.9 (3.1–6.6; n=16)	5 (3–6)
d	17.6 (13.7–21.9; n=18)	20 (19–21)	13.5 (11.6–15.1; n=12)	13 (11.9–14.5; n=7)	11.1 (9.6–12.9; n=16)	12 (10–14)
e	11.3 (8.6–13.3; n=18)	12–14	11.3 (10.3–12; n=12)	13.2 (12.4–14.3; n=7)	12.1 (9.9–13.6; n=16)	14 (13–15)
Hook length						
N sclerite	9.6 (7.9–11.5; n=18)	8–10	8.2 (7–9.9; n=12)	9.5 (7.8–10.7; n=7)	9.1 (6.9–10.8; n=16)	8–10
I	16.3 (12–19.4; n=18)	16 (15–18)	16.9 (15.7–18.7; n=12)	20.5 (17.9–22.8; n=7)	20.6 (19–23.5; n=16)	18–20
II	15.9 (12.6–20.4; n=18)	16 (15–18)	18.1 (16.8–19.5; n=12)	15.6 (14.2–19.9; n=7)	17.4 (15.2–21.3; n=16)	20–22
III	16.9 (12.8–20.9; n=18)	15–16	18.9 (17.2–21.6; n=12)	16.3 (14.5–19.3; n=7)	17.8 (15.8–23.6; n=16)	15–16
IV	17.9 (15.4–26.8; n=18)	15–16	19.3 (17.3–21; n=12)	14.9 (13.3–16.3; n=7)	17.3 (14.9–19.5; n=16)	15–16
V	17.9 (14.5–21.8; n=18)	18 (17–19)	19.5 (18.3–39.8; n=12)	20.3 (14.5–24.3; n=7)	20.9 (14.1–23.5; n=16)	15–16
VI	16.4 (12.8–19.3; n=18)	18 (17–19)	16.6 (14.2–18.4; n=12)	15.4 (13.6–17.9; n=7)	17.6 (14.6–22.2; n=16)	15–16
VII	16.1 (11.9–18.4; n=18)	18 (17–19)	17.7 (16.5–19.3; n=12)	15 (13.9–16.2; n=7)	16.3 (14.4–20.1; n=16)	15–16
Dorsal Bar						
x	20.1 (18.6–21.6; n=18)	18 (17–20)	17.9 (16.8–19.5; n=12)	24.8 (23.6–25.9; n=7)	23.5 (21.1–26.4; n=16)	24–28
w	3.7 (2.8–5.4; n=18)	3–5	2.9 (2.5–3.8; n=12)	4.4 (3.6–5.2; n=7)	4.3 (3.3–5.5; n=16)	4–6
Ventral bar						
x	9.2 (6.9–11.1; n=18)	8–10	9.8 (7.8–12.3; n=12)	5.4 (6.2–7.2; n=7)	5.3 (3–10.1; n=16)	4–6
w	1.5 (1.1–1.8; n=18)	–	1.6 (0.9–2.5; n=12)	2 (1.4–2.2; n=7)	2.2 (1.1–3.2; n=9)	–
Male copulatory organ						
Total length	38.7 (29.3–41.9; n=18)	50 (45–52)	45.6 (42.5–48.4; n=12)	38.5 (35.6–42.3; n=7)	46.6 (28.8–55.1; n=16)	35–42
Pe	57.3 (52.1–65.6; n=18)	40–46	45.8 (42.7–47.1; n=12)	88.3 (82.3–95; n=7)	83.6 (74.8–90.4; n=16)	–
Pe Diameter	2.1 (1.6–2.8; n=18)	–	2.7 (2.8–2.9; n=12)	2.9 (2.6–3.1; n=7)	13.7 (10.7–16.7; n=16)	2–3
APb	23.6 (17.8–30.4; n=18)	–	13.3 (11.7–14.8 n=12)	–	–	–
Vagina						
L	10.9 (7.4–17.2; n=18)	–	7.2 (5.6–9.1; n=7)	–	–	–
I	3.6 (1.9–5.1; n=18)	–	3.1 (2.2–3.9; n=7)	–	–	–

*Type host.

Description. The anatomy is that of the *Dactylogyrus*. Body length 339.9 (194.4–402.9; n = 12); width 70.7 (42.5–86.8; n = 12) at the level of ovary. Haptor not really separated from the rest of the body by a constriction; cephalic glands present, two pairs of eye-spots of variable sizes, anterior to pharynx. Dorsal anchor with arched point, guard distinctively longer than shaft, arched narrow handle. Dorsal bar (DB) slightly curved at its median part. Ventral bar (VB) crescent moon-shaped, much smaller than dorsal bar. Presence of seven pairs of hooks with same morphology and size except pair VI smaller than the others; all hooks kept their larval form (oncomiracidia). One pair of needles (N) located near hooks of pair V. Male copulatory organ (MCO): tubular J-shaped penis begins with a basal bulb, runs alongside the accessory piece. Accessory piece straight bar, wrapped around the basal bulb, ends in two branches like in *D. sanagaensis* sp.

nov., one branch straight and sharp ended, the other one longer, thinner at its distal part, folded back at first third, reaches the sharp end then folded back again. Base of accessory piece (APb) shorter than in *D. sanagaensis* sp. nov. Vagina short with large aperture, distal extremity with sclerotised plate.

The measurements of haptor and reproductive sclerites are given in Table 1.

Remarks. *Dactylogyrus noctigalensis* sp. nov. is close to *D. sanagaensis* sp. nov. by the morphology of its haptor and MCO, but differs from it by (i) the length of the penis: 52.1–65.6 μ m vs 42.7–47.1 μ m, (ii) the morphology of the dorsal bar, straight in both species, but slightly curved in the median part in *D. noctigalensis* sp. nov., (iii) the total length of male copulatory organ: 11.7–14.8 μ m vs 17.8–30.4 μ m in *D. sanagaensis* sp. nov., the morphology and size of the vagina, not flame shaped and

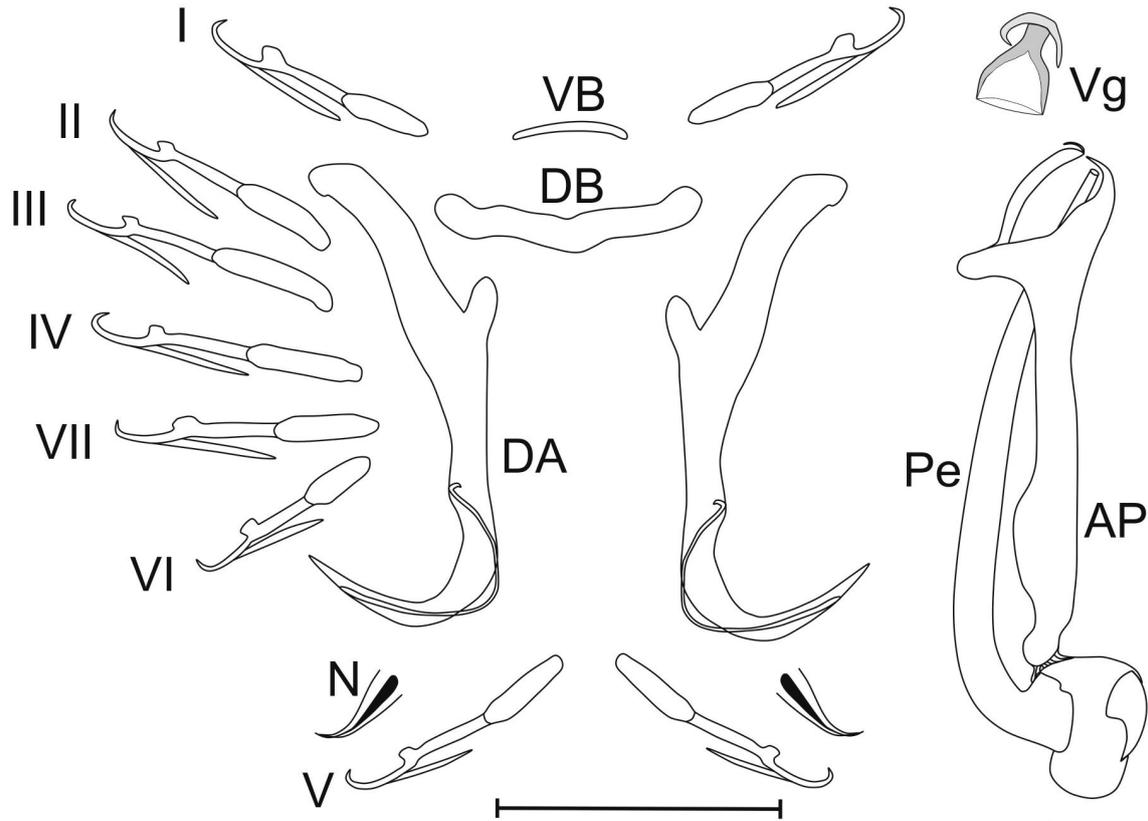


Figure 4. Drawing of sclerotized parts of *Dactylogyrus noctigalensis* sp. nov.: (DA) dorsal anchor, (DB) Dorsal bar, (VB) ventral bar, (Pe) penis, (AP) accessory piece, (Vg) vagina, (N) needle. Scale bar: 20 μ m.

5.6–9.1 μ m vs flame shaped and 7.4–17.2 μ m in *D. sanagaensis* sp. nov. *Dactylogyrus noctigalensis* is also close to *D. dembae* (syn: *D. cf. labeous*) from *Labeo coubie* by the morphology of the haptor and male copulatory organ. The main differences are the length of penis 42.7–47.1 μ m and of the MCO 11.7–14.8 μ m vs 27–34 μ m and 26–30 μ m in *D. dembae*. *Dactylogyrus noctigalensis* sp. nov. also presents the typically morphology of ‘pseudanchoratus-like group’.

Dactylogyrus djimensis Fankoua, Bassock Bayiha & Rahmouni, sp. nov.

Fig. 5

<http://zoobank.org/D703D538-7418-4FE5-843F-95D37AF0DA94>

Type host. *Labeo camerunensis* Trewavas, 1974.

Infection site. Gill lamellae.

Type locality. Djim river: 04°20'50, 1"N; 011°38'00, 3"E; alt.441 m.

Prevalence. 50 %.

Mean intensity. 3.5.

Material studied. 16 whole mounted specimens in GAP.

Type specimens. Holotype RMCA_VERMES_43358, Para-

type RMCA_VERMES_43359, Paratype RMCA_VERMES_43360, Paratype RMCA_VERMES_43361, Paratype RMCA_VERMES_43362, Paratype RMCA_VERMES_43363.

Etymology. Epithet *djimensis* refers to the River Djim in which specimens of the type host were sampled.

Description. Body length 612 (455–822, n = 16) and 141 (14–245, n = 16) width at the level of ovary. Cephalic glands present, two pairs of eye-spots of variable sizes, anterior to pharynx. Haptor well separated from the rest of the body by a narrow constriction. Dorsal anchors strong with arched point, guard longer than shaft. Dorsal bar (DB) straight with spherical and fenestrated extremities. Ventral bar (VB) vestigial shovel-shaped. Presence of seven pairs of hooks morphologically similar with larval form, approximately same length except hooks pairs I and V longer than others. One pair of needles (N) located near hooks pair V. Male copulatory organ (MCO) with: tubular coiled penis starts from a bulb with large base, lacks flange, winds around the accessory piece at its middle and ends in a rounded part; accessory piece slightly sclerotized, forms an asymmetrical triangular frame with a shaft. No sclerotized vagina observed.

New measurements of haptor and reproductive sclerites are given in Table 1.

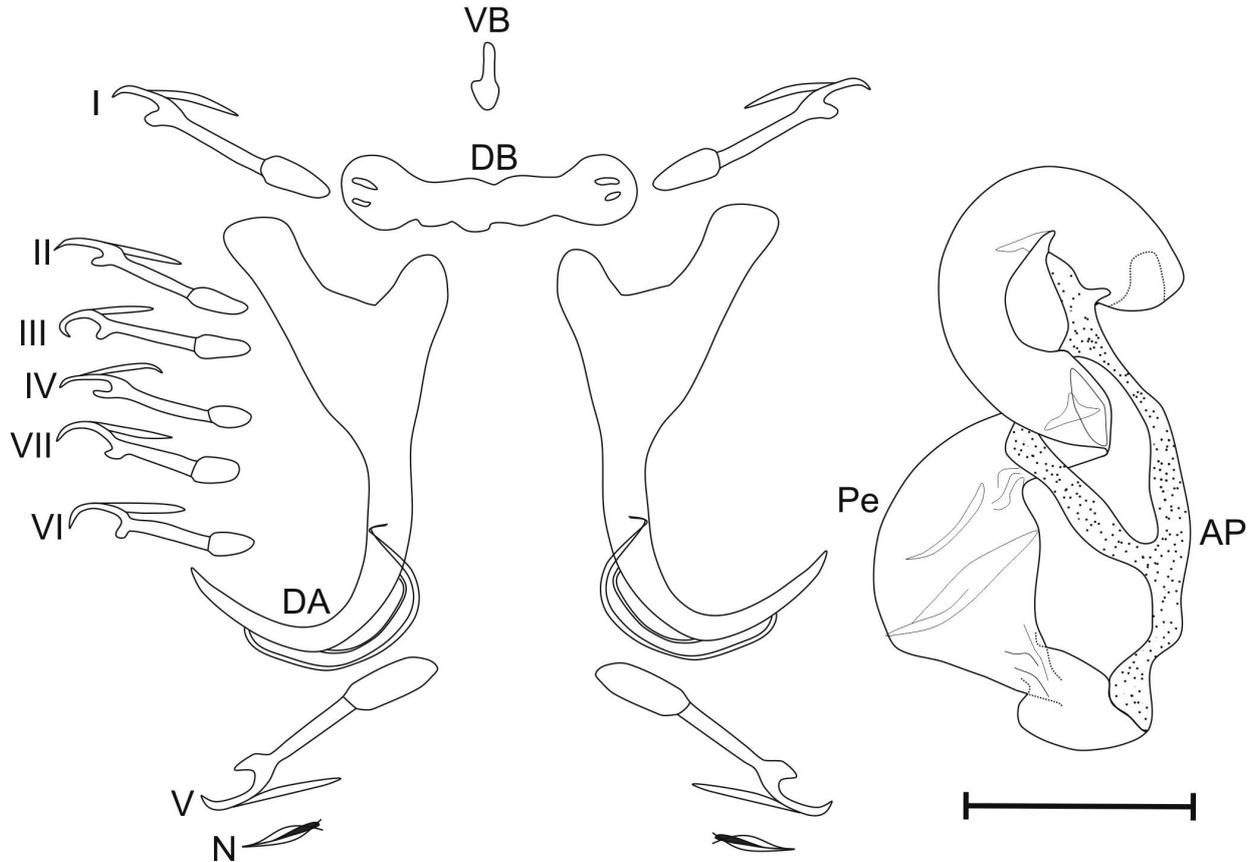


Figure 5. Drawing of sclerotized parts of *Dactylogyrus djimensis* sp. nov.: (DA) dorsal anchor, (DB) Dorsal bar, (VB) ventral bar, (Pe) penis, (AP) accessory piece, (Vg) vagina, (N) needle. Scale bar: 20 μ m.

Remarks. By the morphology of the haptor sclerites and the MCO, this species is close to *D. yassensis* Musilová, Řehulková & Gelnar, 2009 from *L. coubie*, *D. cyclocirrus* Paperna, 1973 from *Labeo coubie*, *L. cylindricus* Peters, 1852, *L. victorianus* and *L. senegalensis* Valenciennes, 1842, *D. digitalis* Paperna, 1969 from *L. coubie*, *D. nathaliae* Guégan & Lambert, 1988 from *Labeo* sp. from Mali, and *D. omega* Guégan & Lambert, 1991 from *L. parvus* and *L. rouaneti*. It differs from *D. yassensis* by the length of anchor inner root 9.6–12.9 μ m and outer root 3.1–6.6 μ m vs 12–14 μ m and 5–7 μ m, dorsal bar 21.1–26.4 μ m vs 26–27 μ m, penis 74.8–90.4 μ m vs 74–79 μ m; from *D. cyclocirrus* by the length of anchor inner root 9.6–12.9 μ m vs 24–28 μ m, dorsal bar 21.1–26.4 μ m vs 23–27 μ m, penis 74.8–90.4 μ m vs 62–69 μ m; from *D. digitalis* by the length of dorsal bar 21.1–26.4 μ m vs 28–34 μ m, and its coiled penis 74.8–90.4 μ m vs simple penis 70 μ m; from *D. nathaliae* by the size of anchor inner length 32.7–36.3 μ m vs 26–30 μ m, its coiled penis 74.8–90.4 μ m vs curved penis 37–45 μ m; from *D. omega* by the length of anchor inner root 9.6–12.9 μ m and outer root 3.1–6.6 μ m vs 10–14 μ m and 3–6 μ m, dorsal bar 21.1–26.4 μ m vs 24–28 μ m, though hooks length and diameter of penis 10.7–16.7 μ m vs 2–3.

Dactylogyrus yassensis Musilová, Řehulková & Gelnar, 2009

Fig. 6

Type host and locality. *Labeo coubie*, Gambia River near the Campement du Lion, Niokolo-Koba National Park, Senegal.

Other records. *Labeo senegalensis*, Niger River (Bamako), Baoulé River (Missira), Mali; Guiers Lake, Senegal, (Guégan et al. 1988); *Labeo coubie*, Gambia River near the hotel Simenti, Niokolo-Koba National Park, Senegal; *Labeo horie* Heckel, 1847, White Nile, Kosti, Sudan; Blue Nile, Sennar.

Present record. *Labeo batesii*, 1911 in Sanaga at Nachtigal (04°20'50.1"N; 011°38'00.3"E), in Sanaga at Ndokoa (04°23'56.64"N; 011°44'14.52"E), National Park of Mpem and Djim (5° 6'37.23"N; 11°33'28.91"E) and Assamba (04°24'33"N; 011°49'47.34"E).

Infection site. Gill lamellae.

Prevalence. 60%

Mean intensity. 5.2

Material studied. Whole mounted specimens in GAP.

Redescription. Body length 594.3 (491.9–758.7; n = 7);

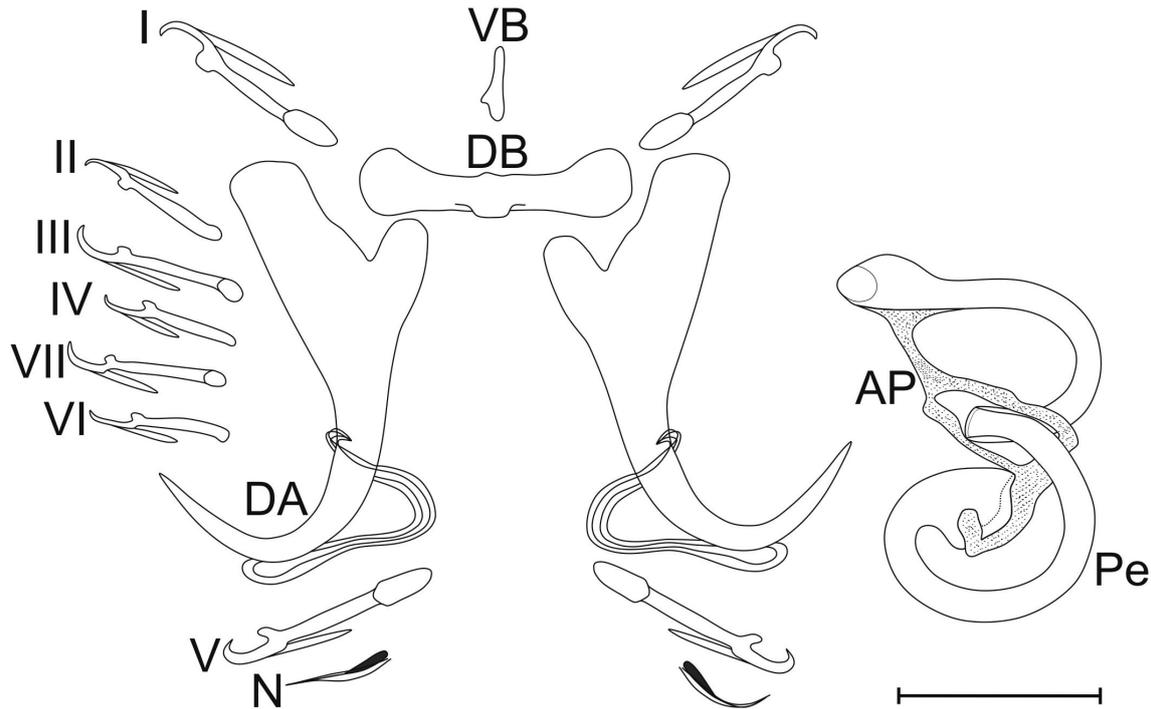


Figure 6. Drawing of sclerotized parts of *Dactylogyrus yassensis*. (DA) dorsal anchor, (DB) Dorsal bar, (VB) ventral bar, (Pe) penis, (AP) accessory piece, (Vg) vagina, (N) needle. Scale bar: 20 μ m.

width 141 (100.7–206.4; $n = 7$) at the level of ovary. Cephalic glands present, two pairs of eyes present anterior to the pharynx. Single pair of anchors (dorsal); long inner root truncate; short outer root blunt; curved shaft slightly swollen at level of filament hitch; point not reaching level of tip of inner root. Dorsal bar bonelike, with short truncate posteromedial process; ventral bar reduced, vestigial. Presence of 7 pairs of hooks, similar with larval form, approximately same length except hooks pairs I and V. One pair of needles located near hooks of pair V. No sclerotized vagina observed. Copulatory organ is a coiled wide tube, winds around the accessory piece. Accessory piece slightly sclerotized, articulated to base.

New measurements of haptoral and reproductive sclerites are given in Table 1.

Remarks. The morphology and measurements of the specimens parasitizing *Labeo batesii* in the Sanaga basin (Cameroon) correspond to the original description of *Dactylogyrus yassensis* from *L. coubie* in five countries: Niger, Mali, Ghana, Gambia and Senegal (Musilová et al. 2009; Pravdová et al. 2018). The only difference that could be detected is that of the penis length 82.3–95 μ m vs 74–79 μ m from the original description by Musilová et al. (2009) in West Africa. *Dactylogyrus yassensis* can be confused with *D. omega* but differs mainly from it by larger anchor, dorsal bar smaller and without fenestrated extremities, penis length longer, and the other sclerotized structures slightly smaller.

Morphometric study by PCA

The principal component analysis (PCA) performed on the measurements of sclerotized parts of the haptor and the MCO showed that Monogeneans collected in the present work belong to four well distinct groups (Fig. 7). With regard to the haptor data and the MCO, axe 2 isolated two subsets made up of two groups each. Axe 1 separated *D. nachtigalensis* sp.nov. from “*D. sanagaensis* sp.nov. + *D. longiphalooides*” on the one side, and *D. yassensis* from “*D. djimensis* sp.nov. + *D. omega*” on the other side.

DISCUSSION

Prior to this study, no record of *Dactylogyrus* was made from *Labeo* species in Cameroon because they were not investigated in this country. With the three new Monogeneans described, the number of *Dactylogyrus* species parasitizing the gills of *Labeo* spp. in Africa reaches 30. In the current work, *D. nachtigalensis* sp. nov. and *D. djimensis* sp. nov. infect only a single host species; *L. batesii* and *L. camerunensis* respectively; they are momentarily strictly host specific or oixenous (Euzet and Combes 1980). *Dactylogyrus yassensis* found parasitizing the gills of *L. batesii*, is also known from *L. coubie*, *L. senegalensis* and *L. horie* (Musilová et al. 2009, Pravdová et al. 2018). Therefore, in the Sub-Saharan area, this monogenean is stenoxenous (Euzet and Combes 1980) or precisely mesostenoxenous (Caira et al.

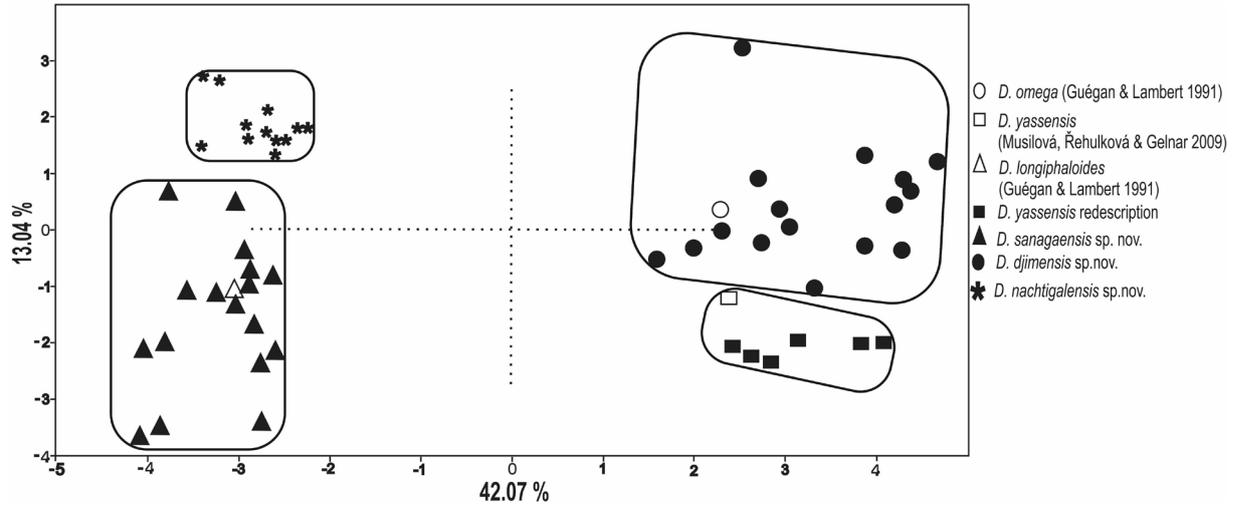


Figure 7. Result of the principal component analysis performed on measurements (μm) of sclerotized parts of monogeneans.

2003). *Dactylogyrus sanagaensis* sp. nov. is described from four host species, namely *L. sanagaensis*, *L. nunensis*, *L. annectens* and *L. camerunensis*; therefore, it is also mesostenoxenous (Caira et al. 2003). It is worthy to notice that the five *Labeo* species studied are sympatric (De Weirdt et al. 2007, Bitja et al. 2020). Their parasitic richness is low, i.e. one for *L. annectens*, *L. nunensis* and *L. sanagaensis*, two for *L. batesii* and *L. camerunensis*, while in West Africa monogenean richness reaches 12 species in *L. coubie* (Scholz et al. 2018). This low number of *Dactylogyrus* spp. parasitizing *Labeo* spp. in the current work could be due at least to the facts that (1) this study was limited in the middle section of the Sanaga hydrosystem and yet it is known that the infra-community can vary along a watercourse (Valtonen et al. 1997); (2) there are still many *Labeo* in Cameroon (Lévêque et al. 1990, De Weirdt et al. 2007) for which ectohelminths remain unstudied.

The presence of *D. sanagaensis* in four *Labeo*, namely *L. sanagaensis*, *L. nunensis*, *L. annectens* and *L. camerunensis*, suggests a relationship between these fish species in the one hand, and may be due to the ecological conditions in the other hand (Euzet and Combes 1980, Rhode 1993, Mbondo et al. 2017). The presence of *D. yassensis* in *L. batesii* in the current work is an enlargement of its host spectra, as this parasite was previously described from *L. coubie*, *L. senegalensis* and *L. horie* (Musilová et al. 2009, Pravdová et al. 2018) in West Africa.

Based on the morphology of the haptor and MCO sclerotized parts, *D. sanagaensis* sp. nov. and *D. nachtigalensis* sp. nov. are ranged in the ‘pseudanchoratus like-group’ (Paperna 1979), while *D. djimensis*, *D. omega*, and *D. yassensis* in addition to *D. cyclocirrus* and *D. nathaliae* may form a new type named “cyclocirrus” (Fig. 8). This new group is characterized by a straight dorsal bar, ventral bar vestigial, shovel-shaped and perpendicular to the dorsal bar, tubular coiled penis, accessory piece an elongated ring lying on either side of the penis. In the Sanaga

river basin, *D. sanagaensis* and *D. nachtigalensis* are not hosted by the same fish. The morphological similarities of their sclerotized parts suggest an alloxenic speciation phenomenon (Euzet and Combes 1980, Combes and Théron 2000, Pouyaud et al. 2006). For *D. djimensis* and *D. yassensis*, the alloxenic and or allopatric diversification could have taken place.

At the level of our investigations, we cannot give a definite number of monogenean types of haptors associated to MCO found in Cameroon from *Labeo* spp. in particular, and from Cyprinids in general. It is however important to notice that the ‘pseudanchoratus-like group’, ‘afrobarbae-like group’ and ‘varicorhini-like group’ were already observed in this country (Birgi and Lambert 1987).

It is noticed that measurements of monogenean individuals studied in this work overlap those of some species already known (Fig. 7); case of: *D. djimensis* sp. nov. and *D. omega*; *D. sanagaensis* sp. nov. and *D. longiphalooides* (Guégan & Lambert 1991); *D. yassensis* redescribed and original *D. yassensis* (Musilová, Řehulková & Gelnar, 2009). Further genetic analyses are therefore needed to reveal the phylogenetical relationships between these parasite species.

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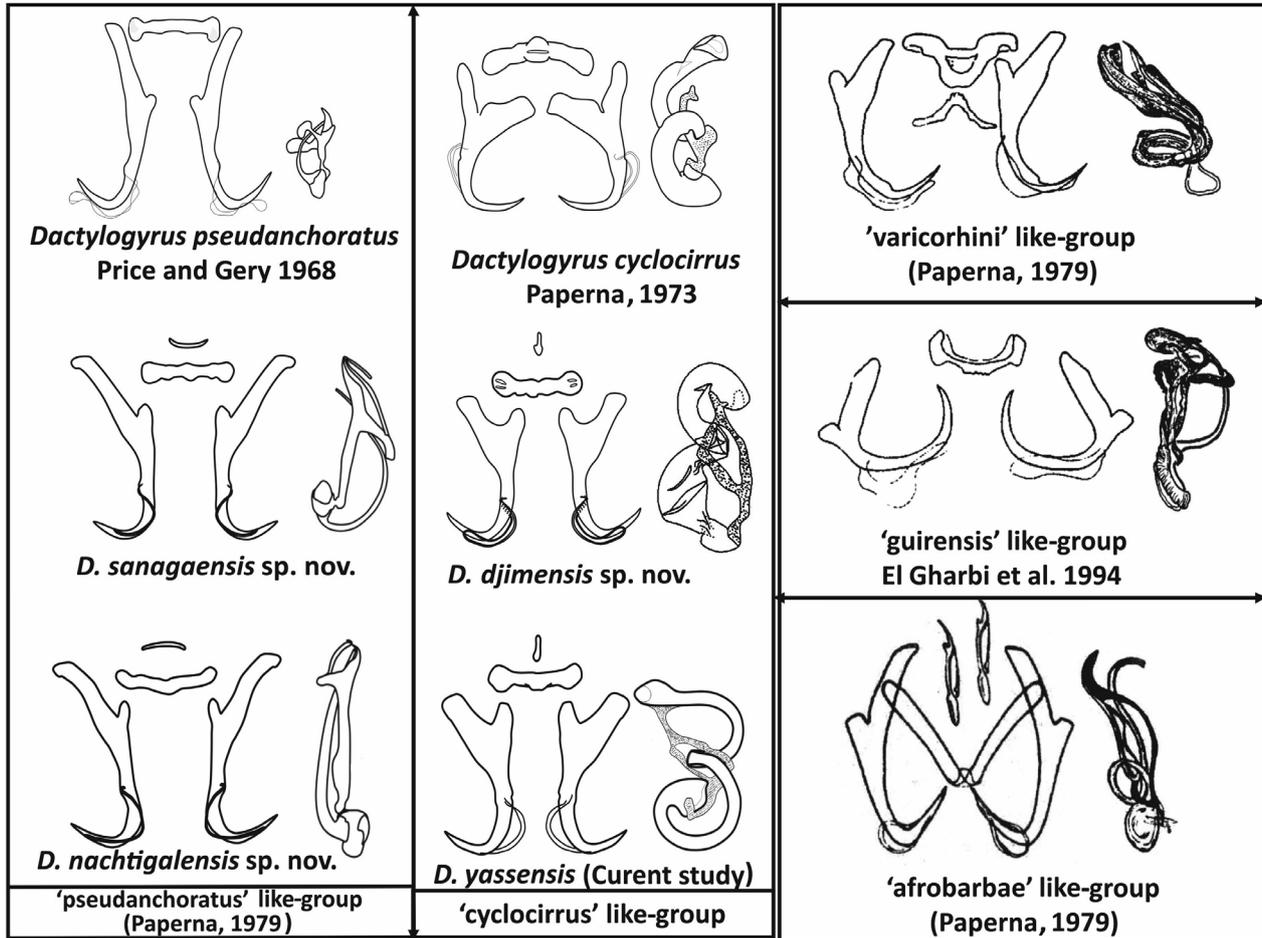


Figure 8. *Dactylogyrus*-groups based on the morphology of dorsal anchors and male copulatory organ.

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FS-O BBED BNAR and BBCF designed the experiments; FS-O BBED BNAR and BBCF conducted the experiments; FS-O BBED RI and BBCF analyzed the data; FS-O BBED BNAR RI NNAR and BBCF wrote the paper

Competing Interests

The authors have declared that no competing interests exist.

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