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RESEARCH ARTICLE

Description of three new species of *Protoancylodiscoides* (Monogenea: Dactylogyridae) and biogeography of those parasitizing *Chrysichthys nigrodigitatus* (Siluriformes: Claroteidae) in Sanaga and Dibamba rivers, Cameroon

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ABSTRACT. *Chrysichthys nigrodigitatus* (Lacépède) specimens were sampled in the Sanaga River and in the Dibamba River. Three new species, *Protoancylodiscoides edeaensis* **sp. nov.**, *P. yombai* **sp. nov.** from both rivers, and *P. dibambaensis* **sp. nov.** from the Dibamba River alone, are described. *Protoancylodiscoides edeaensis* **sp. nov.**, close to *P. mansourensis* El-Naggar, 1987 and *P. chrysichthes* Paperna, 1969 by the morphology of the haptor sclerotised parts, differs from these species by the penis length and the morphology of the vagina. *Protoancylodiscoides yombai* **sp. nov.** is close to *P. edeaensis* **sp. nov.**, *P. mansourensis*, and *P. chrysichthes* by the morphology of some sclerotised parts of the haptor (ventral bar, ventral anchors, dorsal onchium and hooks). However, it differs from these species by the morphology of the vagina, of the outer root of the dorsal anchor, and the size of some sclerotised parts (dorsal anchor total length, dorsal bar length, ventral anchor length, and penis length). *Protoancylodiscoides dibambaensis* **sp. nov.** is close to *P. ivoiriensis* Bouah, N'Douba & Pariselle, 2021 by the lack of the onchium and the morphology of some sclerotised parts of the haptor. However, it differs from this species by the morphology of the dorsal bar, penis length, dorsal bar length, and of the ventral anchor total length. This study on monogeneans raises the question of ichthyofauna exchange between adjacent streams; it also reveals a longitudinal gradient of *Protoancylodiscoides* species richness in the Sanaga River.

KEYS WORDS. Morphology, parasite, host, holotype, paratype, onchium.

INTRODUCTION

Six species are recognized in the subgenus *Chrysichthys* (*Melanodactylus*) Bleeker, 1858 (Risch 1986), of which three are represented in Lower Guinea: *C. dageti* Risch, 1992; *C. ogooensis* (Pellegrin, 1900), and *C. nigrodigitatus* (Lacépède, 1803) (Risch and Vreven 2007). These species are greatly appreciated by the local population because of their palatable meat; this may explain their overfishing which threatens the natural stock (Lalèyè 1995), but also the development of its aquaculture (Adite et al. 2017). *Chrysichthys nigrodigitatus* (Siluriformes: Claroteidae) is found in most river basins and can reach a total length of 650 mm (Risch and Vreven 2007). A small percentage of known African fishes have been examined for parasites; therefore, information on their parasite fauna is still fragmentary and represent only a tip of the iceberg (Scholz et al. 2018). Knowledge of the pathogenic agents of fish diseases is crucial to decrease the economic losses they may cause, especially in aquaculture which is rapidly developing in many African countries (Scholz et al. 2018). Several parasite taxa have been described and/or reported from *C. nigrodigitatus* including representatives of Protista, Myxozoa, Trematoda, Nematoda, Crustacea and Monogenea (Carvalho-Schaeffner 2018). *Protoancylodiscoides* Paperna,

1969 (11 species) have been described from fish of the genera *Chrysichthys*, *Clarotes* Kner, 1855 and *Malapterurus* Lacépéde, 1803 (Siluriformes: Malapteruridae) (Paperna 1969, El-Naggar 1987, Bilong Bilong et al. 1997, N'Douba and Lambert 1999, Bassock Bayiha et al. 2016, 2017, Bouah et al. 2021). Amongst them, four parasitise *C. nigrodigitatus* viz the type species *Protoancylodiscoides chrysichthes* Paperna, 1969; *P. valentini* Bassock Bayiha, Nack & Pariselle, 2017; *P. spirovagina* Bassock Bayiha, Nack & Pariselle, 2017 and *P. sanagaensis* Bassock Bayiha, Nack & Pariselle, 2017. This study describes three new species of *Protoancylodiscoides,* all of them parasitising the gills of *C. nigrodigitatus* collected in two adjacent rivers.

MATERIAL AND METHODS

Ten and 12 *C. nigrodigitatus* specimens were sampled in January 2022 in the Sanaga River at Edéa-Cameroon (3°47'43.25"N, 10°08'12.18"E) and in the Dibamba River at Douala-Cameroon (3°55'31"N, 9°40'21"E) (Fig. 1) respectively. Fish caught using gill nets were preserved in a portable deep freezer (Engel-fridge), then transported to the Parasitology and Ecology Laboratory of the University of Yaounde I for subsequent parasitic and host investigations. After thawing, gill arches were removed and placed in Petri dishes containing tap water. Monogeneans were detached from gill filaments, under a Stereomicroscope (Wild Heerbrugg), using an entomological needle. They were then placed between slide and cover slip in a drop of ammonium picrate glycerin (Malmberg 1957) following Bassock Bayiha et al. (2016); 24 hours later, the slide was sealed with Glyceel (Bates 1997). The morphological study of haptoral and copulatory complex sclerotised (hard) parts was realised under a binocular microscope Leica DM 2500. Measurements, taken with LAS 3.6 software, are those defined by Gussev (1962) and modified by N'Douba (2000) (Fig. 2). They are given in micrometers (µm) and expressed as follows: mean (minimum-maximum, number of measurements). The drawings were made from photos refined through the software Corel Draw X4® (v. 14.0.0.701). Numbering the haptoral pieces followed Llewellyn (1963). Type specimens were deposited in the Helminthological Collection of the Royal Museum for Central Africa (MRAC, Tervuren, Belgium).

TAXONOMY

In the current work, six species including three already described (*P. valentini*, *P. sanagaensis* and *P. spirovagina*) and three new (*P. dibambaensis* sp. nov., *P. yombai* sp. nov. and *P. edeaensis* sp. nov.) parasitised *C. nigrodigitatus* in Dibamba River. All of them, except *P. dibambaensis* sp. nov., were also found on the gills of this host species in the lower course of Sanaga River. Dibamba river represents a new locality of hosts parasitised by *P. valentini*, *P. sanagaensis* and *P. spirovagina*.

The three new monogenean species studied below belong to *Protoancylodiscoides* Paperna, 1969 whose diagnosis was emended by Kritsky and Kulo (1999). The authors of these new taxa are different from those of this paper: Article 50.1 and Recommendation 50A of the International Code of Zoological Nomenclature (ICZN 1999).

Class Monogenea Carus, 1863
Subclass Polyonchoinea Bychowsky, 1937
Order Dactylogyridea Bychowsky, 1937
Dactylogyridae Bychowsky, 1933

Protoancylodiscoides edeaensis Bassock Bayiha, Bahanak & Bilong Bilong, sp. nov.

Fig. 3

https://zoobank.org/7B156B2E-3540-44D0-8368-815C3781A2E4

Type host and locality. *Chrysichthys nigrodigitatus* (Siluriformes: Claroteidae), the Sanaga River in Edea (Cameroon), 3°47'43.25"N and 10°08'12.18"E.

Other locality. The Dibamba River in Douala, 3°55'31"N, 9°40'21"E.

Infection site. Gill lamellae.

Type material. Holotype RMCA_VERMES_43392; Paratypes RMCA_VERMES_43393-43399.

Description based on 23 parasite specimens. Dorsal anchor with long and thick inner root (= guard, superficial root, ventral root), distal end slightly curved outwardly; outer root (= shaft, deep root, dorsal root) very short and less thick than inner root; blade with arched base ends distally in point; thick filament covers blade and apart of point. Dorsal bar slightly curved anteriorly with more or less rounded extremities pierced, each with a small circular hole. Ventral anchor, small with outer root narrower and shorter than inner root; presence of eccentric small lenticular fenestration at base of the inner root; hull and thick, slightly sclerotised filament covers blade ending in little fine and short point. Ventral bar, V-shaped, made up of two straight symmetrical arms separated medially. Presence of seven pairs of hooks in three types according to their shape, size and position. Latero-ventral hooks II, V, VI, VII of similar shape and size [i.e. thin, without shank (= distal subunit)], resemble those

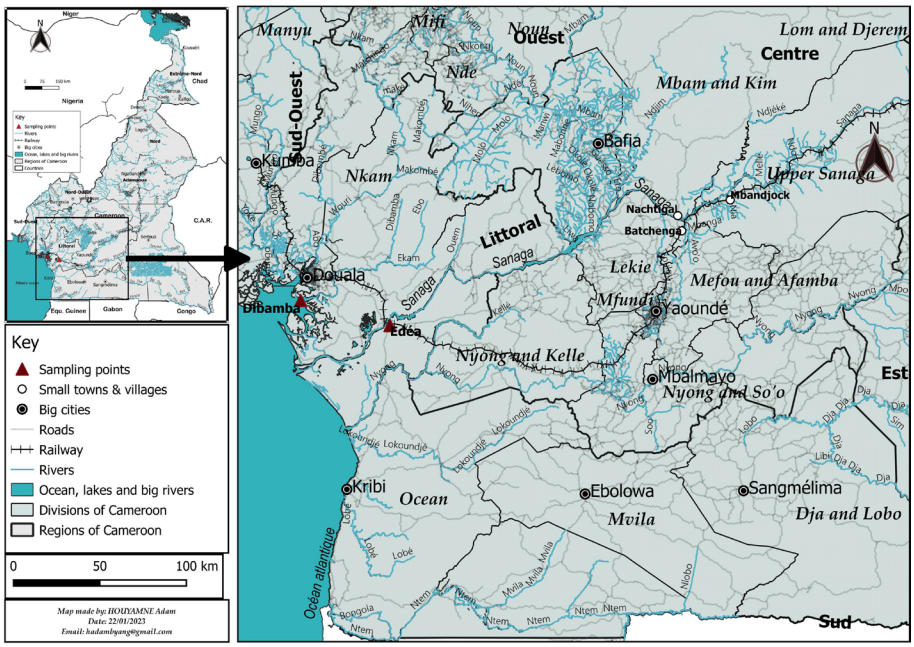

Figure 1. Map of the Sanaga and Dibamba Rivers indicating sampling locations.

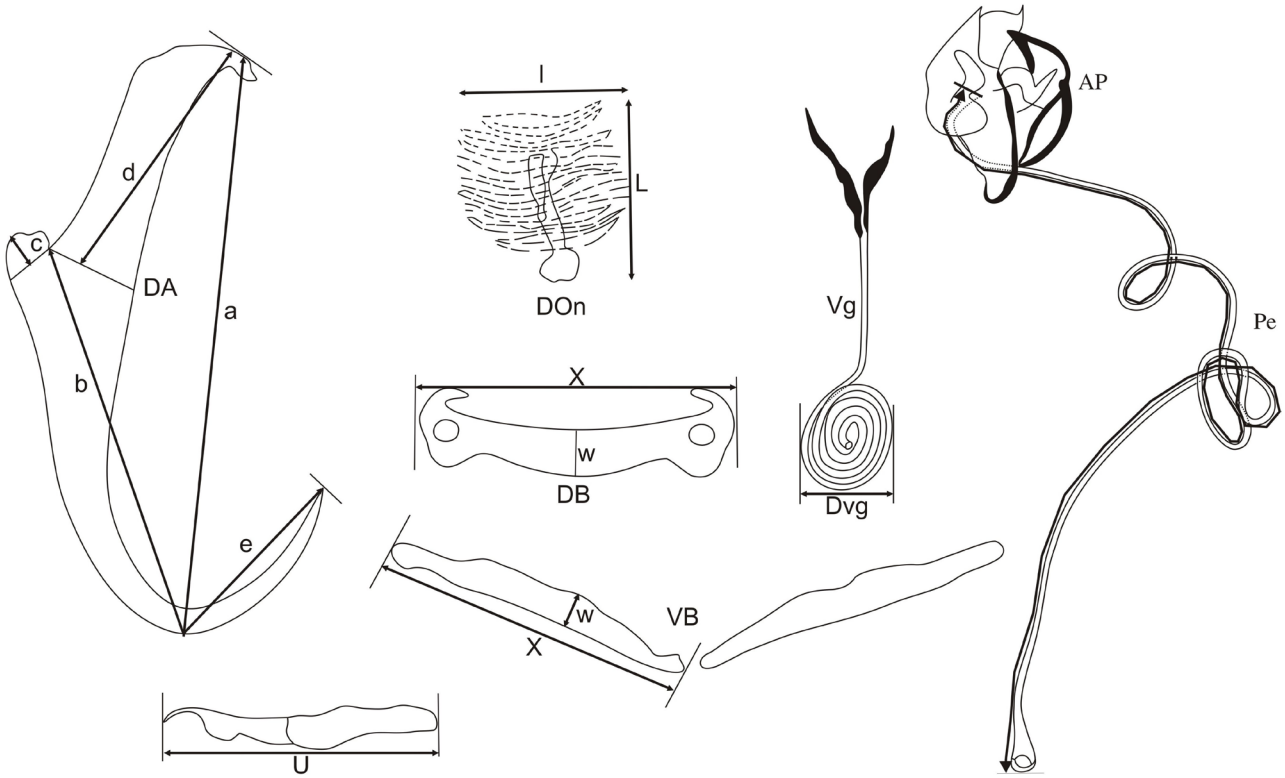

Figure 2. Nomenclature used for the measurement of sclerotised parts according to Gussev (1962) amended by N'Douba (2000). Anchor: (a) total length, (b) blade length, (c) outer root (=shaft, deep root, dorsal root) length, (d) inner root (=guard, superficial root, ventral root) length, (e) point length. Transverse bar (dorsal bar and ventral bar): x = length, w = width. (Don) Dorsal onchium: L = length, l = width; (AP) accessory piece; (Pe) penis length; (Vg) vagina length; (DVg) diameter of vagina; (U) hook length.

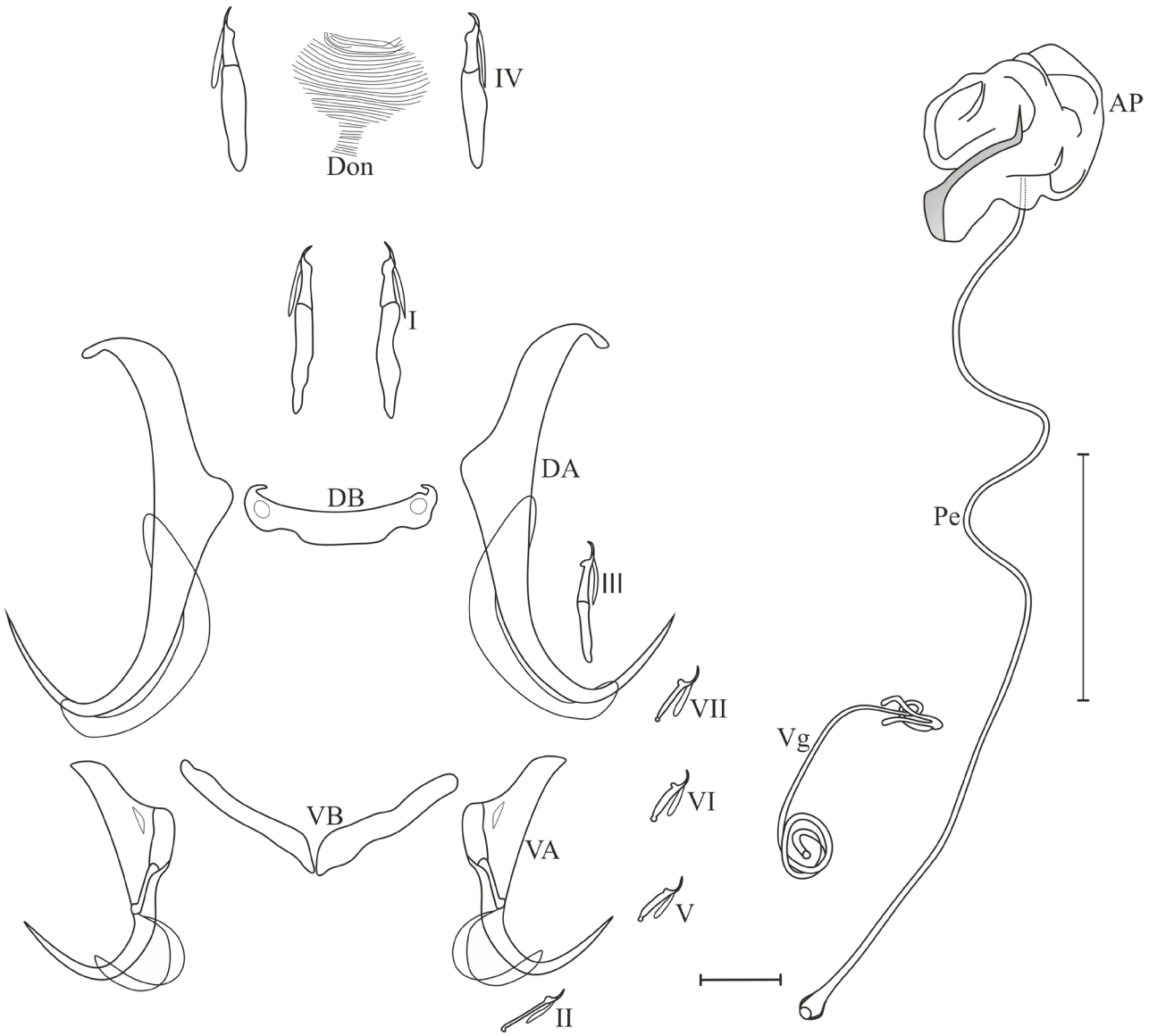

Figure 3. *Protoancylodiscoides edeaensis* sp. nov.: (DB) dorsal bar, (VB) ventral bar, (DA) dorsal anchor, (VA) ventral anchor, (I to VII) haptoral hooks, (Don) dorsal onchium, (AP) accessory piece, (Pe) penis, scale bar: 50 µm, (Vg) vagina, scale bar: 20 µm.

present in ancyrocephaline oncomiracidia (larval hook). They correspond to proximal subunit (= outer root +thumb+point) in Kritsky and Kulo (1999); medio-ventral hook pairs I and IV enlarged with thick and long shank; latero-dorsal hooks III with moderately developed shank; presence of dorsal structure in shape of flared amphora (onchuim). Male copulatory organ (MCO) consists of long tubular penis (average 249 µm) associated with complex accessory piece composed of single unit, round ends, presenting ridges and a crumpled protuberance, with grooves at distal portion of MCO. Vagina, slightly coiled (2 turns) at its base, ends in sclerotised structure.

The measurements of the parasite in toto, the haptoral and the copulatory sclerotised parts are shown in Table 1.

Etymology. *edeaensis* refers to locality where the type host was collected.

Remarks. *Protoancylodiscoides edeaensis* sp. nov. is close to *P. mansourensis* El-Naggar, 1987 and *P. chrysichthes* Paper-

Table 1. Measurements of *Protoancylodiscoides* spp. from *Chrysichthys* spp.

Specific Names	*P. edeaensis* sp. nov.	*P. yombai* sp. nov.	*P. mansourensis*	*P. chrysichthes*	*P. dibambaensis* sp. nov.	*P. ivoiriensis*
Hosts	*C. nigrodigitatus**	*C. nigrodigitatus**	*C. auratus**	*C. nigrodigitatus**	*C. nigrodigitatus**	*Cl. laticeps**
Type Locality	Sanaga river (Edéa)	Dibamba river (Douala)	Nile River (Mansoura, Egypt)	Togo	Dibamba River	Bagoué (Ivory coast)
Other locality	Dibamba river (Douala)	Sanaga river (Edéa)	–	–	–	–
Total length	1160 (808–1609, n = 20)	732 (524–1080, n = 5)	835 (710–1000)	637 (410–884, n = 29)	670 (507–1111, n = 16)	1093 (623–1429, n = 20)
Total width	136 (106–183, n = 20)	130 (98–171, n = 5)	187 (142–261	90 (73–115, n = 33)	132 (75–184, n=16)	215 (139–302, n=20)
Haptoral length	179 (117–225, n = 20)	–	99 (79–140, n = 29)	–	–	–
Haptoral width	182 (128–255, n = 20)	–	94 (74–127, n = 23)	–	–	–
Pharyngeal diameter	48 (37–64, n = 20)	–	30 (23–43, n = 35)	–	–	–
Peduncle length	19 (10–30, n = 20)	–	30 (23–43, n = 35)	–	–	–
Dorsal anchor						
a	93 (87–97, n = 20)	76 (75–78, n = 5)	88 (81–93)	64 (55–69, n = 10)	62 (57–65, n = 18)	61 (55–65, n = 20)
b	67 (64–70, n = 20)	54 (51–57, n = 5)	–	50 (44–56, n = 31	49 (45–52, n = 18)	50 (43–51, n = 20)
c	6 (5–7, n = 20)	5 (4–6, n = 5)	4 (4–5)	–	5 (4–6, n = 18)	3 (3–4, n = 20)
d	36 (33–40, n = 20)	31 (28–32, n = 5)	28 (25–32)	–	27 (24–35, n = 18)	28 (24–31, n = 20)
e	32 (29–40, n = 20)	23 (21–23, n = 5)	24 (22–25)	31 (27–36, n = 6)	27 (25–30, n = 18)	28 (23–31, n = 20)
Dorsal bar						
x	48 (45–53, n = 20)	38(36–39, n = 5)	45 (40–48)	41 (34–46, n = 6)	42 (38–47, n = 18)	29 (27–34, n = 20)
w	8 (6–9, n = 20)	6 (4–7, n = 5)	–	5 (4–7, n = 31)	6 (5–7, n = 18)	3 (2–4, n = 20)
Ventral anchor						
a	48 (46–51, n = 20)	34 (32–36, n = 5)	44 (39–47)	33 (29–38, n = 5)	34 (31–36, n = 18)	27 (24–28, n = 20)
b	41 (39–43, n = 20)	29 (27–31, n = 5)	–	31 (27–35, n = 31)	29 (27–32, n = 18)	23 (21–24, n = 20)
c	7 (6–9, n = 20)	5 (5–6, n = 5)	4 (3–4)	–	6 (4–8, n = 18)	7 (6–8, n = 20)
d	15 (13–17, n = 20)	10 (10–11, n = 5)	17 (16–19)	–	13 (11–15, n = 18)	16 (15–18, n = 20)
e	23 (22–25, n = 20)	15 (15–19, n = 5)	22 (19–24)	20 (17–22, n = 3)	20 (18–22, n = 18)	12 (9–14, n = 20)
Ventral bar						
x	41 (38–46, n = 20)	42 (39–44, n = 5)	41 (38–43)	45 (35–69, n = 15)	28 (26–31, n = 17)	29(27–34, n = 20)
w	6 (5–8, n = 20)	5 (4–5, n = 5)	–	4 (3–5, n = 31)	5 (4–5, n = 17)	3(2–4, n = 20)
Hook length (U)						
I	40 (34–43, n = 20)	35 (33–36, n = 5)	36 (32–35)	42 (38–45, n = 3)	23 (21–25, n = 18)	15–17
II	18 (16–19, n = 20)	16 (15–17, n = 5)	14 (13–16)	18 (17–19, n = 4)	19 (16–22, n = 15)	15–17
III	32 (29–33, n = 20)	27 (27–28, n = 5)	30 (28–32)	23 (20–26, n = 6)	20 (19–22, n = 18)	15–17
IV	39 (35–42, n = 20)	36 (34–40, n = 5)	34 (33–35)	30 (22–35, n = 4)	22 (20–25, n = 17)	15–17
V	16(15–18, n = 20)	15 (14–15, n = 5)	16 (14–17, n = 12)	–	15 (13–17, n = 18)	15–17
VI	16 (15–17, n = 20)	14 (14–15, n = 5)	16 (14–17, n = 12)	–	15 (13–16, n = 17)	15–17
VII	16 (14–17, n = 20)	14 (14–15, n = 5)	16 (14–17, n = 12)	–	15 (14–6, n = 17)	15–17
Medio-dorsal onchium						
L	32 (29–35, n = 20)	28 (20–35, n = 5)	33 (29–36)	–	–	–
l	29 (21–35, n = 20)	19 (15–23, n = 5)	33 (28–38)	–	–	–
Penis length	249(222–278, n = 20)	152 (136–168, n = 5)	325 (302–347)	255 (162–365, n = 5)	155(118–191, n = 17)	103(74–116, n = 20)
Vagina length	–	–	–	–	106(90–135, n = 3)	77(68–85.5, n = 5)
Diameter of vagina	14 (12–22, n = 20)	15 (13–16, n = 4)	10 (8–12, n = 10)	–	10(9–11, n = 2)	–

Cl= *Clarotes;* *=type host.

na, 1969 by the morphology of haptor sclerotised parts. It is distinguished from *P. mansourensis* and *P. chrysichthes* by: (1) size of some sclerotised parts, mainly: (i) dorsal anchor a = 93 (87–97) in *P. edeaensis* sp. nov. *vs* a = 88 (81–93) in *P. mansourensis* and a = 64 (55–69) in *P. chrysichthes*; b = 67 (64–70) in *P. edeaensis* sp. nov. *vs* b = 50 (44–56) in *P. chrysichthes* (ii) ventral anchor a = 48 (46–51) in *P. edeaensis* sp. nov. *vs* a = 33 (29–38) in *P. chrysichthes*;(2) penis length 249 (222–278) in *P. edeaensis* sp. nov. *vs* 325 (302–347) in *P. mansourensis*; (3) morphology of vagina: less coiled (2 turns) with a ridge-like

structure *vs* 4–5 turns at the base, and flared in the distal part for *P. mansourensis*, while it curls up and turns around at the distal part for *P. chrysichthes*.

Protoancylodiscoides yombai Bassock Bayiha, Bahanak & Bilong Bilong, sp. nov.

Fig. 4

https://zoobank.org/7CC0A832-309A-438F-8333-6CBA6B46EC0C

Type host and locality. *Chrysichthys nigrodigitatus* (Siluriformes: Claroteidae), the Sanaga River in Edéa (Cameroon), 3°47'43.25"N and 10°08'12.18"E.

Other locality. The Dibamba in Douala, 3°55'31"N, 9°40'21"E.

Infection site. Gill lamellae.

Type material. Holotype RMCA_VERMES_44350; Paratypes RMCA_VERMES_44351-44352.

Description based on five individuals. Dorsal anchors with long and thick inner root, ending by trunk-like structure, outer root quite non-existent, blade arched at its base but ending in point, thick filament covers middle section of blade. Dorsal bar in chevron, slightly curved, with hole at each extremity where small extension folds towards front face of bar. Ventral anchors, smaller than their dorsal counterparts, with narrow outer root shorter than inner one, lenticular fenestration at base of each inner root, hull and thick filament less sclerotised; blade with thin and short point. Ventral bar V-shaped made up of two arms joined medially. Presence of seven pairs of hooks in three types according to their shape, size and position. Latero-ventral hooks II, V, VI, VII of similar shape and size [i.e. thin, without shank (= distal subunit)], resemble those present in ancyrocephaline oncomiracidia (larval hook). They correspond to proximal subunit (= outer root +thumb+point) in Kritsky and Kulo (1999); medio-ventral hook pairs I and IV enlarged with thick and long shank; latero-dorsal hooks III with moderately developed shank; presence of dorsal structure in shape of elongated amphora with sclerification in its central part (onchuim). Presence in haptor of dorsal onchium longer than wide. Male copulatory organ consists of long tubular penis associated with accessory piece made up of two subunits: one as an irregular structure with ridges, and the second one a massive plate. Vagina presenting one coil at its base, turns around at its distal extremity which is in form of calyx.

The measurements of the parasite in toto, the haptor and the copulatory sclerotised parts are shown in Table 1.

Etymology. *yombai* refers to Mr. André Pierre Yomba for his invaluable contribution in fish collection.

Remarks. *Protoancylodiscoides yombai* sp. nov. is close to *P. edeaensis* sp. nov., *P. mansourensis* and *P. chrysichthes* by the morphology of ventral bar, ventral anchors, dorsal onchium and hooks. However, it differs from these species by: (1) morphology of vagina with a turn of whorl at distal part before calyx in *P. yombai* sp. nov., while well coiled at base in *P. mansourensis*, and looped (1 turn) in *P. chrysichthes*; (2) morphology of onchium, that of *P. yombai* sp.nov. is in shape of elongated amphora with sclerification in its central part while that of *P. edeaensis* sp.nov. is in shape of flared amphora; (3) the size of some sclerotised parts, mainly: (i) dorsal anchor a = 76 (75–78) *in P. yombai* sp. nov. *vs* a = 93 (87–97) *in P. edeaensis* sp. nov, a = 88 (81–93) *in P. mansourensis* and a=64 (55–69) *in P. chrysichthes*; (ii) dorsal bar x=38 (36–39) in *P. yombai* sp. nov. *vs* x = 48 (45–53) *in P. edeaensis* sp. nov, x = 45 (40–48) in *P. mansourensis* and x = 41 (34–46) in *P. chrysichthes*; (iii) ventral anchor x=34 (32–36) in *P. yombai* sp. nov. *vs* x = 48 (46–51) in *P. edeaensis* sp. nov and x = 44 (39–47) in *P. mansourensis*; (iv) penis length =152 (136–168) in *P. yombai* sp. nov. *vs* 249 (222–278) *in P. edeaensis* sp. nov, 325 (302–347) in *P. mansourensis* and 255 (162–365) in *P. chrysichthes*.

Protoancylodiscoides dibambaensis Bassock Bayiha, Bahanak & Bilong Bilong, sp. nov.

Fig. 5

https://zoobank.org/28E573E2-8C58-48A4-953A-E4738F1F64AC

Type host and locality. *Chrysichthys nigrodigitatus* (Siluriformes: Claroteidae), Dibamba River (Cameroon), 3°55'31"N and 9°40'21"E.

Infection site. Gill lamellae.

Type material. Holotype RMCA_VERMES_44345; Paratypes RMCA_VERMES_44346-44349.

Description based on 18 individuals. Dorsal anchors with long and thick inner root ending less thick and curved distal extremity, outer root with shallow dent, blade arched and ending by strong point, thick filament covers middle of blade. Dorsal bar in chevron slightly curved with rounded extremities each pierced with circular hole. Ventral anchors, smaller than their dorsal counterparts, have an outer root narrower, off-center triangular fenestration at the base of each inner root, hull, thick and slightly sclerotised filament covers the base of the blade which ends in a thin and short point. Ventral bar V-shaped, consisting of two arms joined medially. Presence of seven pairs of hooks in three types according to their shape, size and position. Latero-ventral hooks II, V, VI, VII of similar shape and size [i.e. thin, without shank (= distal subunit)], resemble those present in ancyro-

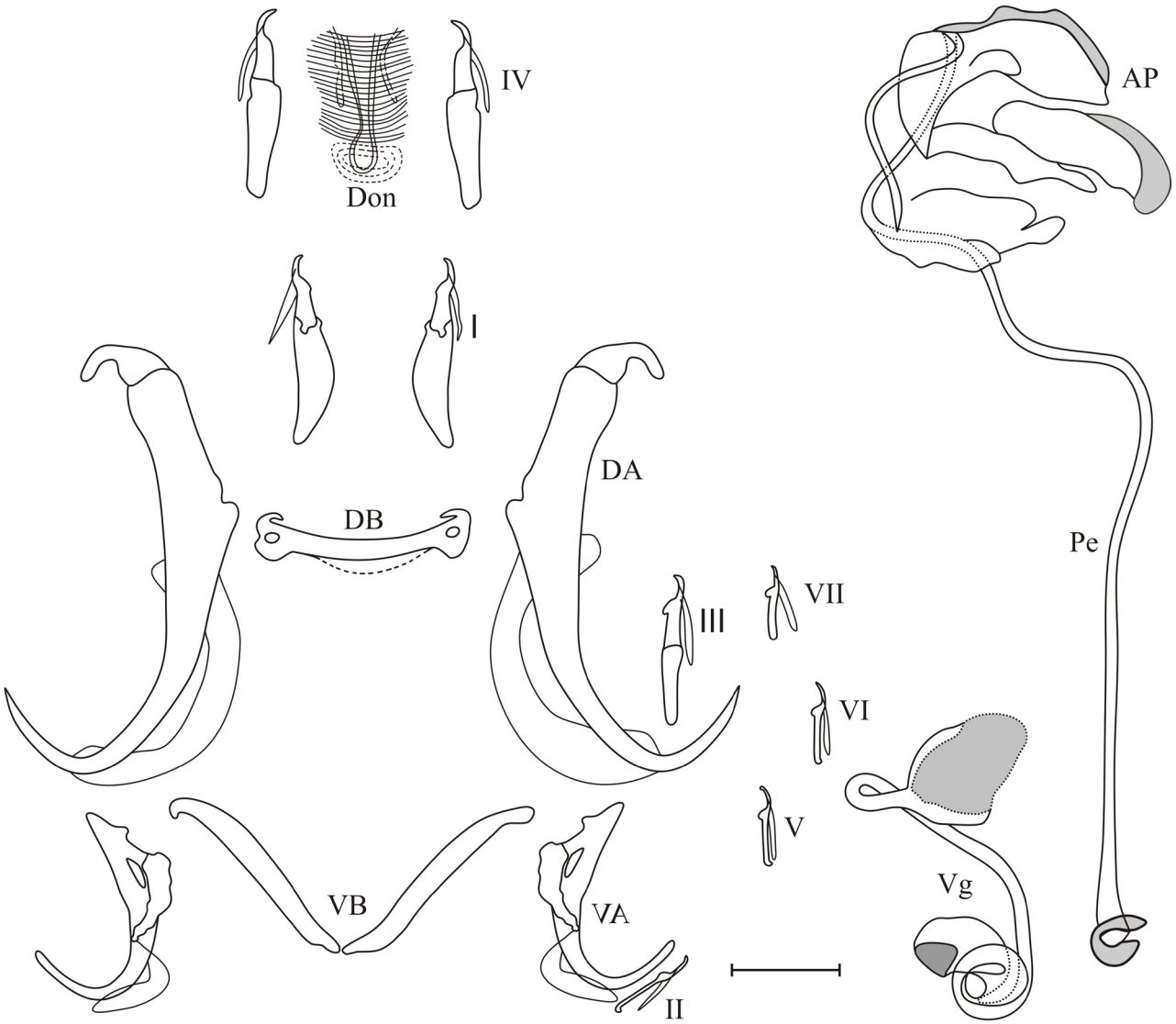

Figure 4. *Protoancylodiscoides yombai* sp. nov.: (DB) dorsal bar, (VB) ventral bar, (DA) dorsal anchor, (VA) ventral anchor, (I to VII) haptoral hooks, (Don) dorsal onchium, (AP) accessory piece, (Pe) penis, (Vg) vagina. Scale bar: 20 µm.

cephaline oncomiracidia (larval hook). They correspond to proximal subunit (= outer root +thumb+point) in Kritsky and Kulo (1999); medio-ventral hook pairs I and IV enlarged with thick and long shank; latero-dorsal hooks III with moderately developed shank; presence of dorsal pouch-like structure (onchuim) wider than long. Male copulatory organ consists of a long tubular penis (228 µm) associated with accessory piece, composed of two superimposed subunits, of unequal thickness, forming a body with their crumpled distal parts. The sclerotised vagina is coiled at its base and flared in the distal part.

The measurements of the parasite in toto, the haptor, and the copulatory sclerotised parts are shown in Table 1.

Etymology. *dibambaensis* refers to the River Dibamba where fish hosts were collected.

Remarks. By the lack of the onchium and morphology of some sclerotised parts of the haptor, mainly ventral bar and dorsal anchor, *Protoancylodiscoides dibambaensis* sp. nov. is close to *P. ivoiriensis* Bouah, N'Douba & Pariselle, 2021 from *Clarotes laticeps* (Rüppell, 1829). However, it differs from this species by the morphology of: (1) the dorsal bar: presence of fenestrations and folds at the extremities

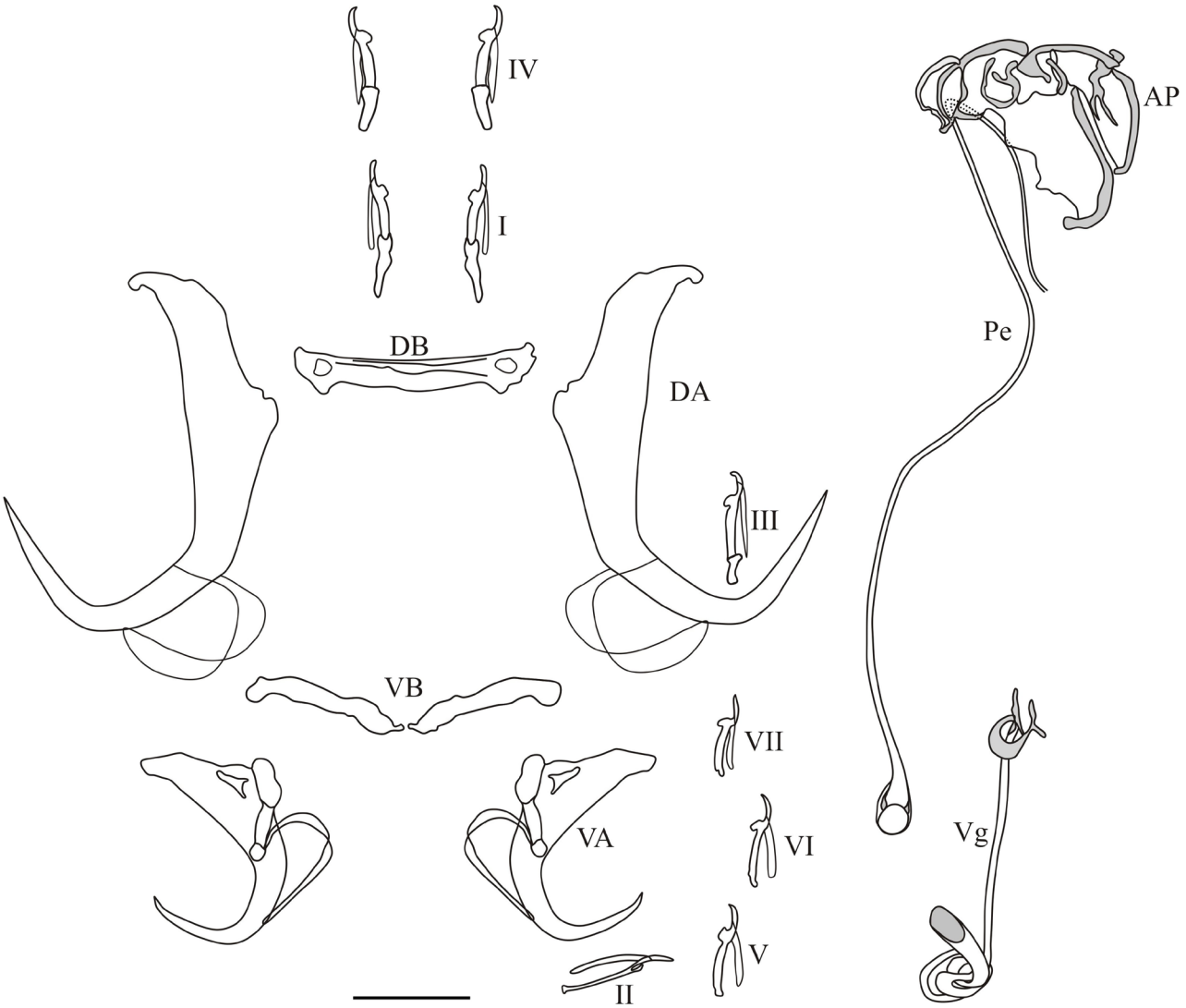

Figure 5. *Protoancylodiscoides dibambaensis* sp. nov.: (DB) dorsal bar, (VB) ventral bar, (DA) dorsal anchor, (VA) ventral anchor, (I to VII) haptoral hooks, (AP) accessory piece, (Pe) penis, (Vg) vagina. Scale bar: 20 µm.

in *P. dibambaensis* sp. nov. *vs* absence of these features in *P. ivoiriensis*, (2) the ventral anchor: presence of a fenestration at each extremity in *P. dibambaensis* sp. nov. *vs* lack of the fenestration in *P. ivoiriensis*; (3) the hooks: all hooks keep the larval form (ancyrocephaline oncomiracidia) in *P. ivoiriensis* unlike only hook pairs II, V, VI and VII have retained the larval form in the new species. *Protoancylodiscoisdes dibambaensis* sp. nov. also differs from *P. ivoiriensis* by the size of: (1) the penis length = 155 (118–191) *vs* 103 (74–116); (2) the dorsal bar x = 42 (38–47) *vs* 29 (27–34); (3) the ventral anchor a=34 (31–36) *vs* 27 (24–28).

DISCUSSION

The description of *P. edeaensis* sp. nov., *P. yombai* sp. nov. and *P. dibambaensis* sp. nov. brings the number of species in the genus *Protoancylodiscoides* up to 14. These species parasitise fish from Claroteidae, precisely from *Chrysichthys* and *Clarotes* (see Paperna 1969, El-Naggar 1987, N'Douba 2000, Bassock Bayiha et al. 2016, 2017, Bouah et al. 2021), also from Malapteruridae i.e. *Malapterurus* (see Bilong Bilong et al. 1997, N'Douba and Lambert 1999). This parasitism corroborates the close phylogenetic relationship between

species of both Claroteidae and Malapteruridae (Sullivan et al. 2006, Schedel et al. 2022).

In the current work, *P. edeaensis* sp. nov., *P. yombai* sp. nov., and *P. dibambaensis* sp. nov. collected from *C. nigrodigitatus*, although distinguishable from each other, revealed morphologically close to: *P. chrysichthes* from *C. nigrodigitatus*, *P. mansourensis* from *C. auratus*, and *P. ivoiriensis* from *C. laticeps*. However, molecular data are still necessary to better elucidate the phylogenetic relationship between these monogenean species.

Protoancylodiscoides spp. known from the gills of *Clarotes* and *Chrysichthys* fish are characterised by absence or presence of a single onchium in the haptor (Bouah et al. 2021), while those found in *Malapterurus* fish are remarkable by the presence of two onchia (one ventral and one dorsal) in the haptor (Bilong Bilong et al. 1997, N'Douba and Lambert 1999). So far, no host genus harbors all three morphotypes (absence, presence of one or two onchia in the haptor) of *Protoancylodiscoides*. We agree with Bouah et al. (2021) who recently argued that "only a genetic study will allow to determine the ancestral haptoral form, and to reveal the co-evolutionary scenario of *Protoancylodiscoides* species and its hosts.

Hooks I, III and IV in *P. ivoiriensis* lack subunit of the shank unlike the hooks of the other *Protoancylodiscoides*. It is important to know whether these hook morphological differences relate to the adaptive character of the haptor and infer all the evolutionary consequences for new hosts. According to Šimková et al. (2001, 2002, 2006), the morphology of the attachment organ, the haptor, is supposed to play an important role in parasite specialization and adaptation to host species.

Monogeneans as strictly hosts specific organisms (Šimková et al. 2007, Pariselle et al. 2011) may provide information on their hosts' biogeography and/or phylogeny. It is worth to note that *C. laticeps* and *C. nigrodigitatus* live in sympatry in the Bénoué basin (Lévêque et al. 1992, Paugy et al. 2017), and to study the parasite fauna of both host species in that hydrographic system where parasite transfers could be promoted. *Protoancylodiscoides dibambaensis* sp. nov. and *P. edeaensis* sp. nov. parasitise only *C. nigrodigitatus*. Therefore, in both two study localities, these species appear to be oioxenous (Euzet and Combes 1980). All species of *Protoancylodiscoides* already described (Paperna 1969, El-Naggar 1987, Bilong Bilong et al. 1997, N'Douba and Lambert 1999, Bassock Bayiha et al. 2016, 2017, Bouah et al. 2021) as oioxenous or mesostenoxenous (Caira et al. 2003), could be useful tools to (1) identify their hosts and consequently to better manage stocks in fish farming, and (2) study their biogeography.

The absence of *P. dibambaensis* sp. nov. on *C. nigrodigitatus* from the Sanaga River needs to be verified, because its presence on the same host species from the Dibamba River (in Douala) raises the question of ichthyofauna exchange: do these two rivers interchange their fauna?

In the current work, the *Protoancylodiscoides* species richness was six in the Dibamba and five species in the lower course of the Sanaga River *vs* only two species (*P. valentini* and *P. sanagaensis*) in middle and upper courses (Bassock Bayiha et al. 2017).

In the case of trematodes, Blasco-Costa et al. (2013) revealed a decreasing number of parasite species per host as one moves upstream from the river mouth, and wonder whether it is a common river pattern. Data from the present work and those acquired by Bassock Bayiha et al. (2017) reveal a longitudinal gradient concerning the species richness of *Protoancylodiscoides* parasites of *C. nigrodigitatus* from upstream to downstream of the Sanaga river. This monogenean species richness decreases from downstream to upstream. This could be due to: the current speed of the constant unidirectional water flow causing (in the upstream section) drift of juvenile parasitised fish to the downstream (Blasco-Costa et al. 2013). In addition, we suggest that the Edéa falls, representing an important fish dispersion barrier from downstream to upstream (Bassock Bayiha et al. 2017), favour the increase of the host population density. Certainly, other factors may influence this longitudinal gradient of the parasite (*Protoancylodiscoides*) species richness in the Sanaga River.

This study contributes to advancing knowledge of the diversity of *Protoancylodiscoides* by adding three new species to the genus. Other studies are underway in the Sanaga basin and in other hydrographic basins of Cameroon to better understand the biogeography of these Monogeneans, and to clarify the phylogenetic relationships between species of *Protoancylodiscoides* on the one hand and their relationships with other dactylogyrids of Siluriformes on the other hand.

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