

New species of *Doliodrillus* and other Limnodriloidinae (Oligochaeta, Tubificidae) from Hainan and other parts of the north-west Pacific Ocean

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Thirteen species of Limnodriloidinae (Tubificidae) are recorded from marine and brackish-water habitats of Hainan Island, southern China, including 11 species of *Doliodrillus* and two species belonging to *Limnodriloides*. Eight species are new to science: *D. bisaccus* sp. n. (types from Japan), *D. longidentatus* sp. n. (types from Hong Kong), *D. ciliatus* sp. n., *D. adiacens* sp. n., *D. fibrissaccus* sp. n. (also from Fiji), *D. brachyductus* sp. n., *D. bidolium* sp. n. and *D. chinensis* sp. n. In addition, material of *D. puertoricensis* Erséus and Milligan, 1988, from New Caledonia, is briefly described. This study shows that *Doliodrillus* is unexpectedly species-rich in Asian seas, in particular, around Hainan. Including an unnamed species from this island, the known members of this genus increase from three to 12.

KEYWORDS: *Doliodrillus*, Limnodriloidinae, Oligochaeta, taxonomy, new species, southern China, Japan, Fiji, New Caledonia.

Introduction

The marine oligochaetes of the South China Sea have been rather well studied inasmuch as a diverse fauna of these worms has been described from Hong Kong and its close surroundings in southern China (Erséus, 1984, 1990a, 1992a, 1992b, 1997a; Sundberg *et al.*, 1992; Erséus and Diaz, 1997). The Hong Kong area, however, is greatly impacted by the activities of a multi-million human population, including the effects of heavy pollution, land reclamation and other physical removal of natural habitats, and it can be assumed that these studies cover only a part of the oligochaete species present along the Chinese coasts of the South China Sea. To broaden the basis of our knowledge, the present authors therefore made a collecting effort for marine and brackish-water oligochaetes on the island of Hainan in southernmost China, in March 2000. The Hainan coastline is less disturbed than that of the Hong

Kong region, and it extends through a slightly more tropical range of latitudes. Sampling was done in the vicinities of the two cities of Sanya (in the south) and Haikou (in the north), and special attention was paid to the oligochaete fauna of mangrove forests (see Erséus, 2002).

In a first account (Wang and Erséus, 2001), a number of species belonging to the tubificid subfamily Phallodrilinae, found in this material, were reported. In the present paper, we describe the members of the Limnodriloidinae (Tubificidae) encountered in Hainan, including eight new species of *Doliodrillus* Erséus, 1984. In this study also, we include material of *Doliodrillus* from Japan, Hong Kong, Fiji and New Caledonia.

Material and methods

All specimens from Hainan were collected from intertidal and subtidal sediments. The samples were repeatedly stirred with habitat water, and the organic suspensions decanted into a fine-mesh sieve (250–300 μm). Some samples were treated by the wet-funnel method (O'Connor, 1955; Healy and Rota, 1992). Live oligochaetes were sorted under dissecting microscopes. Only sexually mature specimens were fixed in Bouin's fluid. After about 1 day in the fixative, they were transferred into 70% ethanol. Worms were stained with paracarmine, cleared in xylene and mounted whole in Canada balsam.

The type specimens of *Doliodrillus bisaccus* sp. n. and *D. longidentatus* sp. n were collected in Japan by Dr K. Ogawa and in Hong Kong by C. Erséus, respectively; the Hong Kong material was previously identified as *D. tener* (Erséus, 1990a). Specimens of *D. longidentatus* from Hong Kong were also provided by A. Mackie and G. Oliver. Additional material of *D. fibrisaccus* sp. n. and new specimens of *D. puertoricensis* Erséus and Milligan, 1988 were collected by C. Erséus from Fiji and New Caledonia, respectively. Type material and other reference specimens in the Swedish Museum of Natural History (SMNH), Stockholm, were re-examined.

Holotypes, some paratypes and other reference specimens are deposited in the Institute of Hydrobiology (IHB), Chinese Academy of Sciences (CAS), Wuhan; the remaining material, including type specimens of *Doliodrillus bisaccus* sp. n. and *D. longidentatus* sp. n., is lodged in SMNH.

When not stated otherwise, material listed in the Systematic account, measurements, and drawings refer to fixed, whole-mounted and slightly compressed specimens.

Abbreviations used in the figures

a, atrium; aa, atrial ampulla; ad, atrial duct; at1, first 'lobe' of atrial ampulla; at2, second 'lobe' of atrial ampulla; bs, blind sac of atrial duct; cs, copulatory sac; ead, ectal atrial dilatation; ed, efferent duct of atrium; mp, male pore; ncc, nuclei clusters close to prostatic pad; nco, nuclei cluster opposite to prostatic pad; od, oesophageal diverticulum; ppd, prostatic pad; pr, prostate gland; s, spermatheca; sf, sperm funnel; sp, spermathecal pore; sz, spermatozeugma; vd, vas deferens.

List of stations in Hainan

The following stations were sampled by the authors; omitted are sites yielding no Limnodriloidinae. The species of the subfamily encountered are listed for each station.

Station SY00-2A. Main flow of Sanya River, at children's park in middle of

Sanya City, 18°15.34'N, 109°30.25'E, soft organic sediment, 14 March 2000; *Doliodrilus tener*, *D. diverticulatus*.

SY00-6. Fish pond at road to Teng Hai, E of Sanya City, 18°17'N, 109°44'E, brackish-water, coarse sand with black mud, 16 March 2000; *Doliodrilus bisaccus* sp. n., *D. fibrisaccus* sp. n., *D. brachyductus* sp. n., *D. bidolium* sp. n., *D. chinensis* sp. n.

SY00-8A. The West Coral Islet (Ximaozhou) (W of Sanya City), reef flat at NW side of island close to tourist resort, 18°14.56'N, 109°21.97'E, barely subtidal, poorly oxygenated coarse sand with smell of H₂S, 17 March 2000; *Limnodriloides macinnesi*.

SY00-9C. Lower end of estuary SE of Teng Qiao Town, 18°23.18'N, 109°45.71'E, lower intertidal, silty medium sands with black mud, 18 March 2000; *Doliodrilus tener*, *D. adiacens* sp. n., *D. fibrisaccus* sp. n., *Limnodriloides parahastatus*.

SY00-10. Brackish-water shrimp pond connected with estuary SE of Teng Qiao Town, 18°22.93'N, 109°45.57'E, lower intertidal, medium to coarse sand with black mud and filamentous algae, 18 March 2000; *Doliodrilus fibrisaccus* sp. n.

HU00-14A. Dong Zhai Harbour nature reserve E of Haikou, edge of mangrove channel immediately N of dock located at end of concrete walkway from off nature reserve gate, 19°57.00'N, 110°34.01'E, subtidal, about 1 m, mud, 21 March 2000; *Doliodrilus tener*.

HU00-14B. Same as HU00-14A, but under branches of mangrove trees N of dock, lower intertidal, clay and mud, 21 March 2000; *Doliodrilus longidentatus* sp. n., *D. ciliatus* sp. n.

HU00-19A. Haikou City, bay (surrounded by wall) in Wan Lu Yuan Park, 20°02.10'N, 110°18.66'E, subtidal, mud with some sand, 22 March 2000; *Doliodrilus tener*, *D. sp.*, *D. diverticulatus*.

Systematic account

Family TUBIFICIDAE Subfamily LIMNODRILOIDINAE

Genus *Doliodrilus* Erséus, 1984

Remarks. This genus was established by Erséus (1984) with *D. tener* Erséus, 1984 from Hong Kong as type species, and then expanded to accommodate *D. diverticulatus* Erséus, 1985 from Saudi Arabia (Erséus, 1985). Later, a third species, *D. puertoricensis* Erséus and Milligan, 1988, was added from Puerto Rico (Erséus and Milligan, 1988). In this paper, we describe eight new species belonging to this genus, but some of them do not conform completely with the previous diagnosis, which thus needs to be revised, and this will be done in a more comprehensive study of the subfamily Limnodriloidinae elsewhere. As a rule, the members of *Doliodrilus* are characterized by: (1) a modified, enlarged, tract of oesophagus in IX (sometimes involving also a part of VIII) bearing a reticulate blood plexus (see Gustavsson and Erséus, 1999); (2) distinct prostatic pads, each restricted to a limited region of the atrial ampulla (see Erséus, 1982); (3) weakly granulated atrial ducts (see Erséus, 1982), generally provided with blind sacs or ectal dilatations, and terminating in simple male pores; (4) large, deeply staining, nucleus-like bodies in the prostate glands of some species, their true nature being unknown; and (5) vestibules at the ectal orifices of the spermathecal ducts.

Doliodrilus tener Erséus, 1984
(figure 1)

Doliodrilus tener Erséus, 1984: 159–160, figure 15; Erséus, 1990a (*partim*): 287–288, figure 11A, B, E–G, I, J; Erséus *et al.*, 1990: 113, figure 2K; Erséus and Hsieh, 1997: 100–101.

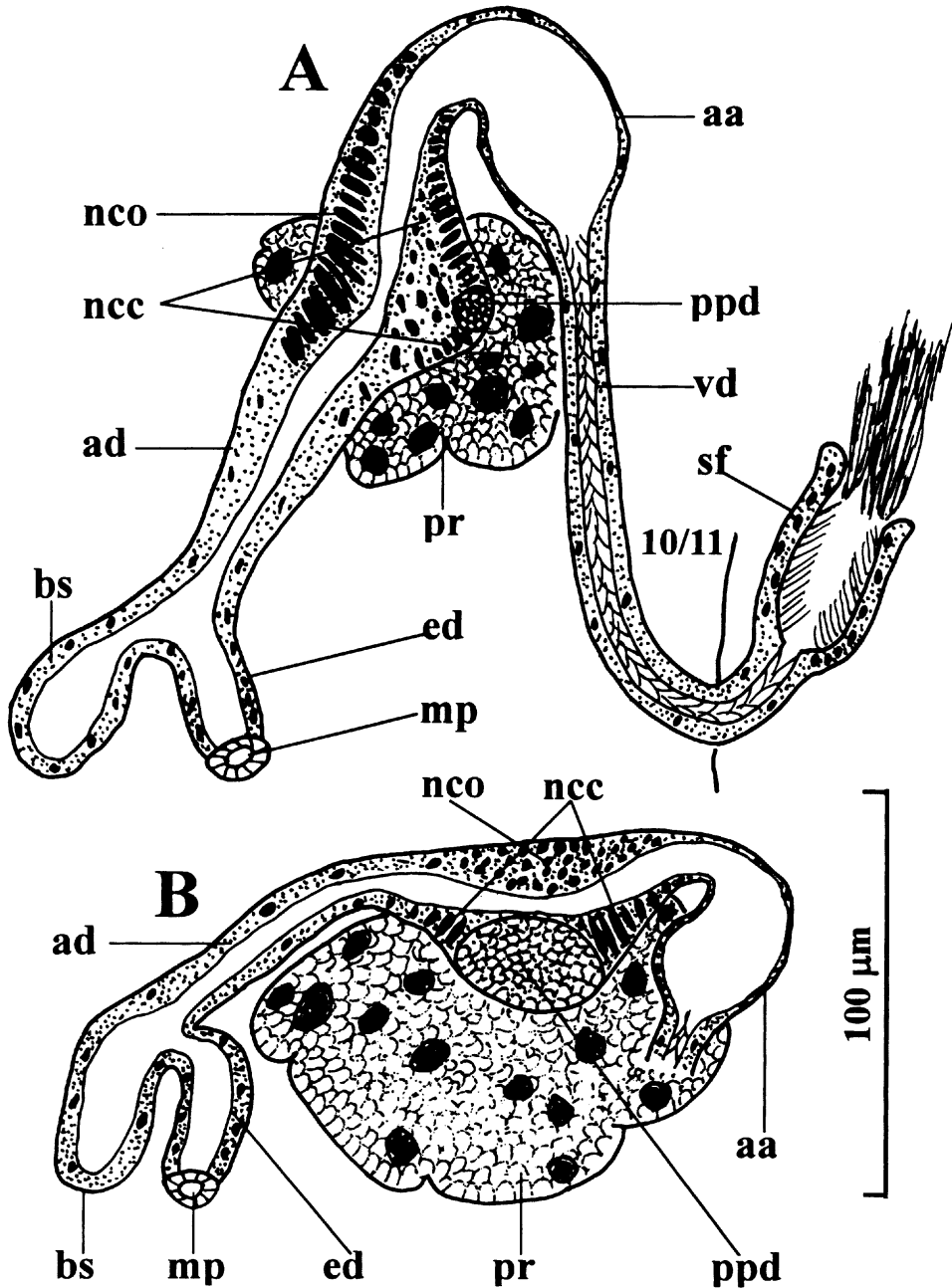


FIG. 1. *Doliodrilus tener* Erséus, 1984. Male ducts of two specimens, with triangular (A) or hemispherical (B) prostatic projections, respectively.

New material. IHB HANA2000003b–e, HANA2000017e, HANA2000022a–e, HANA2000029c–f, 14 specimens: four from SY00-2A, one from SY00-9C, five from Station HU00-14A, four from HU00-19A. SMNH Main Coll. 43665–43677, 13 specimens: three from SY00-2A, seven from HU00-14A, three from HU00-19A.

Brief description of new material. Six complete specimens 5.1–9.8 mm long, 28–45 segments. Diameter at XI about 0.4 mm. Prostomium usually conical. Clitellum extending over XI–XII. Chaetae 50–75 μm long, about 2.5 μm thick, with upper teeth 1–1.5 times as long as, and thinner than or as thick as, lower; two to five per bundle anteriorly, one to three per bundle in post-clitellar segments. Chloragogen cells from VI onwards. Oesophagus in IX barrel-shaped, thick-walled and granulated, with or without chloragogen cells; semi-embedded blood plexus permeating dorsal region, with regular transverse vessels and less regular longitudinal ones. Vasa deferentia (figure 1A: vd) about 135 μm long, 12–19 μm wide. Atria totally 200–220 μm long, 14–36 μm wide; ental end of atrial ampullae thin-walled and distinctly dilated; ventral projections on ampullae either (1) triangular (figure 1A), each with small (only 10–17 μm long) prostatic pad (ppd) at bottom, and with numerous spindle-shaped nuclei (ncc) along both sides of pad (especially ental to pad), or (2) hemispherical (figure 1B), with large (29–34 μm long) prostatic pad (ppd), and with dense, but smaller patches of slender nuclei (ncc) around pad. Dense cluster of nuclei also present in dorsal wall of ampulla opposite to prostatic pad; these nuclei slender and regularly arranged when ventral projection triangular (figure 1A: nco), but oval and less regular when projection hemispherical (figure 1B: nco). Prostate glands (figure 1A, B: pr) usually medium to large, sometimes small, with small nuclei and large nucleus-like bodies, latter oblong to round, maximally 12 μm long, 11 μm wide. Atrial ducts (figure 1A, B: ad) each with (1) posterior blind sac (bs), 25–50 μm long, 15–30 μm wide, and (2) efferent duct (ed), 25–35 μm long, 19–27 μm wide. Sperm sac in one to five segments within IX–XIII, when developed at all. Egg sac in one to three segments within XI–XIII, when developed. Spermathecal ducts 45–95 μm long, 24–44 μm wide, with ectal vestibules; ampullae 85–175 μm long, 30–95 μm wide, with sperm arranged in bundles or masses in lumina.

Remarks. This species was originally described from Hong Kong (Erséus, 1984). In 1990, Erséus reported it from Hong Kong again, noting some morphological variation, but a form with unusually long upper teeth on the chaetae is now regarded as a separate taxon (see *D. longidentatus* sp. n. below). The other known distributional areas of *D. tener* are Qingdao (Erséus *et al.*, 1990) and Taiwan (Erséus and Hsieh, 1997).

The most prominent character of *D. tener*, not specifically noted in the previous descriptions, is the conspicuous thickening of the dorsal wall opposite to the prostatic pad in the atrium, and the clusters of nuclei in this wall and around the pad. We observed this character in all the material from Hainan, as well as in numerous old specimens from Hong Kong [treated by Erséus, 1984, 1990a (*partim*)]. However, there are two different appearances of the ventral projections on the atria; they are either triangular (figure 1A) or hemispherical (figure 1B) (see above description). In the former state, the small prostatic pads seem to have discharged secretion into the atria, and the nuclei around the pads are widely distributed. In the latter state, the large pads appear to be full of secretion, and the nuclei are more restricted in distribution.

The prostate glands were stated to be small in the Hong Kong material (Erséus, 1984, 1990a), but a re-examination shows that the glands in the specimens from

Hong Kong and Taiwan (Erséus and Hsieh, 1997), as well as in the new material, vary considerably, i.e. from small to large.

Distribution and habitat. Known only from China [Hainan (new record), Hong Kong, Jiaozhou Bay (at Qingdao), Taiwan]. Brackish-water, intertidal and subtidal soft mud and muddy sand.

Doliodrilus bisaccus sp. n.
(figure 2)

Holotype. SMNH Type Coll. 5457, whole-mounted specimen.

Type locality. Japan, Honshu, Mie Prefecture, Gokasho Bay, brackish-water; 16 May 1990, coll. K. Ogawa.

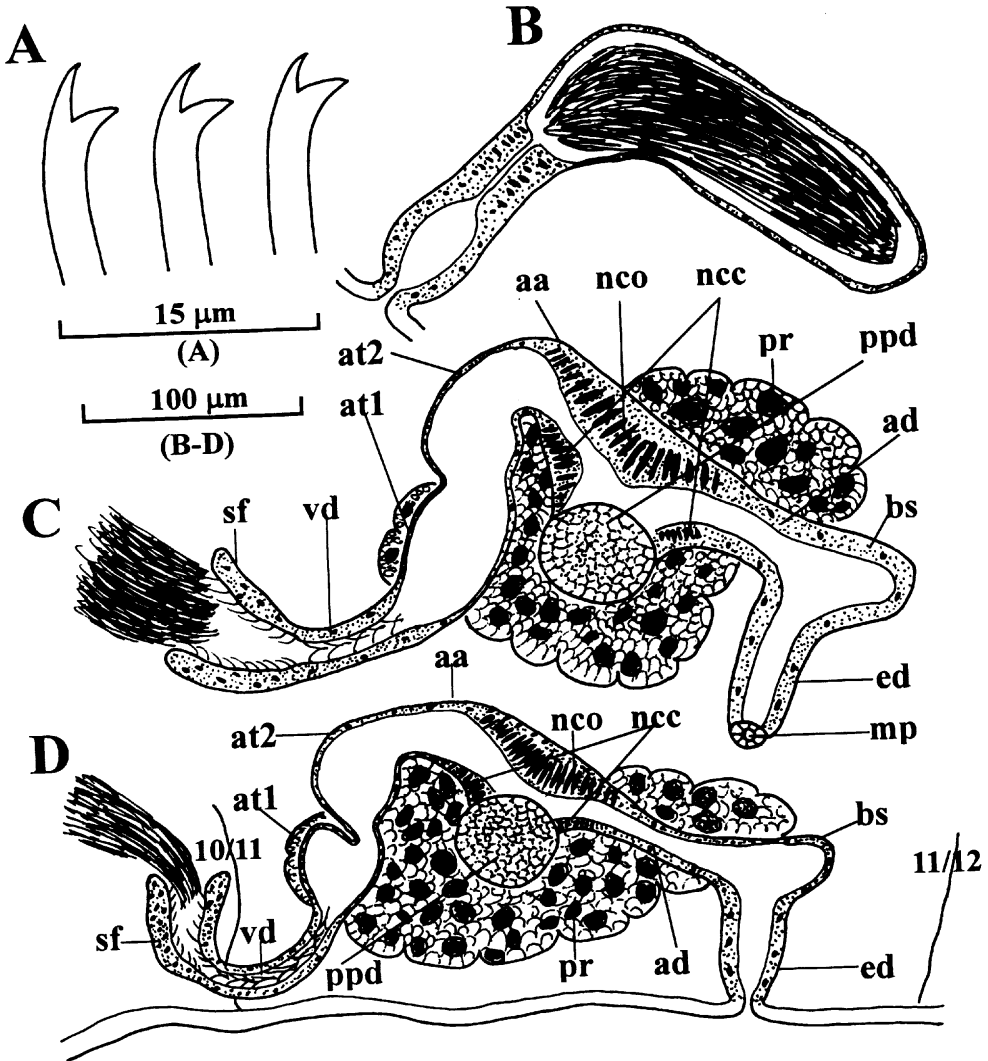


FIG. 2. *Doliodrilus bisaccus* sp. n. (A) Chaetae; (B) spermatheca; (C, D) male ducts of two specimens.

Paratypes. SMNH Type Coll. 5458–5460, three specimens from type locality.

Other material. IHB HANA2000009a1, one specimen from Hainan Island, Station SY00-6.

Etymology. The specific name *bisaccus* is Latin for ‘with two sacs’, and refers to the bilobed atrial ampullae, a feature unique within the genus.

Description of type material. Two complete specimens, holotype 9.7 mm with 43 segments, one paratype 8.4 mm with 41 segments. Diameter at XI 0.3–0.5 mm. Prostomium usually conical. Clitellum well developed over XI–XII. Chaetae bifid, with upper teeth more or less as long as, and thinner than, or sometimes as thick as, lower (figure 2A). Chaetae 45–60 μm long, about 2.5 μm thick; (zero) one to two (three) per bundle anteriorly, zero to two per bundle in post-clitellar segments. Ventral chaetae absent in XI. Male pores, paired in line with ventral chaetae in posterior part of XI (figure 2B). Spermathecal pores paired in line with ventral chaetae in anterior part of X.

Pharyngeal glands well developed in IV–V. Chloragogen cells from VI onwards. Oesophagus in IX barrel-shaped, thick-walled and granulated, without chloragogen cells; semi-embedded blood plexus permeating entire region, with regular transverse vessels and less regular longitudinal ones.

Male genitalia (figure 2C, D) paired. Vas deferens (figure 2C, D: vd) short and wide, about 70 μm long, 19–22 μm wide, entering atrium apically. Ental part of atrial ampulla bilobed, thin-walled and dilated; lobes separated by constriction. First ‘lobe’ of ampulla (figure 2C, D: at1) conical or oval, 35–65 μm long, maximally 39–53 μm wide. Second ‘lobe’ oval (at2), 35–50 μm long, maximally 39–44 μm wide. Ectal part of atrial ampulla more duct-like, thick-walled, with numerous slender nuclei close to (figure 2C, D: ncc) and opposite to (nco) prostatic pad. This part 150–155 μm long, 16–48 μm wide. Prostatic pad (figure 2C, D: ppd) round, 46–48 μm long, ventrally attached to middle of duct-like part of atrial ampulla (aa), bulging out from atrium. Prostate gland (figure 2C, D: pr) large, with small nuclei and large nucleus-like bodies, latter oblong or round, maximally 16 μm long, 15 μm wide. Atrial duct (figure 2C, D: ad) with (1) posterior blind sac (bs), 25–50 μm long, 15–48 μm wide, and (2) efferent duct (ed), 45–55 μm long, 31–48 μm wide, opening directly to exterior through simple pore. Sperm sac in IX–XII, or XI–XII. Egg sac in XII–XIII or absent. Spermathecae (figure 2B) large; ducts 75–105 μm long, 36–48 μm wide, with ectal vestibules; ampullae oblong, thin-walled, 145–195 μm long, 50–75 μm wide, with sperm masses in lumina.

Brief description of specimen from Hainan. Specimen complete, 5 mm long, 39 segments. Chaetae 45–55 μm long, about 2.5 μm thick, bifid, with equal teeth; one to two (three) per bundle anteriorly, one to two per bundle in post-clitellar segments. Male pores posterior to middle of XI. Male ducts somewhat twisted and difficult to make out. Spermathecae with oblong ampullae, but without sperm; specimen appears pre-copulatory.

Remarks. This species is easily distinguished from all its congeners by its bilobed atrial ampullae, and low number of chaetae; latter usually no more than two per bundle or even absent. The atria have dorsal thickenings and clusters of slender nuclei around the prostatic pads, as well as blind sacs, suggesting a close relationship to *D. tener*. In the new species, however, the vasa deferentia are shorter than those of the latter, and the prostatic pads are situated at mid-point of the atrium, as opposed to the more ental location in *D. tener*.

Although not all its features were clearly seen, the specimen from Hainan has

