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Records of Naididae and Lumbriculidae (Clitellata) from Tibet, China, with description of a new species of *Nais*

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Abstract

The Tibetan Plateau is considered to have a unique fauna of fish and invertebrates. However, little taxonomic work has been conducted on the aquatic Oligochaeta of Tibet, China. Based on the surveys of rivers and lakes in this region between 2010 and 2011, we recorded 25 species of oligochaetes belonging to 2 families and 15 genera. This paper provides an overview of the species composition of different waterbodies, the description of one new species, *Nais longidentata* **sp. n.**, and re-descriptions of four previously described species. Hitherto, 30 species of aquatic oligochaetes have been recorded from Tibet. The oligochaete fauna is similar to that of the Holarctic, but has several endemic elements.

Key words: Aquatic Oligochaeta, new species, *Nais*, Tibet, China

Introduction

Freshwater oligochaetes have been studied in China for almost one hundred years (Chen 1940; Wang & Cui 2007). Altogether 117 species, representing 7 families and 47 genera have been recorded. Initial research was mainly focused on eastern and central China (Wang & Cui 2007), with only scant research on southwest China, including Tibet. The Tibetan Plateau is considered as one of the global biodiversity hotspots for its unique natural environment (Li & Fang 1999), which accounts for the rich occurrence of endemic species of various taxa in this region (Chiang *et al*. 1983; Cao & Zhu 1988; Chen & Chen 2010). The history of taxonomic work on oligochaetes in Tibet has been reviewed in He *et al*. (2012) and Peng *et al*. (2014).

Between 2010 and 2011, we carried out an investigation of oligochaetes in Tibet, sampling a wide range of waterbodies, including rivers, lakes and wetlands, with the aims of collecting new species and obtaining a better understanding of the distribution patterns across a range of different habitats. Altogether, 25 species belonging to 2 families and 15 genera were identified in these surveys, including two species new to science, *Tubifex conicus* and *Isochaetides palmatus*, described in He *et al*. (2012). This paper gives an overview of the species found in the different waterbodies, with the aim of providing useful baseline data for future studies. We further describe one additional new species of *Nais*. References in the species section are restricted to those dealing with records and descriptions from China.

Description of sampling sites

Sixty-two sites were sampled from six regions, such as the mainstem of the Yarlung Zangbu River, Lhasa River, Niyang River, Lake Yamzhao Yumco, Lake Namco and Lalu Wetland in Tibet (Fig. 1). At each site a range of physical parameters were measured, including water temperature (WT, ºC), dissolved oxygen (DO, mg/L), pH, and conductivity (Cond, μS/cm) at the sampling date (Table 1). Water temperature was measured with a waterproof

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digital thermometer (SATO SK-250WP-N); further devices used were YSI DO200 dissolved oxygen meter, YSI pH 100 pH meter, and YSI EC300 conductivity meter. Measurements are listed in the Table 1. Additional site information is provided below.

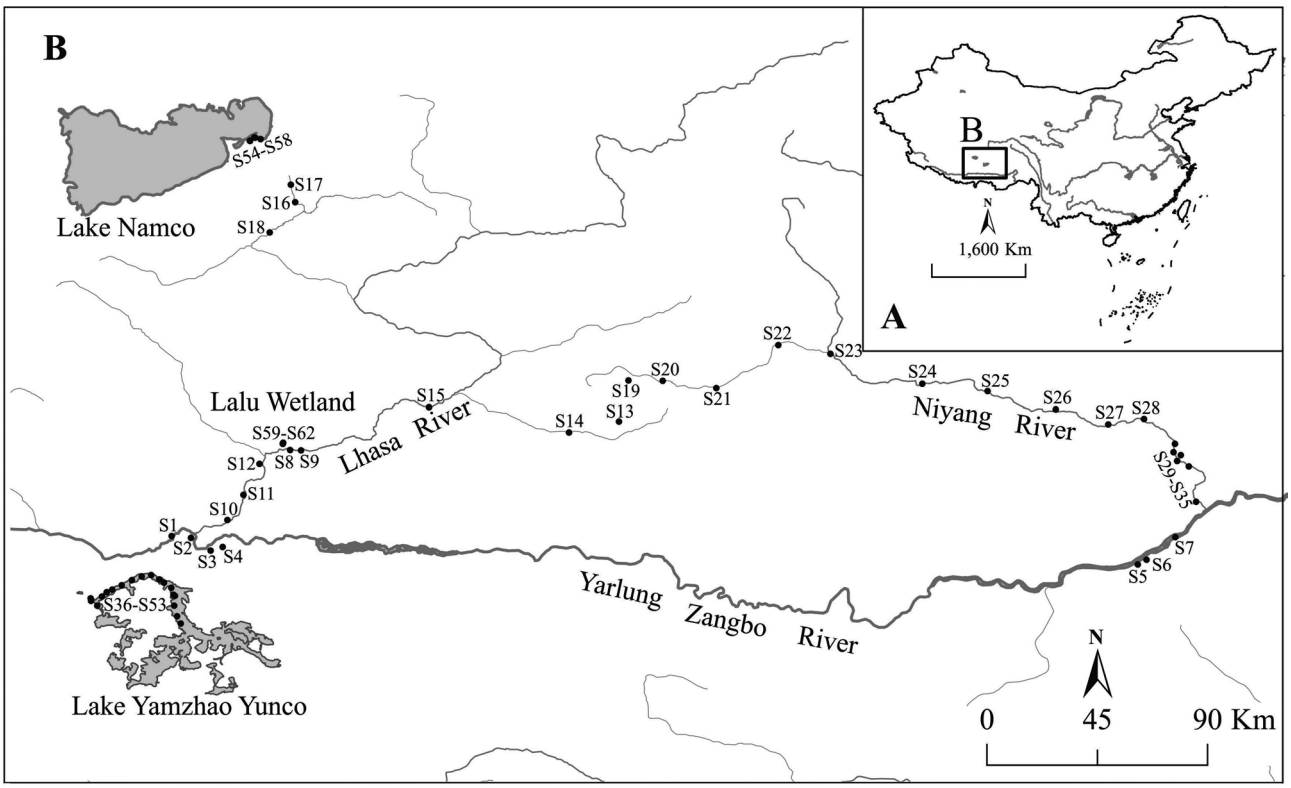


FIGURE 1. Sampling sites in Tibet. **A.** Map of China. **B.** Sampling sites of Yarlung Zangbo River, Lhasa River, Niyang River, Lake Yamzho Yumco, Lake Namco and Lalu Wetland, respectively.

Yarlung Zangbu River, an international water system, is located mainly in Tibet and is among the highest altitude rivers in the world. Its overall length in China is 2,057 km, with a drainage area of 240,480 km^2, and annual runoff volume to India and Bangladesh up to 140 billion m^3. Its source lies in the Gyaimanezong Glacier in Zongba County. The Yarlung Zangbo River belongs to the water system of the Indian Ocean and it flows from west to east across the southern section of the Tibet Plateau. It is the most precipitous river in China as a result of over 5,400 meters in total height drop. Four stations (ST1–ST4) were sampled within the Qushui Reach, and three stations (ST5–ST7) were sampled within the Milin Reach.

Lhasa River is one of the five major tributaries of the Yarlung Zangbo, which originates close to Nyangqentanglha Mountain (5,020 m asl) on the Qinghai-Tibet Plateau. It is approximately 551 km long and drains nearly 30,000 km^2. Five stations (ST8–ST12) on the mainstem of Lhasa River were sampled, and six stations (ST13–ST18) were located on tributaries of the Lhasa River.

Niyang River is a major river in south-west Tibet and the longest tributary of the Yarlung Zangbu River. It has a length of 307.5 km and originates from the Cuomuliangla, west of the Mila Mountain, about 5,000 m asl. The river joins the Yarlung Zangbu River in Cemeng, Nyingchi. Seventeen samples (ST19–ST35) were collected from the mainstem and tributaries of Niyang River.

Lake Yamzhao Yumco. With a maximum length of 74 km and a maximum width of 33 km, Lake Yamzhao Yumco covers an area of 678 km^2 at a water level of 4441 m asl. The maximum depth is 59 m and the mean depth is 30 m. Shoreline development (D_L), a measure of shoreline convolution equals 4.35 (value for a circle is 1). The annual mean air temperature around the lake area is 2.6?. Mean annual precipitation is 373.0 mm (92% occurring in June-September), and mean evaporation is 2074.0 mm. The lake receives surface runoff from the catchment (6,100 km^2) through six rivers, and has a recharge coefficient of 9.0 (Wang & Dou 1998). Sixteen samples (ST36–ST51) were collected from the north part of the lake, and two samples (ST52–ST53) were sampled from the shoreline.

TABLE 1. Sampling sites (comp. Fig. 1), with locality data, geographical coordinates, altitude (A), water depth (WD), water temperature (WT), dissolved oxygen (DO), pH, conductivity (COND), type of sediments, and sampling date. Missing numbers denote stations where no oligochaetes were found: mostly rivers with strong current and cobble substrate; also one marshy grassland site, Lake Namco littoral.

ST	Collection locality: nearest town and waterbody	Geographical coordinates	A (m)	WD (m)	WT (ºC)	DO (mg/L)	pH	COND (µS/cm)	Sediment	Sampling date
1	Qushui County, Yarlung Zangbo River	N29°19'35.1", E90°40'21.4"E	3598	0.4	16.4	6.02	8.42	281.0	mainly sand	1 Jul, 2010
2	Qushui County, Yarlung Zangbo River	N29°19'13.3", E90°44'34.3"	3584	0.5	16.0	7.02	8.22	291.3	mainly silt	1 Jul, 2010
3	Qushui County, Yarlung Zangbo River	N29°16'24.8", E90°48'56.1"	3578	0.2	18.3	6.35	8.33	215.5	clay and stone	1 Jul, 2010
4	Qushui County, Yarlung Zangbo River	N29°17'09.7", E90°51'37.1"	3587	0.5	17.2	5.89	8.30	216.6	clay and gravel	1 Jul, 2010
5	Milin County, Yarlung Zangbo River	N29°13'19.9", E94°12'58.2"	2949	0.3	12.2	7.82	8.2	97.8	mainly sand	25 Jun, 2011
6	Milin County, one small stream inflow to the Yarlung Zangbo River	N29°14'21.4", E94°14'54.6"	2945	0.15	8.1	8.92	9.23	26.6	clay and sand	25 Jun, 2011
7	Milin County, Yarlung Zangbo River	N29°19'22.6", E94°21'15.6"	2936	0.5	15.2	7.08	8.54	164.7	clay and sand	25 Jun, 2011
8	Lhasa City, Lhasa River	N29°38'27.8", E91°08'48.2"	3660	0.4	18.4	7.5	8.38	233.3	cobbles and clay	19 Jun, 2010
9	Lhasa City, Lhasa River	N29°38'34.0", E91°06'26.3"	3646	0.5	18.2	7.6	8.41	231.4	mainly cobbles	19 Jun, 2010
10	Qushui County, Lhasa River	N29°23'07.0", E90°52'38.4"	3609	0.25	16.2	6.38	8.23	175.4	mainly cobble	1 Jul, 2010
11	Qushui County, Lhasa River	N29°28'42.2", E90°56'08.9"	3618	0.5	16.5	6.14	8.08	160.0	mainly cobble	1 Jul, 2010
12	Qushui County, Lhasa River	N29°35'27.1", E90°59'39.5"	3637	0.4	19.0	6.57	7.86	383.7	coarse gravel	1 Jul, 2010
29	Near the first bridge of Linzhi County, Niyang River	N29°39'52.7", E94°21'08.5"	2991	–	–	–	–	–	mainly cobbles	26 Jun, 2011
30	Beside the road from Linzhi to Milin, Niyang River	N29°34'56.0", E94°24'12.9"	2967	0.6	12.7	8.54	7.19	38.8	clay	25 Jun, 2011
31	Beside the road from Linzhi to Milin, Niyang River	N29°27'06.3", E94°25'48.6"	2950	0.5	12.4	7.59	9.07	70.4	clay and sand	25 Jun, 2011
32	Near the second bridge of Linzhi County, Niyang River	N29°37'26.6", E94°22'27.5"	3002	0.4	12.5	7.96	8.12	81.3	mainly cobbles	24 Jun, 2011
34	Jiakang Village, Linzhi County, the tributary of Niyang River	N29°36'09.2", E94°21'40.6"	2966	0.2	13.3	6.15	8.14	145.4	clay	24 Jun, 2011
36	Lake Yamzhao Yumco	N29°06'42.4", E90°40'45.9"	4441	5.3	10.6	7.54	9.07	2375	mainly silt	23 Jun, 2010

……continued on the next page

TABLE 1. (Continued)

ST	Collection locality: nearest town and waterbody	Geographical coordinates	A (m)	WD (m)	WT (ºC)	DO (mg/L)	pH	COND (µS/cm)	Sediment	Sampling date
37	Lake Yamzhao Yumco	N29°00'18.1", E90°42'22.6"	4441	35.8	10.8	7.34	8.91	2372	mainly silt	23 Jun, 2010
38	Lake Yamzhao Yumco	N29°01'56.0", E90°41'32.5"	4441	33.2	11.4	7.33	8.89	2379	mainly silt	23 Jun, 2010
39	Lake Yamzhao Yumco	N29°04'18.3", E90°40'55.3"	4441	34.7	11.7	7.12	9.03	2372	mainly silt	23 Jun, 2010
40	Lake Yamzhao Yumco	N29°06'28.4", E90°41'04.9"	4441	38.4	12.2	7.26	9.05	2367	mainly silt	23 Jun, 2010
41	Lake Yamzhao Yumco	N29°08'10.0", E90°40'14.9"	4441	34.2	12.3	7.50	8.96	2377	mainly silt	23 Jun, 2010
42	Lake Yamzhao Yumco	N29°09'18.0", E90°38'37.5"	4441	36.3	12.0	7.10	8.91	2380	mainly silt	23 Jun, 2010
43	Lake Yamzhao Yumco	N29°10'00.7", E90°37'36.6"	4441	33.3	12.1	7.29	8.90	2375	mainly silt	23 Jun, 2010
44	Lake Yamzhao Yumco	N29°11'03.1", E90°35'51.7"	4441	28	11.5	7.33	9.07	2387	mainly silt	23 Jun, 2010
45	Lake Yamzhao Yumco	N29°10'41.2", E90°33'44.7"	4441	38.1	11.8	7.19	9.12	2384	mainly silt	24 Jun, 2010
46	Lake Yamzhao Yumco	N29°09'51.8", E90°31'33.9"	4441	31.2	12.5	7.58	9.13	2376	mainly silt	24 Jun, 2010
47	Lake Yamzhao Yumco	N29°08'44.1", E90°29'19.0"	4441	26.2	13.2	6.83	9.08	2363	mainly silt	24 Jun, 2010
48	Lake Yamzhao Yumco	N29°07'49.1", E90°27'15.5"	4441	25.0	13.6	6.96	8.94	2359	mainly silt	24 Jun, 2010
49	Lake Yamzhao Yumco	N29°06'18.6", E90°25'01.6"	4441	19.8	14.2	6.86	8.89	2362	mainly silt	24 Jun, 2010
50	Lake Yamzhao Yumco	N29°05'18.8", E90°22'39.3"	4441	12.8	14.8	6.76	9.06	2340	mainly silt	24 Jun, 2010
51	Lake Yamzhao Yumco	N29°04'15.4", E90°23'57.2"	4441	16.7	14.3	6.75	9.04	2343	mainly silt	24 Jun, 2010
52	Small stream inflow to Lake Yamzhao Yumco	N29°05'54.9", E90°22'32.4	4441	0.3	13.0	6.63	10.8	305.4	coarse gravel	30 Jun, 2010
53	Small stream inflow to Lake Yamzhao Yumco	N29°07'16.2", E90°26'01.9"	4441	14.2	0.3	7.3	9.91	372.2	fine gravel and silt	30 Jun, 2010
54	Small lake beside Lake Namco	N30°46'33.6", E90°57'36.7"	4708	7.0	4.4	6.68	9.12	4203	–	27 Jun, 2010
56	Littoral Lake Namco	N30°47'17.3", E90°58'32.7"	4729	0.3	10.7	7.5	9.25	1853	cobbles and coarse gravel	2 Jul, 2011
57	Littoral Lake Namco	N30°47'12.6", E90°58'43.9"	4716	0.3	10.0	7.48	10.4	1783	coarse gravel and sand	2 Jul, 2011
59	Small pond beside Lalu Wetland	N29°40'09.6", E91°04'53.2"	3563	0.3	18.4	3.74	7.26	224.0	silt	19 Jun, 2010
60	The small river beside Lalu Wetland	N29°39'53.3", E91°04'51.4"	3650	0.2	19.6	6.56	7.76	248.1	cobbles and gravel	19 Jun, 2010
61	Small pond beside Lalu Wetland	N29°39'58.1", E91°04'50.7"	3584	0.6	17.6	2.56	8.76	193.1	silt	21 Jun, 2011
62	The small river beside Lalu Wetland	N29°39'52.5", E91°04'49.5"	3650	0.3	14.8	7.31	8.80	186.4	silt and gravel	21 Jun, 2011

Lake Namco. The lake covers an area of 1961.5 km^2 at a water level of 4,718 m asl, with a maximum length of 78.6 km and a maximum width of 50.0 km. The maximum depth is 95 m and the mean depth is 59.6 m. Shoreline development (D_L) equals 2.05. The annual mean air temperature around the lake area is 1.3 ºC. Mean annual precipitation is 486.9 mm, and mean evaporation is 975.0 mm. The lake receives surface runoff from the catchment (8648.5 km^2) through many streamlets, and the recharge coefficient is 5.53 (Wang & Dou 1998; Kang *et al*. 2010). Five stations (ST54–ST58) in the southeast of the lake were sampled.

Lalu Wetland, located north of Lhasa City, is the highest natural wetland in the world (3,584 m asl), covering 12.2 km^2. Four samples (ST59–ST62) were taken from a pond and a river.

Methods of investigation

Benthic samples were collected with a weighted Petersen grab (1/16 m^2) in lakes, and a D-frame dip net (mesh size 250 µm, collecting area about 0.3 m ×5 m) in rivers. Three samples were taken at each station. Large worms were sorted manually in a white porcelain dish, while small ones were sorted under a dissecting microscope. Specimens were preserved in 10% formalin. Preserved specimens were examined first in temporary glycerine mounts, then stained with borax carmine, dehydrated in an alcohol series, cleared in xylene and mounted in Canada balsam. Measurements of body and chaetae were made on glycerine mounts. Other dimensions were measured on the permanent mounts. Drawings were made with a camera lucida. The types and other specimens are deposited in the Institute of Hydrobiology (IHB), Chinese Academy of Sciences, Wuhan, China.

Abbreviations used in the figures. Roman numerals = segment number; at = atrium; cs = copulatory sac; pe = penis; pr = prostate gland; ps = penial sheath; sa = spermathecal ampulla; sd = spermathecal duct; sf = sperm funnel; vd = vas deferens

Results, systematic account

Family Naididae

Subfamily Naidinae

1. *Chaetogaster diaphanus* (Gruithuisen, 1828)

(Figure 2)

Chaetogaster diaphanus (Gruithuisen). Chen 1940: 29–31; Liang 1964: 643–644, 1979: 274; Wang 2002: 80; Timm & Vsivkova 2007: 26; Cui 2008: 60.

Material examined. Lhasa River: ST12, 1 specimen (spm). Niyang River: ST30, 1 spm; ST31, 1 spm; ST32, 1 spm. Lalu Wetland: ST62, 3 spms.

Description of new material. Length 2.4–5.0 mm, width 0.8–1.0 mm, segments 10–15. No eyes. Prostomium inconspicuous. Pharynx developed, with thick muscle layer, pharyngeal glands in II–IV. Oesophagus narrow in IV. Stomach in V–VI, and dilatation sudden in V. Stomachal plexus forming transverse ducts only anteriorly. No dorsal chaetae. Ventral chaetae (Fig. 2A–C) of II 9 per bundle, 225–238 µm long, about 4.5 µm thick, upper prong longer than lower, with distal or median nodulus; from III on 7–11 per bundle, 174–221 µm long, about 3 µm thick, upper prong curved, longer and thinner than lower, with almost median nodulus. Penial chaetae (Fig. 2D–F; Fig. 2G, pc) 7 per bundle, about 112 µm long, 4 µm thick, simple-pointed or with 2–3 short fine teeth, with distal nodulus. Male pores paired in line with ventral chaetae, middle VI. Spermathecal pore paired in line with ventral chaeta, anterior to mid-V. Clitellum in 1/2V–VI. Male genitalia paired in V–VI. Male funnel (Fig. 2G, sf) cup-shaped, 80 µm long, 84 µm wide, with 12.5 µm thick wall. Vasa deferentia (Fig. 2G, vd) short, 28 µm wide, joining atria apically. Atrial ampulla (Fig. 2G, at) large, round, 168 µm long, 144 µm in diameter, 17.5–22.5 µm thick wall, with sperm masses (Fig. 2G, sm) in lumina. Spermathecal ampulla (Fig. 2G, sa) pear-shaped, about 75 µm long, 87 µm wide, with 10 µm thick wall, ducts very short.

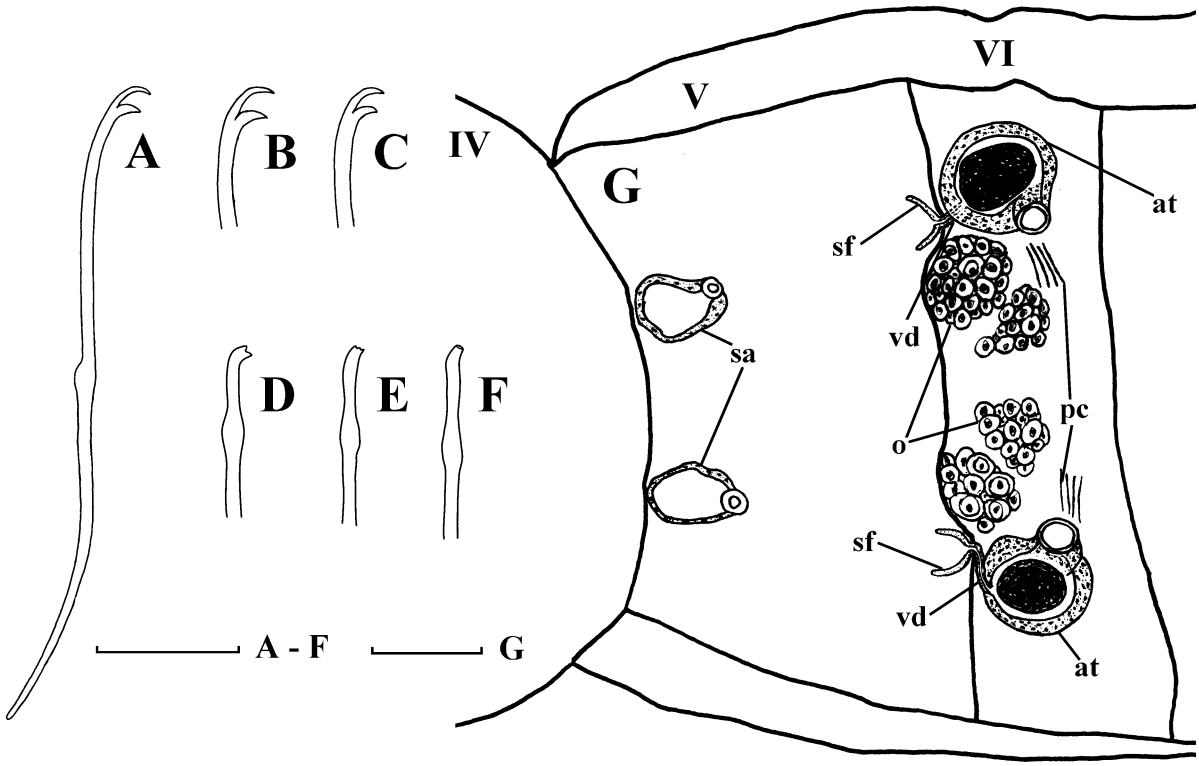


FIGURE 2. *Chaetogaster diaphanus* (Gruithuisen, 1828). **A–C.** Ventral chaetae (A: VI; B: II; C: posterior). **D–F.** Penial chaetae. **G.** Ventral view of sexual organs in segments IV–VI. Scale bars: A–F 40 µm, G 160 µm.

Remarks. This species is widely distributed in China (Wang & Cui 2007) and has also been recorded from Tibet by Stephenson (1909). The new material conforms to previous descriptions in most aspects except the body width and the number of penial chaetae (Chen 1940; Sperber 1948; Timm 1999). The new specimens are thicker than previously collected material from China (Liang 1964), but within the range given by Timm (2009) for European specimens. In our specimens there are usually 7 penial chaetae per bundle, whereas in previous descriptions there are only 3–5 per bundle (Chen 1940; Sperber 1948; Liang 1964; Brinkhurst & Jamieson 1971; Timm 1999).

2. *Dero digitata* (Müller, 1773)

Dero digitata (Müller). Chen 1959: 25; Liang 1979: 275; Wang 2002: 92–93; Cui 2008: 63.
Dero limosa Leidy. Chen 1940: 52–55.

Material. Lalu Wetland: ST61, 3 spms.

Remarks. First record from Tibet. This species is most likely a cosmopolitan species, with records from every continent except Antarctica (Brinkhurst & Jamieson 1971).

3. *Uncinais uncinata* (Ørsted, 1842)

Uncinais uncinata (Ørsted). Sokolskaya 1961: 79–89; He 2011: 66.

Material. Yarlung Zangbu River: ST7, 10 spms. Niyang River: ST30, 4 spms.

Remarks. First record from Tibet; also recorded in areas of northern China, such as Helongjiang, Xinjiang, Qinhai and Guizhou (Wang & Cui 2007). This species is widely distributed in Europe and middle Asia (Brinkhurst & Jamieson 1971).

4. *Stylaria lacustris* (Linnaeus, 1767)

Stylaria lacustris (Linnaeus). Chen 1959: 23; Liang 1962: 20.
Stylaria proboscidea (Müller). Chen 1940: 44–46.

Material. Lhasa River: ST9, 11 spms; Niyang River: ST29, 2 spms; ST31, 4 spms; ST32, 15 spms. Lalu Wetland: ST61, 22 spms.

Remarks. First record from Tibet; recorded in areas of northern China, such as Helongjiang, Xinjiang, and Guizhou (Wang & Cui 2007; Mezzanotte 2008). This species is widely distributed in Europe, west Asia and North America (Brinkhurst & Jamieson 1971; Wetzel *et al*. 2006).

5. *Stylaria fossularis* Leidy, 1852

Stylaria fossularis Leidy. Chen 1940: 44–46, 1959: 23; Liang 1962: 19, 1979: 274–275; Wang 2002: 88; Cui 2008: 62.

Material. Lhasa River: ST8, 12 spms. Lalu Wetland: 61, 8 spms.

Remarks. Cosmopolitan (Brinkhurst & Jamieson 1971). First record from Tibet.

6. *Nais simplex* Piguet, 1906

Nais simplex Piguet. Liang 1964: 645–646, 1979: 274.
Nais barbata Müller. Liang 1962: 16–17.

Material. Lhasa River: ST8, 2 spms; ST9, 1 spm; ST10, 5 spms.

Remarks. Cosmopolitan (Brinkhurst & Jamieson 1971). First record from Tibet.

7. *Nais barbata* Müller, 1773

Nais barbata Müller. Liang 1964: 646.

Material. Lhasa River: ST8, 3 spms; ST9, 1spm; Niyang River: ST29, 4 spms; ST32, 2 spms; ST34, 6 spms; Lalu Wetland: ST61, 4 spms.

Remarks. First record from Tibet; also recorded from Xinjing, China (Wang & Cui 2007). This species is distributed in Europe, Asia and North America (Brinkhurst & Jamieson 1971, Wetzel *et al*. 2006).

8. *Nais elinguis* Müller, 1773
(Figure 3)

Nais elinguis Müller. Liang 1964: 644–645.
Nais barbata Müller. Liang 1962: 16–17.

Material. Lhasa River: ST8, 5 spms (2 balsam mounts); ST9, 2 spms; ST11, 4 spms; ST17, 11 spms; ST61, 1 spm; ST62, 12 spms.

Description of new material. Length 2.6–3.2 mm, 13–18 segments. Eyes present. Stomachal dilatation gradual in VII–VIII. Ventral chaetae of II–V 4–5 per bundle, 90–98 μm long, with nodulus slightly distal or median, from III on 2–5 per bundle, 82–88 μm long, with nodulus distal. Distal tooth of all ventral chaetae 2–3 times as long as proximal. Dorsal chaetae beginning in VI, hairs 1–3 per bundle, 275–350 μm long, needles (Fig. 3A) with two teeth about 4 μm long, distal tooth slightly longer than proximal tooth. Penial chaetae (Fig. 3B; Fig. 3C, ps) 5 per bundle, 102–110 μm long, 4 μm width, with a simple distal hook. Vas deferens (Fig. 3C, vd) short, wholly surrounded by abundant prostate gland (Fig. 3C, pr) cells, joining atria subapically. Atrial ampulla (Fig.

3C, at) ovoid, with a thick wall. Spermathecae (Fig. 3C, sa) paired in V, pear-shaped, duct short, spermatozeugmata absent.

Remarks. Cosmopolitan. The characters of the new material agree with previous descriptions (Sperber 1948; Timm 1999). Specimens are redescribed here because this is the first record of sexually mature individuals of this species from China. First record from Tibet.

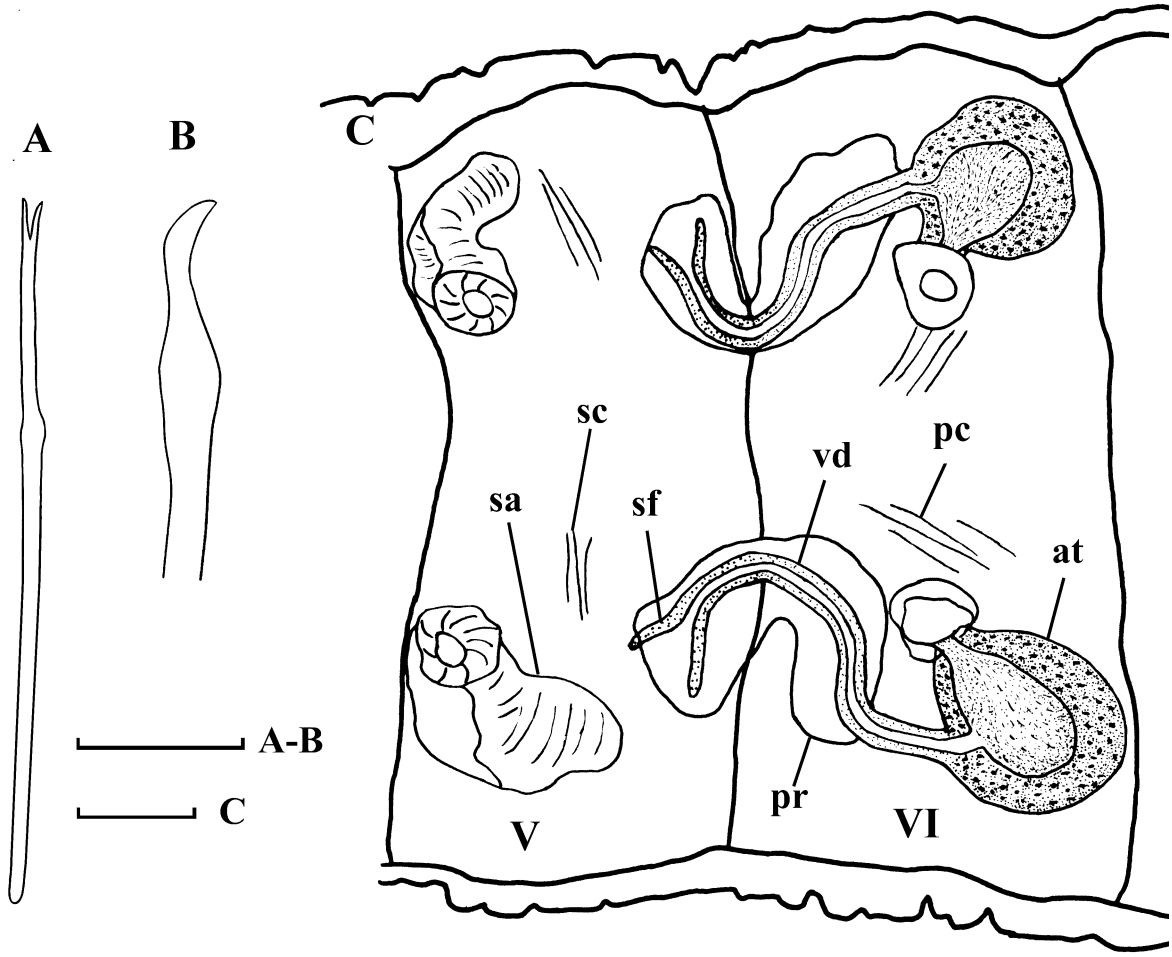


FIGURE 3. *Nais elinguis* Müller, 1774. **A.** Needle chaeta. **B.** Penial chaeta. **C.** Ventral view of sexual organs in segments V–VI. Scale bars: A–B 20 µm, C 40 µm.

9. *Nais bretscheri* Michaelsen, 1899

Nais bretscheri Michaelsen. Liang 1962: 17–18, 1964: 644; Wang 2002: 85; Cui 2008: 61; [non] Chen 1940: 35–36.

Material. Yarlung Zangbu River: ST5, 5 spms. Lhasa River: ST8, 4 spms; ST9, 2 spms; ST10, 11 spms; ST11, 3 spms. Niyang River: ST31, 1 spm; ST32, 3 spms; Lake Yamzhao Yumco: ST53, 14 spms.

Remarks. Cosmopolitan. First record from Tibet.

10. *Nais communis* Piguet, 1906

Nais communis Piguet. Chen 1940: 33–34; Liang 1964: 644, 1979: 274; Wang 2002: 83–84; Cui 2008: 61.

Material. Yarlung Zangbu River: ST5, 2 spms. Lhasa: ST8, 3spms; ST9, 1spm; ST10, 9 spms; ST11, 7 spms; ST12, 6 spms; Niyang River: ST29, 5 spms; ST32, 3 spms; Lake Nmco: ST57, 12 spms. Lalu Wetland: ST60, 13 spms.

Remarks. Cosmopolitan. First record from Tibet.

11. *Nais pardalis* Piguet, 1906

Nais pardalis Piguet. Liang 1958: 43, 1964: 644, 1979: 274; Brinkhurst, Qi & Liang 1990: 906–907; Wang 2002: 85–86; Cui 2008: 62.
Nais bretscheri Michaelsen. Chen 1940: 35–36.

Material. Yarlung Zangbu River: ST5, 8 spms. Lhasa River: ST8, 12 spms; ST9, 3spms; ST10, 14 spms; Lake Yamzhao Yunmco: ST53, 4 spms. Lalu Wetland: ST59, 20 spms; ST60, 9 spms; ST62, 12 spms.

Remarks. Cosmopolitan. First record from Tibet.

12. *Nais variabilis* Piguet, 1906

Nais variabilis Piguet. Liang 1958; Chen 1959: 27; Wang 2002: 84; Cui 2008: 61.
Nais communis Piguet.Chen, 1940: 33–34.

Material. Yarlung Zangbu River: ST2, 2 spms; ST5, 7 spms; Niyang River: ST29, 12 spms; ST30, 4 spms; ST32, 4spms.

Remarks. Cosmopolitan. First record from Tibet.

13. *Nais longidentata* sp. n.

(Figures 4, 5; Table 2)

Holotype. IHB NMC20110702a, mature specimen mounted in Canada balsam, and stained with borax carmine.

Type locality. ST57, N 30°47'12.6", E 90°58'43.9", Lake Namco of Tibet, ca. 4,716 m asl, lake shore substrate type coarse gravel and sand; water depth 0.3 m, water temperature 10.0°C, dissolved oxygen 7.48 mg/L, pH 10.42, conductivity 1,783 μS/cm. 2 July 2011, collected by X. B. He, Y. D. Cui.

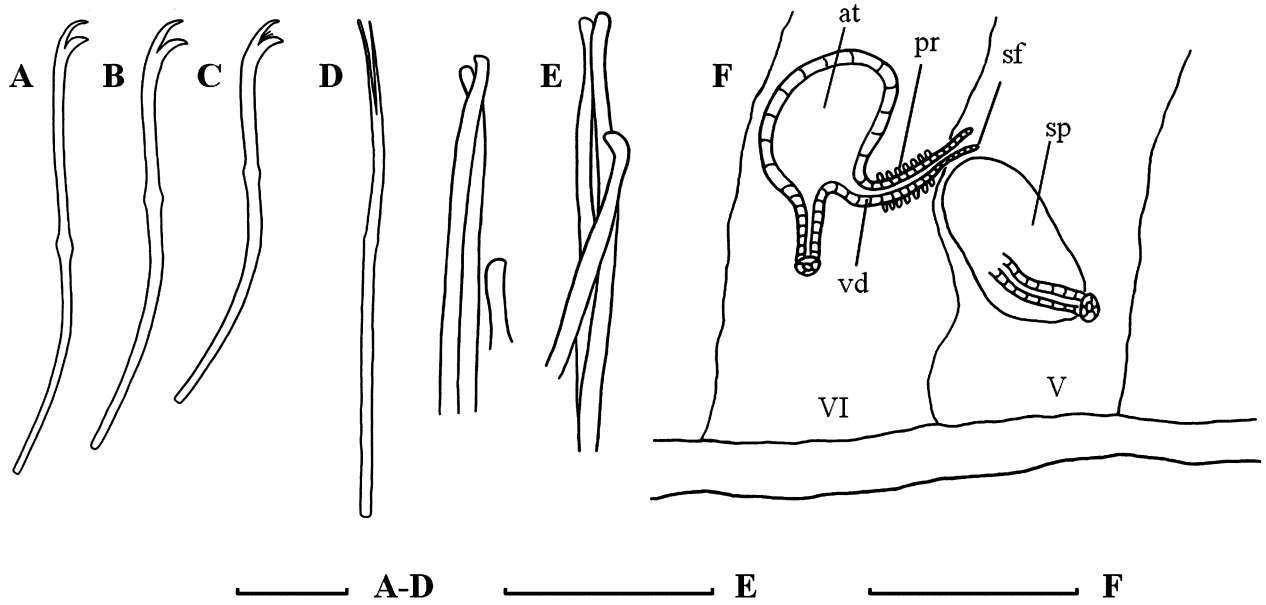


FIGURE 4. *Nais longidentata* **n. sp. A–C.** Ventral chaetae (III, VI, posterior, respectively). **D.** Needles. **E.** Penial chaetae. **F.** Lateral view of sexual organs in segments V–VI. Scale bar: A–D 20 μm; E 50 μm, F 100 μm.

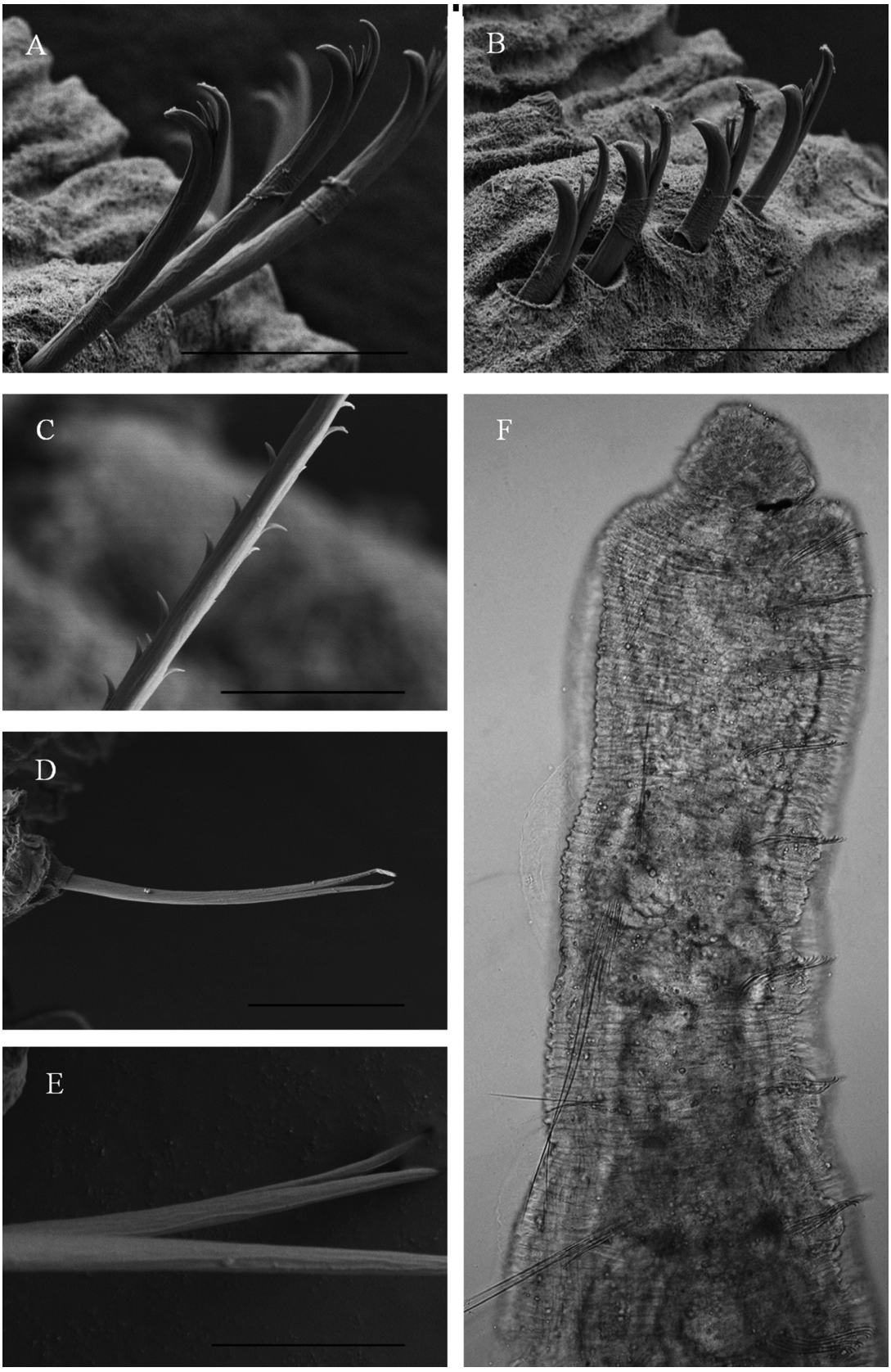
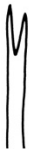
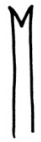


FIGURE 5. SEM (A–E) and optical microscope (F) micrographs of *Nais longidentata* **n. sp. A–B.** Ventral chaetae in IX (A) and XIII (B). **C.** Hair in VII. **D–E.** Needles in X (D) and a posterior segment (E). **F.** Lateral view of anterior body. Scale bars: A,B, D 20μm, C 5μm, E 10 μm.

TABLE 2. Comparison of *Nais longidentata* **sp. n.** with allied species. Data from Sperber (1948), Liang (1964), Brinkhurst & Jamieson (1971), Semernoy (2004), Peng *et al.* (2014).

Species	*N. longidentata* **sp. n.**	*N. bretscheri* Michaelsen, 1899	*N. communis* Piguet, 1906	*N. elinguis* Müller, 1774	*N. pardalis* Piguet, 1906	*N. variabilis* Piguet, 1906	*N. badia* Peng *et al.*, 2014
Length (mm)	4.3–5.7	3–7	1.8–12	2.2–12	2.5–7.0	3–10	4.2–9.1
Segment number	34–39	19–34	12–32	15–37	19–32	18–38	24–54
Ventral chaetae II–V	3–5	2–7	2–6	2–5	2–5	2–7	7–8
Ventral chaetae from VI	4–5	1–6, with giant chaeta	2–6	2–5	1–5, with thick chaeta	2–7	2–7
Hairs	(0)1, serrate	1–2	1–2	1–3	1–2	1–2	1–3, serrate
Needles number	1–2	1–2	1–2	1–3	1–2	1–2	2–3, pectinate
Needle tip							
Stomachal dilatation	Sudden	Gradual	Gradual	Gradual	Sudden	Sudden	Sudden
Vasa deferentia	Completely surrounded by strong gland cells	With prostate gland	Thick, with gland cells only on posterior part	Long, curved, wholly surrounded by abundant gland cells	Surrounded by gland cells in front of atria	Completely surrounded by strong gland cells	Surrounded by gland cells only on posterior part
Penial chaetae	3	2	2–3	4–5	3	2–3	4
Swimming type	No swimming	No swimming	No swimming	Lateral movements	Spiral movements	Spiral movements	Wave-like movements
Distribution	Tibet, China	Cosmopolitan	Cosmopolitan	Cosmopolitan	Cosmopolitan	Cosmopolitan	Southern Tibet, China

Paratypes. IHB NMC20110702b–e, 4 specimens from the type locality mounted in Canada balsam, and stained with borax carmine.

Other material. More than 50 immature specimens from ST5, ST9, ST31, ST53, ST57, preserved in 10% formalin, collected by X. B. He, Y. D. Cui.

Etymology. The specific name "*longidentata*" is Latin for "with long teeth", and refers to the needle with two long teeth.

Description. Length 3.3–7.4 mm (holotype 4.3 mm), width at VI 0.3–0.6 mm (holotype 0.5 mm), segments 34–41(holotype 34). Prostomium conical. Eyes present, body pigment absent. Pharynx in II–III. Stomach in VII–VIII, dilatation sudden in VII, no elongate cells. Clitellum inconspicuous. Coelomocytes abundant. No swimming.

Dorsal chaetae from VI onwards (Fig. 5F). Hairs (0)1–2 per bundle, 225–450 μm long, with faint serration (Fig. 5C). Needles 1–2 per bundle, 92–112 μm long, with two long parallel teeth (10.0–13.8 μm long), distal tooth slightly thinner and shorter than proximal, or subequal; nodulus ca. 2/5 from distal end (Fig. 4D, Fig. 5D–E). Ventral chaetae of II–V 3–4 per bundle, 78–84 μm long, distal tooth longer and thinner than proximal, with median or slightly distal nodulus, hardly longer and thinner than the rest. Ventral chaetae from VI 2–5 per bundle, 68–78 μm long, distal tooth slightly longer than proximal, with 1–3 fine intermediate teeth, nodulus 2/5 from distal end (Fig. 4A–C; Fig. 5A–B). Penial chaetae (Fig. 4E) 3 per bundle, 70–112 μm long, 4 μm thick, simple-pointed. Male pores paired in segment VI. Spermathecal pores paired in segment V.

Clitellum in V–VI. Male genitalia paired in V–VI. Vasa deferentia (Fig. 4F, vd) 90–100 μm long, 8–9 μm wide, completely surrounded by abundant prostate gland cells (Fig. 4F, pr), joining the atria subapically. Atrial ampullae large and round, 120 μm in length, 45 μm in diameter, wall 5 μm thick (Fig. 4F, at). Spermathecal ampulla pear-shaped, 90 μm long, 50 μm wide, with distinct duct 60–70 μm long, 9–10 μm wide (Fig. 4F, sp).

Distribution. Known only from Lake Nam Co and Lake Yamzho Yumco of Tibet.

Remarks. Considering the characters such as the presence of eyes, coelomocytes abundant, dorsal chaetae from VI with hairs and double-pronged needles, ventral chaetae of II–V longer and thinner than the rest, pharynx in II–III, stomach beginning in VII, spermathecae with distinct ducts, vasa deferentia with prostate gland cells joining the atria subapically, atria without prostate glands, penial chaetae present with a simple hook, we think that the new species fits the definition of *Nais* Müller, 1773 (Sperber 1948; Brinkhurst & Jamieson 1971; Hrabě 1979; Timm 1999; Envall *et al.* 2012).

About 31 species have been described in *Nais*, and ten species are distributed in China (Sperber 1948; Liang 1964; Brinkhurst & Jamieson 1971; Semernoy 2004; Envall *et al.* 2012; Peng *et al.* 2014). *N. longidentata* **sp. n.** is distinguished from congeners in having long and parallel needle teeth, faintly serrated hairs, and pectinate ventral chaetae with 1–2 intermediate teeth.

Comparing *N. longidentata* **sp. n.** with allied species (Table 2), the new species is similar to *N. elinguis* by the long and parallel needle teeth. However, the needles of the new species are longer than those of *N. elinguis* (10.0–13.8 μm *vs*. 3.1–4.6 μm). *N. badia* Peng *et al*., 2014 resembles the new species in serrate hairs and pectinate ventral chaetae, but its large area of reddish brown pigment in I–VIII, wave-like body movements, and vasa deferentia with prostate gland cells only on their posterior parts are significantly different from *N. longidentata* **sp. n.**. Among further similar species, *N. bretscheri* Michaelsen, 1899 differs from the new species in giant chaetae in some anterior ventral segments; *N. communis* Piguet, 1906 differs in the thick prostate gland cells only on their posterior parts; *N. variabilis* Piguet, 1906 and *N. pardalis* Piguet, 1906 swim with spiral body movements and their stomach has elongate cells. In all these species the needle teeth are considerably shorter than in *N. longidentata* **sp. n.**

14. *Pristina jenkinae* (Stephenson, 1931)

Pristina jenkinae (Stephenson). Liang 1964: 649–650; Cui 2008: 66.
Pristinella jenkinae (Stephenson). Wang 2002: 105–106.

Material. Niyang River: ST32, 3 spms.

Remarks. First record from Tibet.

15. *Paranais frici* Hrabě, 1941

Paranais frici Hrabě. Erséus 1990: 116–117, Wang 2002: 82; Cui 2008: 60–61.
Paranais mobilis Liang. Liang 1958: 43–44; Chen 1959: 27.

Material. Yarlung Zangbu River: ST5, 2 spms.

Remarks. First record from Tibet. This species has previously been found to be widespread in brackish water (Erséus 1990), but thus far has not been found in the brackish lakes of Tibet.

Subfamily Rhyacodrilinae

16. *Rhyacodrilus stephensoni* Černosvitov, 1942
(Figure 6)

Rhyacodrilus stephensoni Černosvitov, 1942: 284–285, Liang & Xie 1992: 196–197.

Material. 1 spm, whole-mounted in Canada balsam, from ST59, 4 specimens in 10% formalin from ST59 and ST61.

Description. Length 7.8 mm, width in X 0.37 mm, 35 segments. Coelomocytes abundant. Prostomium cylindrical. Pharynx in III–IV. No hairs. Chaetae bifid, distal tooth shorter or equal to proximal, nodulus distal. Chaetae (Fig. 6B) of anterior segments 3–4 per bundle, posteriorly 2–4 (3) per bundle. Vas deferens (Fig. 6C, vd) short, 22.5 μm in diameter, wall 7.5 μm thin, attached to atrium subapically. Atrium (Fig. 6C, at) oval-like, ampulla thickly covered with diffuse unicellular prostate gland (Fig. 6C, pr). Pseudopenes (Fig. 6C, pe) present, 35 μm in diameter. Spermathecae (Fig. 6C, sa) oval-shaped, walls of ampulla 7.5–12.5 μm thin. Duct (Fig. 6C, sd) short, 35 μm long, 47.5 μm in diameter, 20μm in its thick wall. Spermathecal chaetae unmodified, 4 per bundle, penial chaetae (Fig. 6A) straight, bifid, with a very short distal tooth, 3 per bundle.

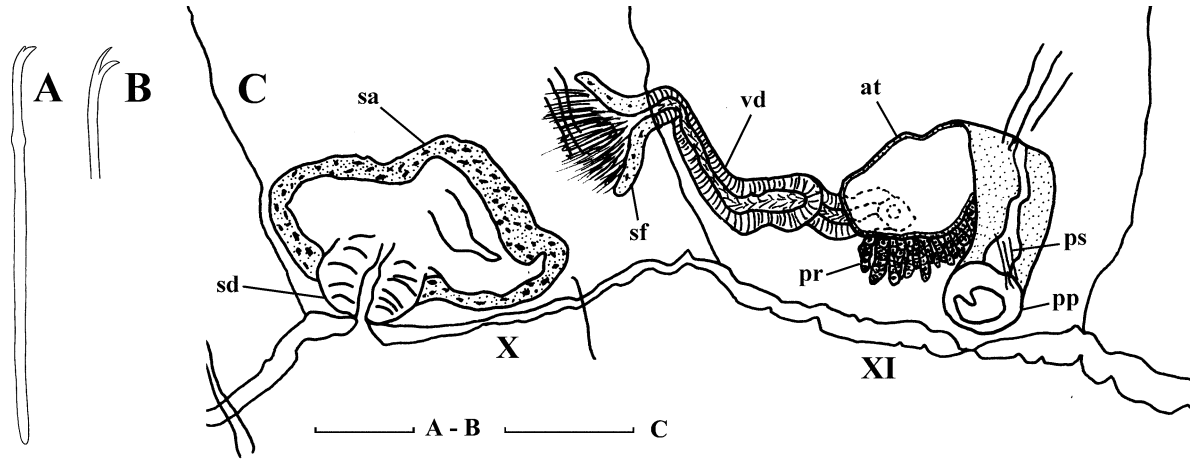


FIGURE 6. *Rhyacodrilus stephensoni* Černosvitov, 1942. **A.** Spermathecal chaeta. **B.** Dorsal chaeta. **C.** Lateral view of male duct and spermatheca in segments X–XI. Scale bars: A–B 20 μm, C 80 μm.

Remarks. This species was recorded by Stephenson (1909) for the first time as *Limnodrilus* sp. in Tibet, and then Černosvitov (1942) redescribed it, recognized it as a new species, and transferred it to the genus *Rhyacodrilus*. This species is also distributed in terrestrial habitats of Tianmu Mountain in Zhejiang Province (Liang & Xie 1997).

17. *Branchiura sowerbyi* Beddard, 1892

Branchiura sowerbyi Beddard. Chen 1940: 90–96, 1959: 19; Liang 1962: 22, 1979: 276–277; Brinkhurst, Qi & Liang 1990: 912; Wang 2002: 132–131; Cui 2008: 107–108.

Material. Yarlung Zangbu River: ST5, 3 spms. Niyang River: ST30, 2 spms; ST32, 5 spms. Lake Yamzhao Yumco: ST52, 4 spms. Lalu Wetland: ST59, 5 spms; ST60, 5 spms.

Remarks. Cosmopolitan species. First record from Tibet.

Subfamiliy Tubificinae

18. *Limnodrilus hoffmeisteri* Claparède, 1862

Limnodrilus hoffmeisteri Claparède. Chen 1940: 109–114; Sokolskaya 1961: 86; Liang 1962: 24–25; Wang 2002: 109–110; Cui 2008: 68.
Limnodrilus pacificus Chen, 1940: 118.

Material. Yarlung Zangbu River: ST1, 4 spms; ST2, 10 spms; ST3, 20 spms; ST4, 7 spms; ST5, 12 spms; ST6, 23 spms; ST7, 9 spms. Lhasa River: ST8, 20 spms; ST9, 11 spms; ST10, 15spms; ST11, 7 spms; ST12, 2 spms. Niyang River: ST29, 9 spms; ST30, 2 spms; ST32, 10 spms; ST34, 7 spms. Yamzhao Yumco: ST38, 1 spm; ST53, 12spms; ST54, 5 spms. Lake Namco, ST56, 2 spms; Lalu Wetland: ST59, 7 spms; ST60, 4 spms; ST61, 12 spms; ST62, 22 spms.

Remarks. Cosmopolitan. First record from Tibet.

19. *Limnodrilus claparedeianus* Ratzel, 1868

Limnodrilus claparedianus Ratzel. Chen 1940: 116–118.
Limnodrilus claparedeianus Ratzel. Liang 1987: 196; Wang 2002: 110–111; Cui 2008: 68.

Material. Yarlung Zangbu River: ST2, 3 spms; ST3, 4 spms.

Remarks. Cosmopolitan. First record from Tibet.

20. *Limnodrilus profundicola* (Verrill, 1871)
(Figure 7)

Limnodrilus helveticus Piguet. Liang 1962: 23–24.
Limnodrilus profundicola (Verrill). He 2011: 107–108.

Material. Lake Yamzhao Yumco, shoreline, ST53, 1 mature specimen, mounted in Canada balsam (dissected). In 10% formalin: Yarlung Zangbu River, ST1, 2 spms; ST2, 1 spm. Lake Namco, ST56, 2 spms.

Description. Length 19 mm, width 1.0 mm anteriorly, 0.5 mm posteriorly, 57 segments. Prostomium conical. Coelomocytes absent. No hairs. Ventral and dorsal chaetae all the same shape, distal teeth shorter or equal to proximal, nodulus distal. In anterior segments dorsally and ventrally 6–9 and 6–11 chaetae per bundle, respectively, 4–7 per bundle posteriorly. Vasa deferentia (Fig. 7B, vd) long, 23–30 μm wide, 5–8 μm wall thick, with cilia. Atrium (Fig. 7B, at) of fusiform shape, 55 μm wide, 238 μm long, about 4x as wide as long. Prostate gland (Fig. 7B, pr) large, solid, lobulated, attached to middle portion of atrium. Ejaculatory ducts (Fig. 7B, ed) present, 15–25 μm wide. Penis sheath (Fig. 7B, ps) cylindrical, 65 μm wide at proximal base, 290 μm long, 5x as long as wide, thick-walled. Penis sheath widest at proximal base, gradually narrowing distally, narrowest in the middle, slightly wider at the distal top; distal end expanding abruptly to form a head of circular form, which is generally reflected back over the tube. Spermathecae (Fig. 7A, sa) paired in X, pear-shaped. Spermatozeugmata (Fig. 7A, sz) worm-like, 4 of them in ampulla. Duct (Fig. 7A, sd) short, expanded in the middle (Fig. 7A, sv), with fine sperm bundles in the cavity (Fig. 7A, sb).

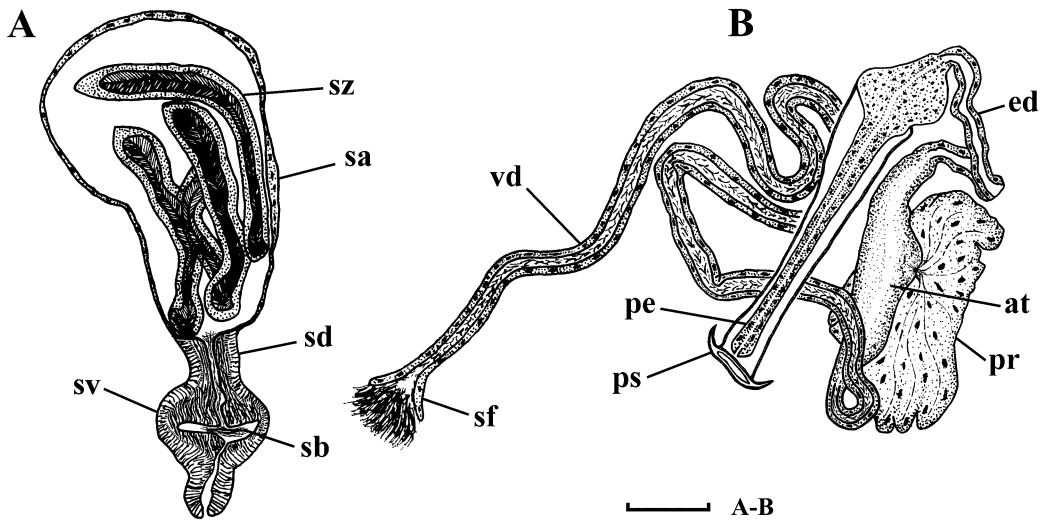


FIGURE 7. *Limnodrilus profundicola* (Verrill, 1871). A. Spermatheca. B. Male duct. Scale bar 80 μm.

Remarks. This species was recorded as *Limnodrilus helveticus* in Heilongjiang, Xinjiang, Qinghai Province in China (Liang 1962; Wang & Cui 2007). Following Brinkhurst & Jamieson (1971), *L. helveticus* is a junior synonym of *L. profundicola*; hence the record of *L. helveticus* recorded in Liang (1962) should be changed to *Limnodrilus profundicola*. Our material agrees with previous descriptions (Brinkhurst & Jamieson 1971; Hrabě 1979; Timm 1999), notably in the shape of the penial sheaths, being 5x as long as wide and with mushroom-like distal end. First record from Tibet.

21. *Ilyodrilus templetoni* (Southern, 1909)

Ilyodrilus templetoni (Southern). Liang, Wang & Xie, 1998: 57–58; Wang, 2002: 112–114; Cui, 2008: 69.

Material. Lhasa River: ST10, 12 spms; ST11, 5 spms; ST12, 6 spms. Lalu Wetland: ST59, 16 spms; ST61, 7 spms.

Remarks. Cosmopolitan. First record from Tibet.

22. *Tubifex tubifex* (Müller, 1774)

Tubifex tubifex (Müller). Liang 1962: 20–22; Wang 2002: 109; Cui 2008: 67.
Tubifex sp. Yamaguchi 1940: 387–388.

Material. Yarlung Zangbu River: ST1, 3 spms; ST5, 6 spms. Lhasa River: ST10, 12 spms; ST12, 3 spms. Niyang River: ST29, 7 spms; ST30, 1 spm; ST32, 6 spms; ST34, 3 spms. Lake Yamzhao Yumco: ST38, 1 spm; ST52, 2 spms. Lalu Wetland: ST60, 4 spms; ST61, 7 spms; ST62, 2 spms.

Remarks. Cosmopolitan. First record from Tibet.

23. *Tubifex conicus* He, Cui & Wang, 2012

Tubifex conicus He, Cui & Wang, 2012: 160–162.

Material. Lake Yamzhao Yumco: ST36, 2 spms; ST37, 17 spms; ST39, 45 spms; ST40, 12 spms; ST41, 24 spms; ST42, 6 spms; ST43, 27 spms; ST44, 2 spms; ST47, 36 spms; ST48, 29 spms; ST49, 21 spms.

Remarks. Known only from Lake Yamzhao Yumco.

24. *Isochaetides palmatus* He, Cui & Wang, 2012

Isochaetides palmatus He, Cui & Wang, 2012: 162–164.

Material. Lake Yamzhao Yunmco: ST36, 9 spms; ST37, 57 spms; ST38, 8 spms; ST39, 55 spms; ST40, 52 spms; ST41, 51 spms; ST42, 64 spms; ST43, 51 spms; ST44, 36 spms; ST45, 97 spms; ST46, 103 spms; ST47, 42 spms; ST48, 57 spms; ST49, 8 spms; ST50, 53 spms; ST51, 7 spms.

Remarks. Known only from Lake Yamzhao Yumco.

Lumbriculidae

25. *Lumbriculus variegatus* (Müller, 1774)

Lumbriculus variegatus (Müller). Černosvitov, 1942: 281; Chen, 1959: 19 (erroneously as *L. variegatum*); Liang & Xie, 1997: 392; Wang & Liang, 2001: 32; Wang, 2002: 39–40.
Lumbriculus sp. (?) Chen, 1940: 123.

Material. Lhasa River: ST10, 40 spms; ST11, 34 spms. Niyang River: ST30, 12 spms; ST32, 22 spms; ST34, 4 spms; Lalu Wetland: ST59, 8 spms; ST61, 10 spms.

Remarks. Numerous specimens were collected, but mature specimens were not found.

Discussion

With this study, there are 30 species of aquatic oligochaetes belonging to 2 families and 15 genera recorded from Tibet. Three species recorded in previous studies (Stephenson 1909; Černosvitov 1942) were not found in this study: *Pristina changtuensis* Liang, 1963, *Limnodrilus udekemianus* Claparède, 1862 and *Aulodrilus limnobius* Bretscher, 1899. In study areas of Tibet, the species diversity in freshwater regions is higher than in brackish lakes, e.g. Lalu wetland, Lhasa River, Niyang River and Yarlung Zangbo River contained 14, 13, 13 and 12 species, respectively, while 9 and 5 species were recorded in Lake Yamzho Yunmco and Lake Namco, respectively, both of which are brackish (Table 1). In this study, we did not find oligochaetes at all in several stations, most of them in rivers with strong current and cobbles as substrate.

With regard to the species composition, the oligochaete fauna of Tibet appears to be dominated by cosmopolitan species (accounting for 17 (57 %) of species). Some species were found at only a small number of stations with distinctive habitats. For example, *Tubifex conicus* and *Isochaetides palmatus* were only sampled from one brackish lake, and *Nais badia* was only found in freshwater wetland. These three species are assumed to have a restricted range and narrow habitat requirements (He *et al*. 2012; Peng *et al*. 2014). In addition, two recorded species, *Pristina changtuensis* and *Rhyacodrilus stephensoni*, are originally known from Tibet; the former is limited to Changdu (Liang 1963) and Hengyan, Henan Province (Wang 2002), the latter has broader habitat tolerances, being capable of surviving in both aquatic and terrestrial habitats (Stephenson 1909; Liang & Xie1992).

The faunal components of the Tibetan Plateau are mostly thought to be of Palearctic and Oriental origin (Yang *et al*. 2009). The study suggests that the Qinghai-Xizang plateau is an independent unit for ichthyo-fauna (Chen *et al*. 1996); the freshwater mollusk fauna seems to be mainly characterized by Palearctic species (Oheimb *et al*. 2011, 2013), and the branchiopod fauna is cosmopolitan and consists of Palearctic species, with few endemic or oriental species (Chiang *et al*. 1983). The Tibetan Plateau is considered as a global biodiversity hotspot, with a unique natural environment (Li & Fang 1999). Extant patterns of diversity and distribution of species throughout the Tibetan Plateau are mainly influenced by extreme geological changes during the plateau's uplift, as well as climate fluctuations especially during the Pleistocene (Yang *et al*. 2009). But the regional freshwater fauna and particularly the oligochaete fauna remains species-poor and scarcely studied. The present study has helped to address this knowledge gap with the description of a new species, and first records from Tibet of 21 additional species. Future studies should focus on faunistic distribution patterns across different regions of the Tibetan Plateau and their vicinities, and expand to phylogenetic and biogeographical work.

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