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Faunistic survey on freshwater annelids from Korea

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Aquatic oligochaete plays an important role in freshwater ecosystem. These worms, therefore, have already been extensively studied around the world. But compared to other countries with East Asia, only 48 species of aquatic oligochaetes have been recorded in Korea. This is because taxonomic study of aquatic oligochaete is in just beginning stages. Our specimens of this study had been collected from eighteen locations in Korean peninsula. Analyzing them we identified twenty unrecorded species including one species of aelosomatid: *Paranais orientalis*, *Pristina breviseta*, *P. notopora*, *P. foreli*, *P. synclites*, *Bratislavia prosetosa*, *Allonais gwaliorensis*, *Aulodrilus pluriseta*, *Limnodrilus neotropicus*, *L. maumeensis*, *L. amblysetus*, *Tubifex ignotus*, *Potamothrix* cf. *bedoti*, *P. bavaricus*, *Peipsidrilus* cf. *pusillus*, *Psammoryctides albicola*, *Varichaetadrilus vestibulatus*, *Tasserkidrilus* cf. *acapillatus*, *Propappus volki*, *Aeolosoma japonicum*.

Keywords: Aelosomatidae, Enchytraeidae, Naidinae, Tubificidae, Tubificinae

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Introduction

Aquatic oligochaetes are an important organism in freshwater ecosystem. They are found in almost all freshwater environments and could be dominant in their habitats depending on surrounding conditions (van Haaren, 2002; Behrend *et al*., 2009; Ragonha and Takeda, 2014). These worms act as mediators between the primary producers and the upper consumers, decomposers, or sometimes intermediate hosts of parasites in freshwater ecosystems (Pandit, 1980; Gardner *et al*., 1981). And withstanding water pollution, some species are preferred as biological indicators for freshwater environments (Chakrabarty and Das, 2006; Ferreira *et al*., 2011).

Oligochaetes are known for more than 5,000 species around the world. Of these, approximately 1,600 species are found in freshwater environment (Martin *et al*., 2008). Faunistic studies on freshwater oligochates have been actively carried out in the East Asian regions mainly by scientists of China and Japan (Hatai, 1898; Chen, 1940). Consequently, about 319 species and 438 species have been reported in China and Japan, respectively (Ohtaka and Nishino, 1999; 2006; Wang and Cui, 2007; Cui *et al*., 2008; 2015; Cui and Wang, 2009a; 2009b; He *et al*., 2010; Ohtaka, 2012; 2014; Pan *et al*., 2014).

Riverine system of the Korean peninsula is composed of several geographically separated freshwater systems, each of which shows its unique freshwater fauna. Therefore, this peninsula possesses biological diversity more than expected (Jung *et al*., 2009). Nonetheless, study of aquatic oligochaete fauna in Korea is still in its beginning stages compared to those of China and Japan. In Korea, the number of reliable species of aquatic oligochaetes is around 48 species (Brinkhurst *et al*., 1994; Yoon *et al*., 2000; Jung, 2011; 2012; Park *et al*., 2013a; 2013b; Lee and Jung, 2014a; 2014b; 2015). Here, we report twenty-two species of aquatic annelids - 20 species of oligochaetes and one species of aelosomatid - as a result of faunistic studies on specimens collected during nationwide surveys conducted from 2013 to 2014.

Materials and Methods

Specimens were collected from eighteen locations of Korea from 2013 to 2014. We used a shovel to gather gravel, sand, mud and sediment (leave or organic materials, etc.) in sampling sites and/or used a hand net (pore size = 100 μm) at sediment under waterweed or gap between rocks. In the laboratory the samples were observed and sorted by a SMZ-168 stereomicroscope (Motic, Hong Kong). They were fixed in either 8% formalin

or 80% ethanol solution. For species identification, the samples were mounted on slide glasses with Canada balsam following the protocol of Erséus (1994). Key characters were closely investigated such as number and shapes of chaetae, structure and location of reproductive organs using a BX41 research microscope (Olympus, Tokyo, Japan). Pictures of these characters were taken with the camera attached to the research microscope, DP22 (Olympus, Tokyo, Japan). An image analyzing software, InnerView^{TM}-I (Innerview Co. Ltd., Korea) was used in measurement and analysis of image. These mounted collections were submitted to the National Institute of Biological Resources (NIBR) of the Republic of Korea. Other materials, preserved in 80% ethanol solution, are being kept in the lab of Ecology Genetic (LEG), Department of Science Education, Ewha Womans University.

Results and Discussion

Phylum Annelida Linnaeus, 1758
Class Clitellata Linnaeus, 1740
Order Tubificida Brinkhurst, 1982
Family Tubificidae Vejdovský, 1884
Subfamily Naidinae Ehrenberg, 1828
Genus *Paranais* Czerniavsky, 1880

1. *Paranais orientalis* Sokolskaya, 1964 (Fig. 1A)
Paranais litoralis orientalis Sokolskaya, 1964: 57.
Paranais orientalis Finogenova, 1982b: 39.

Material examined. 2 individuals were collected from Gaesu-ri, Daehwa-myeon, Pyeongchang-gun, Gangwon-do, E: 128°23′30.38″ N: 37°29′3.28″, 25 Sep 2014 (collector: Lee J). One individual mounted on a slide was deposited at NIBR (KOSPIV0000216639), and another preserved in 80% ethanol solution was deposited at LEG.
Remarks. The genus *Paranais* can be easily distinguished from other naidine genera with that it has no eyes and dorsal chaetae start from segment V. This genus contains seven species. According to Finogenova (1982b), *P. orientalis* is a species in which the ventral chaetae begin in segment II and each ventral chaetal bundle is composed of 4-5 bifid chaetae (Fig. 1A) with the upper tooth of posterior chaetae being equal or slightly shorter than lower tooth. Mature individuals can be identified with the characteristics that it has 4 to 5 penial chaetae which are S-shaped with bifid end. Unfortunately, our specimen is immature. But other characteristics correspond to the description for species identification. This species could be mostly found in brackish water, but we collected them in freshwater. This is the first report of the genus *Paranais* from Korea.
World distribution. Europe, Sakhalin Island (Russia), East Asia.

Genus *Pristina* Ehrenberg, 1828

2. *Pristina breviseta* Bourne, 1891 (Fig. 1B)
Pristina breviseta Bourne, 1891: 353.
Naidium breviseta Stephenson, 1923: 67.

Material examined. One individual was collected from Sangcho-ri, Mungyeong-eup, Mungyeong-si, Gyeongsangbuk-do, E: 128°6′41.73″ N: 36°43′47.20″, 3 Jul 2014 (collector: Lee J). This specimen was mounted on a slide and deposited at NIBR (KOSPIV0000216646).
Remarks. According to Timm (2009), *Pristina breviseta* has one bifid needle in their dorsal chaetal bundle that is distally curved. Hairs are serrated with one per bundle (Fig. 1B). Ventral chaetae have 3 to 5 bifid per bundle that upper teeth are longer than lower. This species has thick curved spermathecal chaetae in mature individuals. Most of appearances of our sample agree with this description. But we can't observe spermathecal chaetae because our specimen is immature.
World distribution. Sweden, Belarus, Russia, Southern Asia, America.

3. *Pristina notopora* Černosvitov, 1937
Pristina notopora Černosvitov, 1937: 140.

Material examined. One individual was collected from Sukam-ri, Bukpyeong-myeon, Jeongseon-gun, Gangwon-do, E: 128°6′41.73″ N: 36°43′47.20″ 1 Mar 2013 (collector: Lee J). This specimen was mounted on a slide and deposited at NIBR (KOSPIV0000216693).
Remarks. According to Brinkhurst and Jamieson (1971), dorsal chaetal bundles of this species have 1-2 finely serrated hairs and 1-2 bifid needles. The edge of teeth of each needle has been diverged with an acute angle and length of both teeth is equally short. Collado and Schmelz (2001) reported unique characteristic of this species that it has nephridiopore near the dorsal chaetae. Unfortunately, it is hard to observe this characteristics in our sample.
World distribution. South America, Africa, France, Spain, Italy.

4. *Pristina foreli* (Piguet, 1906) (Fig. 1C)
Naidium foreli Piguet, 1906: 222.

Material examined. One individual was collected from Majang-ri, Gwangtan-myeon, Paju-si, Gyeonggi-do, E: 126°52′40.06″, N: 37°46′42.36″, 8 Aug 2014 (collector: Lee J). This specimen was mounted on a slide and deposited at NIBR (KOSPIV0000216696).
Remarks. *P. aequiseta* has giant chaetae in segment V

or VI, while *P. forelii* does not. Our specimen has the characteristics of *P. forelii*, having no giant chaetae in segment V or VI (Fig. 1C).
World distribution. Cosmopolitan.

5. *Pristina synclites* Stephenson, 1925 (Fig. 1D)
Pristina synclites Stepheson, 1925: 45.

Material examined. One individual was collected from Jangheung-ri, Gilsang-myeon, Ganghwa-gun, Incheon, E: 126°30′29.44″ N: 37°37′09.95″, 15 Jul 2010 (collector: Jung J). This specimen was mounted on a slide and deposited at NIBR (KOSPIV0000216711).
Remarks. Our specimen has following features. The proboscis is shorter than the prostomium. Dorsal chaetae have 1-2 non-serrated hair chaetae and 1-2 bifid chaetae (Fig. 1D). Our specimen agrees well with the description of Brinkhurst and Jamieson (1971) on *P. synclites*.
World distribution. Europe, North America, South America, India, Africa, Asia, Neotropical region.

Genus *Bratislavia* Kosel, 1976

6. *Bratislavia prosetosa* (Liang, 1964)
Allodero prosetosa Liang, 1964: 643.
Allonais pectinata Lee and Jung, 2014: 119.

Material examined. One individual was collected from Mangchi-ri, Irun-myeon, Geoje-si, Gyeongsangnam-do, E: 128°40′31.15″ N: 34°48′52.38″, 24 Apr 2013 (collector: Lee J). This specimen was mounted on a slide and deposited at NIBR (KOSPIV0000216733).
Remarks. In our specimen, dorsal chaetae start from segment III. The chaetae of this bundle have only two needles with pectinate tips without hair chaetae. Ventral bundles begin from segment II. Most of the ventral bundles have 4 chaetae of which upper teeth are slightly longer and thinner than lower. These characteristics agree well with the original description of *Bratislavia prosetosa*. This is the first record about the species of *Bratislavia* from Korea.
World distribution. North America, Asia, Australia, Africa.

7. *Allonais gwaliorensis* (Stephenson, 1920)
Nais gwaliorensis Stephenson, 1920: 198.
Allonais gwaliorensis (Stephenson) Sperber, 1948: 205.

Material examined. One individual was collected from Wollong-myeon, Paju-si, Gyeonggi-do, E: 126°46′02.54″ N: 37°48′45.44″, 26 Sep 2014 (collector: Lee J). This specimen was mounted on a slide and deposited at NIBR (KOSPIV0000216759).
Remarks. Genus *Allonais* was first reported from Korea by Lee and Jung (2014). But they confused *B. prosetosa* with *A. pectinata*. Therefore, *Allonais gwaliorensis* is the first record about this genus and the only species of *Allonais* from Korea. We collected it from a polluted stream. Lin and Yo (2008) reported this species able to tolerate high levels of pollution in freshwater, such as *Limnodrilus hoffmeisteri*.
World distribution. South Asia, Madagascar, Africa.

Subfamily Tubificinae Vejdovský, 1884
Genus *Aulodrilus* Bretscher, 1899

8. *Aulodrilus pluriseta* (Piguet, 1906) (Fig. 1E, F)
Naidium pluriseta Piguet, 1906: 218.
Aulodrilus pluriseta (Piguet) Piguet and Bretscher, 1913: 118.

Material examined. One individual was collected from Sin-ri, Sinji-myeon, Wando-gun, Jeollanam-do, E: 126° 48′56.72″ N: 34°20′0.09″, 22 Jun 2014 (collector: Lee J). This specimen was mounted on a slide and deposited at NIBR (KOSPIV0000216805).
Remarks. This species can be easily confused with *A. japonicus* (Milbrink, 1973; Hrabě, 1981), because they are similar in habitat preference and the shape of dorsal chaetae. But, *A. pluriseta* can be discriminated from *A. japonicus* based on the shape of male gonoduct and the number of chaetae per bundle (Fig. 1E, F) (van den Hoek and Verdonschot, 2005). This is the first record about the species of genus *Aulodrilus* from Korea.
World distribution. Cosmopolitan.

Genus *Limnodrilus* Cleparéde, 1862

9. *Limnodrilus neotropicus* Černosvitov, 1939
Limnodrilus neotropicus Černosvitov, 1939: 106.
Limnodrilus neotropicus Černosvitov. Brinkhurst, 1963: 38.

Material examined. One individual was collected from Amtae-myeon, Sinan-gun, Jeollanam-do, E: 128°39′ 23.65″ N: 34°58′27.35″, 8 Mar 2013 (collector: Kim H). This specimen was mounted on a slide and deposited at NIBR (KOSPIV0000206592).
Remarks. The appearance of our specimen agrees well with the original description about *L. neotropicus*.
World distribution. South America.

10. *Limnodrilus maumeensis* Brinkhurst and Cook, 1966 (Fig. 1G)
Limnodrilus maumeensis Brinkhurst and Cook, 1966: 15.

Material examined. One individual was collected from

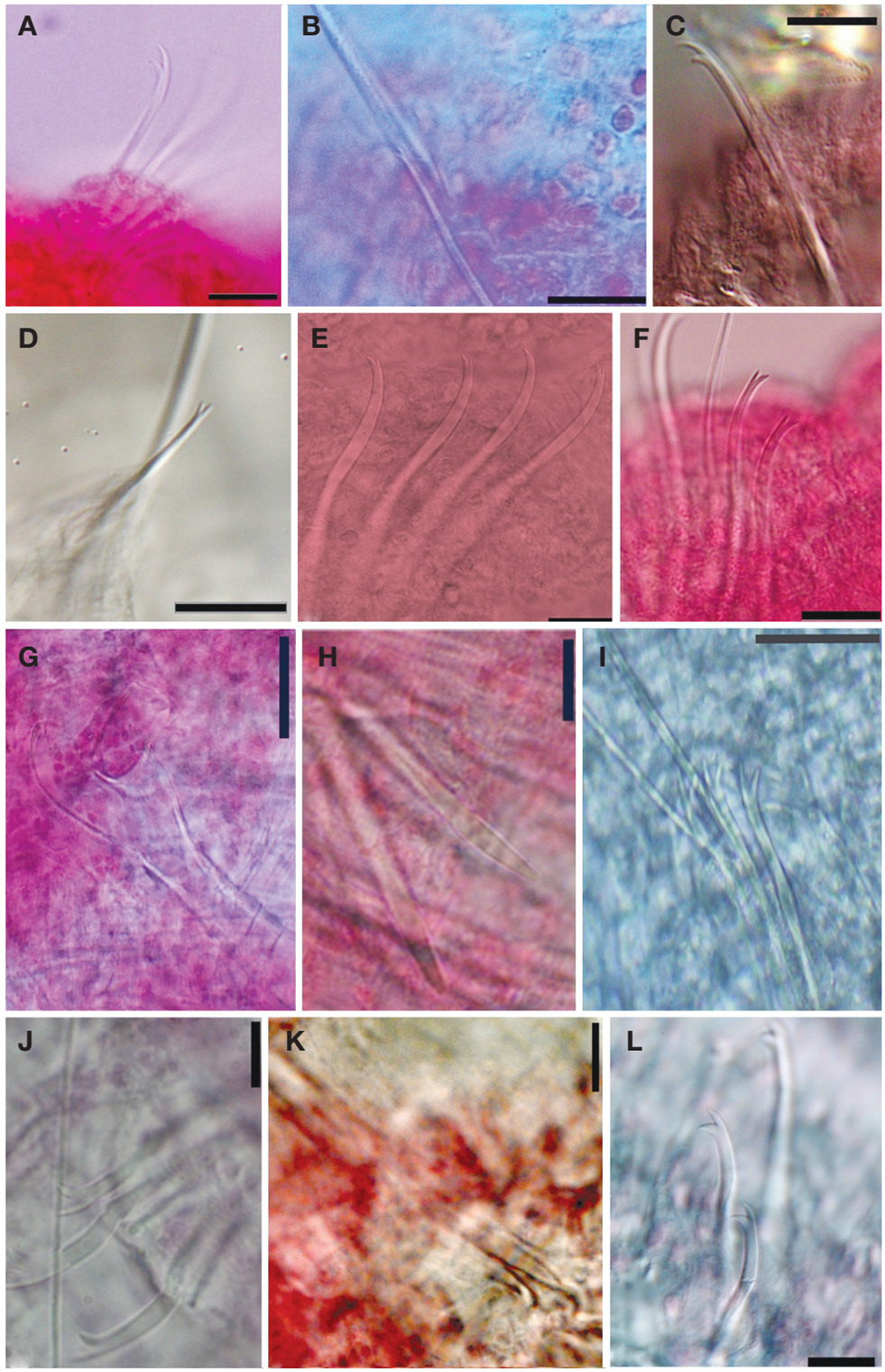


Fig. 1. A. Ventral chaetae of *Paranais orientalis*. B. A dorsal chaetal bundle of *Prisitna breviseta*. C. Ventral chaetae of *P. forelii*. D. A dorsal chaetal bundle of *P. synclites*. E. Ventral chaetae of *Aulodrilus pluriseta*. F. Dorsal chaetae of *A. pluriseta*. G. A penial sheath of *Limnodrilus maumeensis*. H. Chaetae of *L. amblysetus*. I. A dorsal chaetal bundle of *Tubifex ignota*. J. Dorsal chaetae of *Psammoryctides albicola*. K. Spermathecal chaetae of *Varichaetadrilus vestibulatus*. *L.* Ventral chaetae of *Tasserkidrilus* cf. *acapillatus*. Scale bars = A-D, G, K, L = 10 μm, E, F = 20 μm, H-J = 1 μm.

Siljeon-ri, Hacheong-myeon, Geoje-si, Gyeongsangnam-do, E: 128°39′23.65″ N: 34°58′27.35″, 25 Apr 2013 (collector: Lee J). This specimen was mounted on a slide and deposited at NIBR (KOSPIV0000206594).
Remarks. *L. maumeensis* has been confused with *L. cervix*. These species are similar in their penial sheath shape. But the penial hood of *L. cervix* is larger than *L. maumeensis*. Moreover, the penial hood of *L. maumeensis* is larger and has a distal lobe (Van Haaren, 2002; Dumnicka *et al*., 2014). The shape of penial hood of our specimen agrees with that of *L. maumeensis* (Fig. 1G).
World distribution. Netherlands, Belgium, North America.

11. *Limnodrilus amblysetus* Brinkhurst *et al*., 1990 (Fig. 1H)
Limnodrilus amblysetus Brinkhurst *et al*., 1990: 910.
Limnodrilus silvani Eisen, 1879:19; Liang, 1987: 196.

Material examined. One individual was collected from Bureun-myeon, Ganghwa-gun, Incheon, E: 126°31′ 38.89″ N: 37°39′51.10″, 7 April 2013 (collector: Jung J). This specimen was mounted on a slide and deposited at NIBR (KOSPIV0000216811).
Remarks. *L. amblysetus* has chaetae, all of which are bifid or bluntly simple-pointed (Fig. 1H), and the nodulus of anterior chaetae is located at a slightly proximal position (Brinkhurst *et al*., 1990). Our specimen agrees well with the description of Brinkhurst *et al*. (1990).
World distribution. North America, China, Japan.

Genus *Tubifex* Lamarck, 1816 (Fig. 1I)

12. *Tubifex ignota* Štolc, 1886
Lophochaeta ignota Štolc, 1886: 646.
Tubifex ignotus (Štolc): Laakso, 1969. Hrabě, 1981. Chekanovskaya, 1981.

Material examined. One individual was collected from Sugok-ri, Amtae-myeon, Sinan-gun, Jeollanam-do, E: 126°6′17.63″ N: 34°45′46.02″, 7 Mar 2013 (collector: Kim H). This specimen was mounted on a slide and deposited at NIBR (KOSPIV0000206600).
Remarks. This species shows unique feature having long and hispid (barbed) hair chaetae (Fig. 1I) (Timm, 2009; Rodriguez and Achurra, 2010). The shape of our specimen agrees with this diagnostic feature of *T. ignota*.
World distribution. Holarctic.

Genus *Potamothrix* Vejdovsky and Mrazek, 1902

13. *Potamothrix* cf. *bedoti* (Piguet, 1913)
Tubifex (*Ilyodrilus*) *bedoti* Piguet, 1913: 124.
Euilyodrilus bedoti (Piguet). Timm, 1970: 65.
Potamothrix bedoti (Piguet). Timm, 1999: 98.

Material examined. One individual was collected from Siljeon-ri, Hacheong-myeon, Geoje-si, Gyeongsangnam-do, E: 128°39′23.65″ N: 34°58′27.35″, 25 Apr 2013 (collector: Lee J). This specimen was mounted on a slide and deposited at NIBR (KOSPIV0000206595).
Remarks. See remarks on *Potanothrix bavaricus*.
World distribution. Palearctic, North America.

14. *Potamothrix bavaricus* (Öschmann, 1913)
Tubifex (*Ilyodrilus*) *bavaricus* Öschmann, 1913: 559.
Ilyodrilus bedoti Piguet, 1913: 124.
Tubifex (*Ilyodrilus*) *bedoti* Piguet. Piguet and Bretscher, 1913: 67.

Material examined. One individual was collected from Geumchon-dong, Paju-si, Gyeonggi-do, E: 126°46′ 27.01″ N: 37°45′59.37″, 27 Aug 2013 (collector Lee J). This specimen was mounted on a slide, and deposited at NIBR (KOSPIV0000206597).
Remarks. There had been taxonomic debates on the validity of *Potamothrix bedoti* in comparison with *P. bavaricus*. Spencer (1978) performed comparative study on these species from Cayuga Lake in North America. He found that they show difference in habitat preference and some morphological characters. Our results are in accord with those of Spencer's (1978).
World distribution. North America, South America, Australia, New Zealand and Europe.

Genus *Peipsidrilus* Timm, 1977

15. *Peipsidrilus* cf. *pusillus* Timm, 1977
Peipsidrilus pusillus Timm 1977: 279.

Material examined. One individual was collected from Orai-dong, Jeju-si, Jeju-do, E: 126°30′43.75″ N: 33°29′ 44.89″, 22 Jun 2014 (collector: Lee J). This specimen was mounted on a slide and deposited at NIBR (KOSPIV 0000216873).
Remarks. After it was firstly recorded from the North European lakes (Timm, 1977), this species has been described in some central European streams (Hrabě, 1981; Finogenova, 1982a; Arhipova, 2005; Dumnicka and Poznanska, 2006). Morphological features of our specimen agree with the original description of this species. But detailed study on this species should be performed in view of biogeography because this species was rarely reported outside Europe.
World distribution. Europe.

Genus *Psammoryctides* Hrabě, 1964

16. *Psammoryctides albicola* (Michaelsen, 1901) (Fig. 1J)

Lophochaeta albicola Michaelsen, 1901: 4.
Psammoryctides illustris Ditlevsen, 1904: 416.
Tubifex albicola Hrabě, 1931: 309.

Material examined. One individual was collected from Gongneung-dong, Nowon-gu, Seoul, E: 127°6′1.93″ N: 37°38′28.63″, 12 Jun 2014 (collector: Lee J). This specimen was mounted on a slide and deposited at NIBR (KOSPIV0000216896).
Remarks. Morphological features of our specimen agree with original description and re-description of this species (van Haaren and Soors, 2011). This species has easily recognized feature that it has unique long serrated hairs in posterior segments and dorsal chaetae have short intermediate teeth (Fig. 1J).
World distribution. Palaearctic.

Genus *Varichaetadrilus* Brinkhurst and Kathman, 1983 (Fig. 1K)

17. *Varichaetadrilus* cf. *vestibulatus* Cui and Wang, 2009b.

Varichaetadrilus vestibulatus Cui and Wang, 2009b: 47.

Material examined. One individual was collected from Hagwi-ri, Aewol-eup, Jeju-si, Jeju-do, E: 126°24′19.84″ N: 33°29′0.84″, 18 Jun 2014 (collector: Lee J). This specimen was mounted on a slide and deposited at NIBR (KOSPIV0000216893).
Remarks. This species was firstly reported from Yunnan Province, south eastern region of China (Cui and Wang, 2009b). Diagnosis of this species is mostly based on the shape of reproductive organs.

Our specimen has two modified spermathecal chaetae in segment X (Fig. 1K), and segment XI does not have ventral chaetae. Our specimen therefore agree with the original description of this species.
World distribution. China.

Genus *Tasserkidrilus* (Holmquist, 1985)

18. *Tasserkidrilus* cf. *acapillatus* (Finogenova, 1972) (Fig. 1L)

Tubifex acapillatus Finogenova, 1972: 4.

Material examined. One individual was collected from Hagwi-ri, Aewol-eup, Jeju-si, Jeju-do, E: 126°24′19.84″ N: 33°29′0.84″, 18 Jun 2014 (collector: Lee J). This specimen was mounted on a slide and deposited at NIBR; KOSPIV0000216891.
Remarks. According to Timm (2009), this species has 2-6 chaetae with slightly longer, thinner and straighter upper tooth in anterior ventral bundles (Fig. 1L), the penial sheaths of this species look funnel shaped with thin walled. Our specimen agree well with the diagnosis of Timm (2009) about *Tasserkidrilus acapillatus*. This is the first record about *T. acapillatus* in Asian region.
World distribution. Europe.

Order Haplotaxida
Family Enchytraeidae Vejdovský, 1879
Genus *Propappus* Michaelsen, 1905

19. *Propappus volki* Michaelsen, 1916

Propappus volki Michaelsen, 1916: 51-55.

Material examined. One individual was collected from collected from Siseo-ri, Anjwa-myeon, Sinan-gun, Jeollanam-do, E: 126°6′17.63″ N: 34°45′46.02″, 7 Mar 2013 (collector: Kim H). This specimen was mounted on a slide and deposited at NIBR (KOSPIV0000216901).
Remarks. Our specimen agrees with the description of Torii (2006) about Japanese individuals of *Propappus volki*.
World distribution. Palaerctic.

Class Aphanoneura
Order Aeolosomatida
Family Aeolosomatidae Beddard, 1895
Genus *Aeolosoma* Ehrenberg, 1831

20. *Aeolosoma japonicum* (Yamaguchi, 1953)

Aeolosoma japonicum Yamaguchi, 1953: 297.

Material examined. Two individuals were collected from Sangcho-ri, Mungyeong-eup, Mungyeong-si, Gyeongsangbuk-do, E: 128°6′41.73″ N: 36°43′47.20″, 3 Jul 2014 (collector: Lee J). One individual mounted on a slide was deposited at NIBR (KOSPIV0000206602) and the other specimen preserved in 80% ethanol solution was deposited at LEG.
Remarks. This species was mentioned from ecological study about Korean paddy fields (Bang *et al*., 2010). We taxonomically confirmed that morphology of our specimens agree well with the original description of *A. japonicum* (Yamaguchi, 1953).
World distribution. Europe, Japan.

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