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Short communication

An Updated Checklist and Perspective Study of Millipedes (Arthropoda: Myriapoda: Diplopoda) in the Korean Peninsula

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ABSTRACT

The Korean peninsula has diverse habitats and so would be expected to have a rich millipede fauna because of its location between the Paleoarctic and Oriental regions. To facilitate studies on millipedes, this work provides an updated list and discussion of Korean millipedes. A total of 69 species had been recorded up to 2010, but since then no new species have been reported. Among 69 species, 49 are endemic to the Korean peninsula. From 1950 to the present, an average of only seven new species from the Korean peninsula has been described per decade. This number does not reflect the biodiversity of millipedes in Korea, especially when compared to Taiwan, which has only one-third the area of the Korean peninsula, but from which a greater number of millipede species have been recorded (75 vs. 69 species). Japan has twofold the land area of the Korean peninsula, and an almost threefold higher number of millipede species. Further, more-intensive surveys will likely result in identification of more millipede species in the Korean peninsula.

Keywords: Millipedes, Diplopoda, updated list, endemism, Korean peninsula

INTRODUCTION

Millipede (class Diplopoda) is one of the most diverse and ancient groups in nature (Bueno-Villegas et al., 2004; Golovatch and Kime, 2009). To date, about 10,000 species have been described, but 80,000 species are estimated to exist (Bueno-Villegas et al., 2004; Golovatch and Kime, 2009). Millipedes are sarcophagous animals that feed on leaves and tree branches, and play important roles in ecosystems. Their activities accelerate the decay of organic matter, and return materials and nutrients to the ecosystem (Hopkin and Read, 1992; Golovatch and Kime, 2009). Furthermore, millipedes may provide a cure for acquired immune-deficiency syndrome and other serious diseases (Jiang et al., 1981). Therefore, a greater understanding of millipedes will enable more-effective control, use and/or protection of bio-resources.

The Korean peninsula (=Korea, hereafter) is located in northeast Asia. The region's topography is complex, with mountainous areas in the northern and eastern parts and large plains in the southern and western parts; mountains and plains are in some areas integrated. Due to its diverse topography and habitats, the Korean peninsula would be expected harbor a rich millipede fauna.

The millipedes of the Korean peninsula were studied beginning in the late 19th century, and investigations continued during the 20th century. Some important publications need to be taken into account such as Verhoeff (1936, 1937a, 1937b, 1938), Takakuwa (1940). The first list of millipedes in Korea was simply presented by Takakuwa and Kakashima (1940, 1944). The list was updated by Paik (1958) containing 22 species; several species were added later and summarized in

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the other list, which included 33 species (Lim, 1988). Lim (2001) summarized 48 species in his dissertation. This list is out of date due to recent discoveries of new species (Mikhaljova and Lim 2006a, 2006b, 2006c, 2008). Lim (2011) presented the list of 50 species plus 2 subspecies in 28 genera, 13 families and seven orders reported from the Korean peninsula. The most recent list was published by Lim (2013) in the National List of Species of Korea. This list contains 69 species in 32 genera, 15 families of seven orders. However, as species record confirmation and taxonomic treatment made by Mikhaljova (2001), Golovatch (2011), the list of Korean millipedes need to be updated. Thus, the present work aimed to provide an updated list of millipedes inhabiting Korea, a discussion of the millipede fauna, and comparison with neighboring countries. The updated list was compiled based on the previous studies of millipedes in Korea.

RESULTS AND DISCUSSION

A total of 69 species belonging to 31 genera, 15 families, and seven orders has been recorded in the Korean peninsula (Tables 1, 2). In comparison with the previous list presented by Lim (2013), *Angorozonium bonum* (Mikhaljova, 1979) was excluded from the list of Korean millipedes as discussed by Mikhaljova (2001); *Oxidus obtusus* (Takakuwa, 1942) was re-added; and *Koreadesmus proprius* Mikhaljova & Korsós, 2003 was reallocated to the genus *Cawjeekelia* by Golovatch (2011). The millipede fauna of Korea was dominated by julidan and polydesmidan species (20 and 25 species, respectively).

The millipede fauna of Korea has high endemism. Of the 69 species, 49 are considered to be endemic because they are found only in Korea; the following 10 species are present in both Korea and the Asian part of Russia: *Ansiulus matumotoi*, *Skleroprotopus coreanus*, *Anaulaciulus golovatchi*, *Diplomaragna kedrovaya*, *Orientyla dahurica*, *Levizonus variabilis*, *Sichotanus eurygaster*, *Cawjeekelia koreana*, *Epanerchodus koreanus*, and *Epanerchodus polymorphus*. Another 10 species are found in both Korea and Japan: *Amblyiulus lobatus*, *Brachycybe nodulosa*, *Diplomaraga gracilipes*, *Riukiuria semicircularis*, *Orthomorphella pekuensis*, *Oxidus gracilis*, *Oxidus obtusus*, *Nedyopus patrioticus*, *Epanerchodus bifidus*, and *Rhipidopeltis sinuata*.

Table 1. An updated list of millipedes in Korea

Order Polyxenida Lucas, 1840
Family Polyxenidae Lucas, 1840
Genus *Polyxenus* Latreille, 1802
Polyxenus koreanus Ishii & Choi, 1988

Order Glomerida Leach, 1815
Family Glomeridae Leach, 1815
Genus *Hyleoglomeris* Verhoeff, 1910
Hyleoglomeris koreana Golovatch, 1978
Hyleoglomeris unicolorata Lim, 2006
Hyleoglomeris buana Lim, 2006
Hyleoglomeris obscura Lim, 2006
Hyleoglomeris confragosa Mikhaljova & Lim, 2006
Hyleoglomeris alutacea Mikhaljova & Lim, 2006

Order Polyzoniida Newport, 1844
Family Polyzoniidae Newport, 1844
Genus *Angarozonium* Shelley, 1998
Angarozonium munsunum Mikhaljova, Golovatch & Wytwer, 2000

Family Hirudisomatidae Silvestri, 1896
Genus *Kiusiozonium* Verhoeff, 1941
Kiusiozonium okai (Takakuwa & Miyosi, 1949)

Order Julida Leach, 1814
Family Nemasomatidae (Bollman, 1893)
Genus *Antrokoreana* Verhoeff, 1938
Antrokoreana gracilipes Verhoeff, 1938

Family Mongoliulidae Pocock, 1903
Genus *Ansiulus* Takakuwa, 1940
Ansiulus aberrans Mikhaljova & Korsós, 2003
Ansiulus legitimus Golovatch, 1980
Ansiulus matumotoi Takakuwa, 1940
Genus *Skleroprotopus* Attems, 1901
Skleroprotopus coreanus (Pocock, 1895)
Skleroprotopus hakui Takakuwa, 1940
Skleroprotopus laticoxalis laticoxalis Takakuwa, 1942
Skleroprotopus laticoxalis longus Murakami & Paik, 1968
Skleroprotopus ramuliferus Lim & Mikhaljova, 2000
Skleroprotopus chollus Mikhaljova & Korsós, 2003
Skleroprotopus costatus Mikhaljova & Korsós, 2003
Genus *Ussuriiulus* Golovatch, 1980
Ussuriiulus pilifer Golovatch, 1980

Family Julidae Leach, 1814
Genus *Amblyiulus* Silvestri, 1896
Amblyiulus lobatus (Verhoeff, 1937)
Genus *Anaulaciulus* Pocock, 1895
Anaulaciulus koreanus koreanus (Verhoeff, 1937)
Anaulaciulus koreanus salebrosus Mikhaljova & Kim, 1993
Anaulaciulus koreanus boninensis (Verhoeff, 1939)
Anaulaciulus tonggosanensis (Paik, 1976)
Anaulaciulus golovatchi Mikhaljova, 1982
Anaulaciulus riedeli Jdryczkowski, 1982
Anaulaciulus koreacolus Jdryczkowski, 1982

Order Platydesmida de Saussure, 1850
Family Andrognathidae Cope, 1869
Genus *Yamasinaium* Verhoeff, 1939
Yamasinaium koreanum Golovatch, 1981
Genus *Brachycybe* Wood, 1864
Brachycybe nodulosa (Verhoeff, 1935)

Order Chordeumatida Koch, 1847
Family Megalotylidae Golovatch, 1978
Genus *Megalotyla* Golovatch, 1978
Megalotyla glabra Mikhaljova, Golovatch & Wytwer, 2000

Table 1. Continued

Family Diplomaragnidae Attems, 1907
Genus *Diplomaragna* Attems, 1907
Diplomaragna gracilipes (Verhoeff, 1914)
Diplomaragna kedrovaya Mikhaljova, 1993
Genus *Tokyosoma* Verhoeff, 1932
Tokyosoma ronkayi (Shear, 1990)
Tokyosoma hallum Mikhaljova & Korsós, 2003
Tokyosoma bellum Mikhaljova & Lim, 2008
Tokyosoma phialiferum Mikhaljova & Lim, 2008
Genus *Pterygostegia* Miyosi, 1958
Pterygostegia korsosi (Shear, 1990)
Genus *Orientyla* Mikhaljova, 1999
Orientyla kjongsonica Mikhaljova, Golovatch & Wytwer, 2000
Orientyla dahurica (Gerstfeldt, 1859)
Genus *Koreagna* Mikhaljova & Lim, 2008
Koreagna obtecta Mikhaljova & Lim, 2008

Family Hoffmaneumatidae Golovatch, 1978
Genus *Hoffmaneuma* Golovatch, 1978
Hoffmaneuma exiguum Golovatch, 1978

Order Polydesmida Leach, 1815
Family Xystodesmidae Cook, 1895
Genus *Riukiaria* Attems, 1938
Riukiaria semicircularis (Takakuwa, 1941)
Genus *Koreoaria* Verhoeff, 1937
Koreoaria pallida Verhoeff, 1937
Koreoaria amoena Takakuwa, 1942
Genus *Levizonus* Attems, 1898
Levizonus circularis Takakuwa, 1942
Levizonus variabilis Lokshina & Golovatch, 1977
Genus *Parafontaria* Verhoeff, 1936
Parafontaria koreana (Paik, 1963)
Genus *Pachydesmus* Cook, 1895
Pachydesmus bazanensis Takakuwa, 1942[a]

Family Paradoxosomatidae Daday, 1889
Genus *Orthomorphella* Hoffman, 1963
Orthomorphella pekuensis (Karsch, 1881)
Genus *Oxidus* Cook, 1911
Oxidus gracilis (C. L. Koch, 1847)
Oxidus obtusus (Takakuwa, 1942)[b]
Genus *Sichotanus* Attems, 1914
Sichotanus eurygaster (Attems, 1898)
Genus *Nedyopus* Attems, 1914
Nedyopus patrioticus (Attems, 1898)
Genus *Cawjeekelia* Golovatch, 1980
Cawjeekelia gloriosa Golovatch, 1980
Cawjeekelia koreana (Golovatch, 1980)
Cawjeekelia pyongana Mikhaljova & Kim, 1993
Cawjeekelia iksana Mikhaljova & Lim, 2000
Cawjeekelia propria (Mikhaljova & Korsós, 2003)

Family Polydesmidae Leach, 1815
Genus *Epanerchodus* Attems, 1901
Epanerchodus koreanus Verhoeff, 1937
Epanerchodus bifidus Takakuwa, 1954
Epanerchodus kimi Murakami & Paik, 1968
Epanerchodus clavisetosus Murakami & Paik, 1968
Epanerchodus polymorphus Mikhaljova & Golovatch, 1981
Epanerchodus beroni Mikhaljova & Kim, 1993
Epanerchodus gangwonus Mikhaljova & Lim, 2001
Epanerchodus bacilliferus Mikhaljova & Lim, 2006

Family Haplodesmidae Cook, 1895
Genus *Rhipidopeltis* Miyosi, 1958
Rhipidopeltis sinuata Miyosi, 1958

[a]The species, *Pachydesmus bazanensis* Takakuwa, 1942 is being doubtful. Chamberlin and Wang (1953) assigned this species to the genus *Nikkonus* which was subsequently synonymized with the genus *Xystodesmus* by Tanabe and Shinohara (1996). However, the type material of the species was destroyed because of fire in 1945, the taxonomic status of the species is still being questionable. Marek et al. (2014) placed it in the section "Species of uncertain status in *Xystodesmus*" and suggested that confirmation of its generic status awaits collection of fresh topotypic material from South Korea.
[b]The species, *Oxidus obtusus* (Takakuwa, 1942) was described based on a single male from South Korea, and later Chamberlin and Wang (1953) recorded two females from South Japan. However, there are no more records since then. Lim (2001) discussed and synonymized this species with its congener, *Oxidus gracilis* based on small differences in gonopod conformation. It is strongly recommended to have fresh material to confirm the species status.

Of 69 species, *Oxidus gracilis* is widely distributed in the subtropics and tropics, and *Orthomorphella pekuensis* is present in China, Japan, and Taiwan (Nguyen and Sierwald, 2013). Two doubtful species, *Pachydesmus bazanensis* and *Oxidus obtusus*, need to be revised due to they have not been re-found in Korea since their description.

Of 16 known millipede orders, only seven have been recorded in Korea. Some orders, such as Siphonophorida, Spirobolida, Spirostreptida, are found in Japan, China, and Taiwan, but not in Korea to date. Theoretically, Korea is located within the distributional regions of those orders (Shelley and Golovatch, 2011); thus, those orders could be present in Korea and awaiting discovery.

The number of new species found in Korea has increased slowly, with an average of seven new species per decade since 1950 (Fig. 1). The majority of new species (15 species) were described during 2001–2010; however, no new species have been discovered in Korea since 2010.

Table 2. Number of recorded millipede species in Korea

No.	Orders	No. of families	No. of genera	No. of species
1	Polyxenida	1	1	1
2	Glomerida	1	1	6
3	Polyzoniida	2	2	3
4	Julida	3	6	20
5	Platydesmida	1	2	2
6	Chordeumatida	3	7	12
7	Polydesmida	4	12	25
	Total	15	31	69

In comparison with neighboring countries, Korea has medium area, but only 69 species have been recorded. In con-

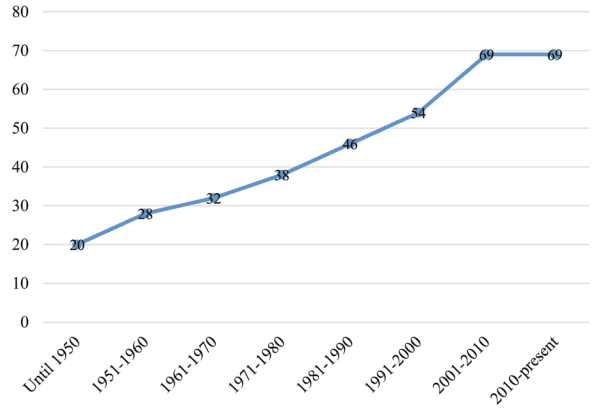

Fig. 1. Number of millipede species recorded in Korea from 1950 to the present.

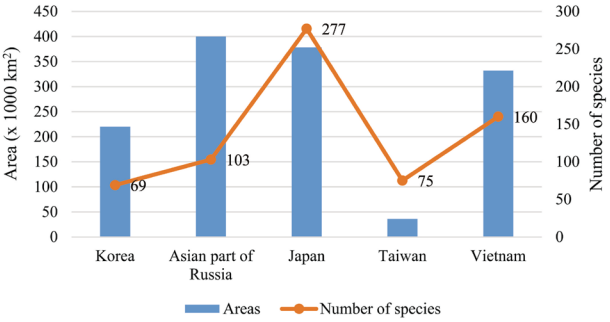

Fig. 2. Number of millipede species from Korea and four Asian neighboring countries in comparison to their territorial sizes. Data sources: Asian part of Russian from Mikhaljova (2004); Japan from Murakami (1993); Taiwan from Korsós (2004) plus Chen et al. (2006, 2008, 2010), Mikhaljova et al. (2010); and Vietnam from Enghoff et al. (2004), plus Nguyen et al. (2005), Golovatch and Nguyen (2007), Nguyen (2009, 2010a, 2010b, 2011, 2012).

trast, Taiwan is a small island, but 75 species have been recorded to date (Fig. 2). Japan is larger, and almost 300 millipede species have been identified to date. Korea is smaller than Vietnam in terms of land area, but has only one-third the number of millipede species. This suggests that the millipede fauna of Korea have not been the subject of sufficient investigations. Further undescribed species may await discovery in Korea.

Korea is considered a valuable site for speciation and evolution studies because of its function as a geographical bridge between the Asian continent and the Pacific Ocean (Lim, 2001). The poor understanding of millipede fauna has impaired our understanding of millipede speciation and evolution. Therefore, further in-depth surveys of the millipedes of Korea are warranted.

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