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Biogeography meets taxonomy: Distribution-based inferences on the accuracy of identification and synonymization of East Asian earthworms

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Abstract

This paper demonstrates that the uniqueness of the geographical location of Taiwan and its adjacent islands can be taken as a basis to evaluate the accuracy of identification and synonymization of East Asian earthworms and further to clarify some disputes in earthworm taxonomy. A comprehensive review of the earthworm fauna from the Ryukyu Archipelago is given; as a result, two recorded species are recognized as new species, named here *Amynthas ishigakiensis* **sp. nov.** and *Amynthas iriomotensis* **sp. nov.** Common but harmful practices in earthworm taxonomy, synonymies with question marks and erection of sympatric subspecies, are commented.

Key words: Earthworms, biogeography, taxonomy, synonym, Taiwan, the Ryukyu Archipelago

Introduction

The earthworm fauna of Taiwan and its adjacent islands is by now very well-known due to great efforts made from the end of the 20th century. Only 26 species were recorded prior to 1999 (Tsai *et al*. 2009) while 110 species have been reported to date (Shen *et al*. 2018). Not only the occurrence of species but also their distributional area is known intimately. So for Taiwan it is known where a species occurs and - equally important! - where not. Taiwan and the adjacent islands have an immense diversity of climatic habitat types, ranging from tropical to alpine. In this climatic gradient, each species occupies a peculiar section, which may be called a niche, depending on its ecological requirements, and origin. In non-endemic species, this section corresponds to the climate of the known distributional area of the species outside Taiwan. This knowledge allows estimates regarding the occurrence or no-occurrence of species in other regions. Earthworm taxonomy in East Asia is difficult owing to an enormous number of species assembled in few genera, the often minute differences between species, and the resulting probability of misidentifications. Misidentifications can have severe effects on the progress of knowledge.

Usually taxonomy (here: the zoological discipline of recognizing and distinguishing species) is made useful for biogeography, but by now we know enough about several species to do the reverse: *to make biogeography useful for taxonomy*. This paper is a first attempt to do so. In brief, the known distributional range of earthworms in Taiwan is used as a template to pinpoint possible misidentifications of species in the literature. In the following chapters, I first summarize how earthworm species are distributed in Taiwan and the adjacent islands. Second I consider how misidentifications and false synonymies have prevented a full understanding of the earthworm diversity of the Ryukyu Island chain, and then I evaluate the accuracy of identification and synonymization of East Asian earthworms based on knowledge gained from the earthworm studies of Taiwan, its adjacent islands and the Ryukyu Archipelago. Last I comment on the erection of sympatric subspecies, an action which neglects the biogeographical implication inherent in each species and subspecies and could be a result of misidentification or misjudgment. Beyond the concept of biogeography, morphological and molecular data (if available) are also used to corroborate the distribution-based inferences concerning identifications and synonymizations. Common but harmful practices in earthworm taxonomy, such as synonymies with question marks, which in subsequent papers convert to fully established synonymies without further evidence, and the establishment of sympatric subspecies as

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mentioned above should not be continued. Otherwise, the already confusing earthworm taxonomy will surely become more chaotic in the future.

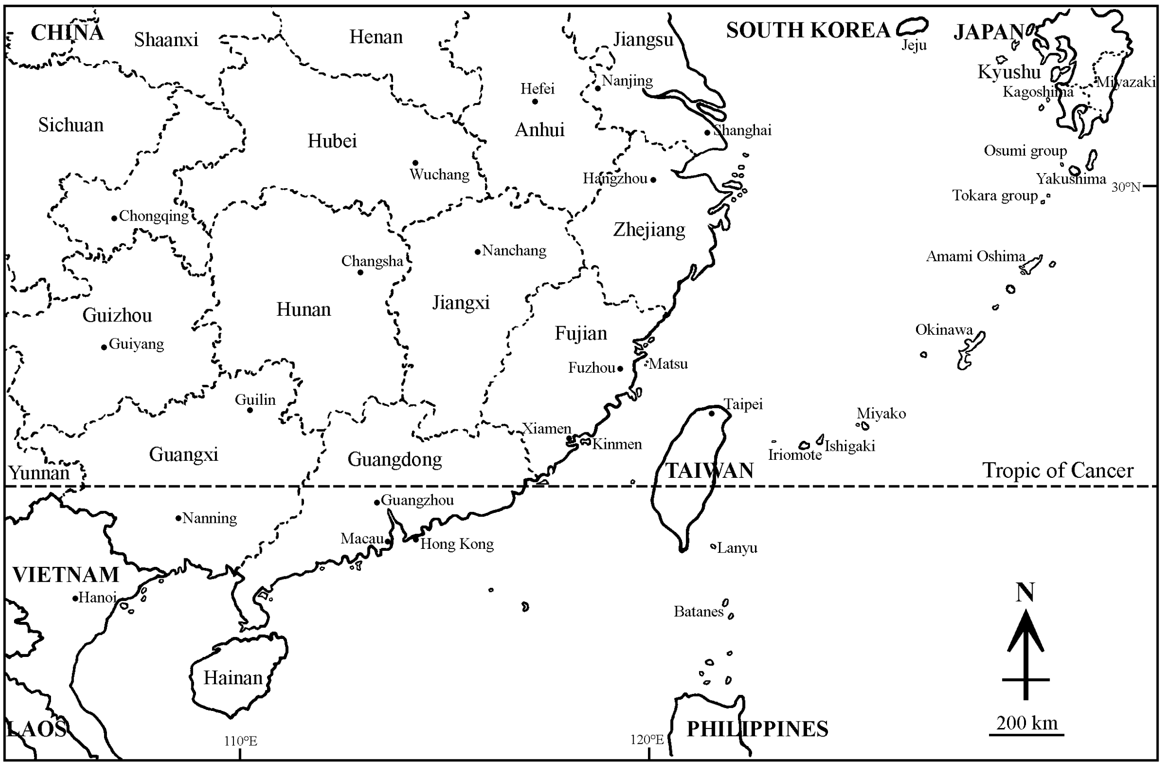

FIGURE 1. Location of Taiwan, Kinmen, Matsu, and Lanyu islands and the Ryukyus.

Geography and earthworm species distribution in Taiwan and its adjacent islands

Situated in the Taiwan Strait about 150 km southeast of China, Taiwan is located approximately in the middle of the East Asian coastline extending from Japan and Korea to Indonesia. The area of Taiwan is about 36000 km^2 with the longitudinal axis measuring 385 km and maximum width 143 km (Ota 1997). With the Tropic of Cancer running through (Fig. 1), the island of Taiwan is divided into a southern tropical and a northern subtropical zone. Taiwan was created by the collision between the Eurasian Plate and the Philippine Sea Plate. This tectonic movement caused the formation of several mountain ranges lying north southward in Taiwan with the highest peak, Yushan (Mt. Jade), reaching 3952 m in elevation. The Central Mountain Range, with more than 200 mountain peaks higher than 3000 m (Chang *et al.* 2008), forms the "backbone" of the island and acts as a major driver of morphological and genetic differentiation and allopatric speciation (Tzeng 1986; Toda *et al.* 1998; Tsai *et al.* 2000b; Hsu *et al.* 2001; Shen *et al.* 2002; Chang *et al.* 2008; Lin *et al.* 2012). In winter, snow often covers the mountain tops. During the Pleistocene ice ages, Taiwan was connected periodically by land bridges to the Chinese mainland, providing species opportunities for the dispersal from the continent into Taiwan (Ota 1997; Tsai *et al.* 2000a; 2002). As a consequence of a combination of the above factors, the fauna and flora in Taiwan include (1) native species arising from within-island speciation, (2) cold climate species from the northern temperate zone of the continent inhabiting the northern area or regions of higher elevation, and (3) warm climate species from Southeast Asia dwelling in the southern area or at lower elevations. Tsai *et al.* (2004) have demonstrated that these different types of biogeographical origin are reflected in an altitudinal stratification in the distribution of earthworm species in centro-western Taiwan. Each native earthworm species occupies a species-specific geographical area within a certain altitudinal range. As for exotic or peregrine species, most of them are common in the coastal plains and foothills, and their highest altitudinal range depends on their adaptability to altitudinal climates (Tsai *et al*. 2004; Fig. 2). For example, species originated from the temperate or warm temperate zone such as *Amynthas corticis* (Kinberg, 1867), *Amynthas gracilis* (Kinberg, 1867) and *Metaphire californica* (Kinberg, 1867) can reach an elevation as high as 2100 m, whereas species from the subtropical or tropical zone like *Amynthas aspergillum* (Perrier, 1872), *Amynthas morrisi* (Beddard, 1892), *Amynthas papulosus* (Rosa, 1896), *Amynthas robustus* (Perrier, 1872), *Metaphire posthuma* (Vaillant, 1869) and *Pontoscolex corethrurus* (Müller, 1856) are only found at elevations under 1100 m or even lower. The above species which have great environmental tolerance show an island-wide distribution. Furthermore, the distribution of the four peregrine species *Amynthas hupeiensis* (Michaelsen, 1895), *Amynthas rockefelleri* (Chen, 1933), *Metaphire houlleti* (Perrier, 1872) and *Polypheretima elongata* (Perrier, 1872) in Taiwan also coincides with their respective origins. Both *A. hupeiensis* and *A. rockefelleri* are from central China (Chen 1933); they are common in northern Taiwan, seldom found in central Taiwan, and have never been collected in southern Taiwan. *Pol. elongata* and *M. houlleti*, on the other hand, are from Southeast Asia (Gates 1972). The former can be found in central and southern Taiwan while the latter occurs in southern Taiwan only. A similar pattern is found when comparing the earthworm species composition of Matsu and Kinmen, two offshore islands of the coast of Fujian Province, southeast China with the former located about 280 km northeast of the latter (Shen *et al*. 2015). Species with tropical origin and present in Kinmen such as *A. papulosus*, *Pon. corethrurus* and *Dichogaster bolaui* (Michaelsen, 1891) were not collected in Matsu. In contrast, *Aporrectodea trapezoides* (Dugès, 1828), a temperate-zone species, and species belonging to Moniligastridae including the newly recorded *Desmogaster sinensis* Gates, 1930 and *Drawida koreana* Kobayashi, 1938 were common in Matsu but not found in Kinmen (Shen *et al*. 2015). Of further interest is the earthworm fauna of Lanyu (Botel Tobago), an oceanic volcanic island about 62 km southeast of Taiwan and about 110 km north of the Batan Islands of the Philippines (Shen & Tsai 2002). Among a total of ten species of earthworms reported from Lanyu, *Pithemera lanyuensis* Shen & Tsai, 2002 is the only endemic species (Shen & Tsai 2002; Shen 2018). Since *Pi. lanyuensis* is closely related to *Pithemera bicincta* (Perrier, 1875) originated from the Philippines, this finding shows the geographical association of Lanyu to the Philippines and further supports the content that the northern Wallace's line should be drawn between Lanyu and Taiwan (Kano 1932a, b, c, d).

Earthworms of the Ryukyu Archipelago

The Ryukyu Archipelago spans the transition zone from subtropical to warm temperate climate with major islands of Iriomote, Ishigaki, Miyako, Okinawa, Amami, Tokara and Ōsumi stretching about 1000 km northeastward from Taiwan to Kyushu, Japan (Fig. 1). The knowledge of its earthworm fauna stems mainly from two papers of Ohfuchi (1956; 1957a). Prior to Ohfuchi (1956; 1957a), Kobayashi (1941) documents 12 peregrine species and subsequent studies add four more species with two of them endemic to Okinawa only (Ishizuka *et al*. 2000; Blakemore *et al*. 2006; Oba *et al*. 2015). Like Taiwan and Matsu Islands, the fauna of the Ryukyu Archipelago should have its own characteristics correlating with the climatic gradient from subtropical in the southwest to warm temperate in the northeast. However, misidentifications and false synonymies made these characteristics unrecognizable. The identifications of more than half of the 19 species and two of the six species of earthworms reported by Ohfuchi (1956) and Ohfuchi (1957a), respectively, from the Ryukyu Islands were in error (Table 1). These erroneous records subsequently misled earthworm taxonomists who did not read or inspect the related descriptions and/or figures carefully or were unaware of the arguments about Ohfuchi's misidentifications sporadically distributed in Gates (1972), and caused further confusion (Easton 1981; Blakemore 2003; Nguyen *et al*. 2016). For example, both Easton (1981) and Blakemore (2003) tentatively synonymized *Pheretima houlleti bidenryoana*, *Pheretima leucocirca* and *Pheretima noharuzakiensis* described in Ohfuchi (1956) with *Amynthas flavescens* (Goto & Hatai, 1898) [adding question marks to the synonymy, but synonymy without question marks for *houlleti bidenryoana* and *noharuzakiensis* can also be seen in Blakemore (2003, p. 6)] (Table 1), even though the four taxa are distinctively different (see comparisons in Table 2). Later, Blakemore (2012b) retained *leucocirca* in synonymy with *A. flavescens* with a question mark and *bidenryoana* and *noharuzakiensis* without question marks (Table 1). The type locality of *A. flavescens* is Tokyo, Japan (35°42'N, 139°42'E), while specimens of *bidenryoana*, *leucocirca* and *noharuzakiensis* described by Ohfuchi (1956) were all collected from places south of 25°N. The latter three taxa in Ohfuchi (1956) are possibly earthworms native to the Ryukyu Archipelago since they are morphologically distinguishable from the other members of *Amynthas* with three pairs of spermathecal pores in 6/7–8/9.

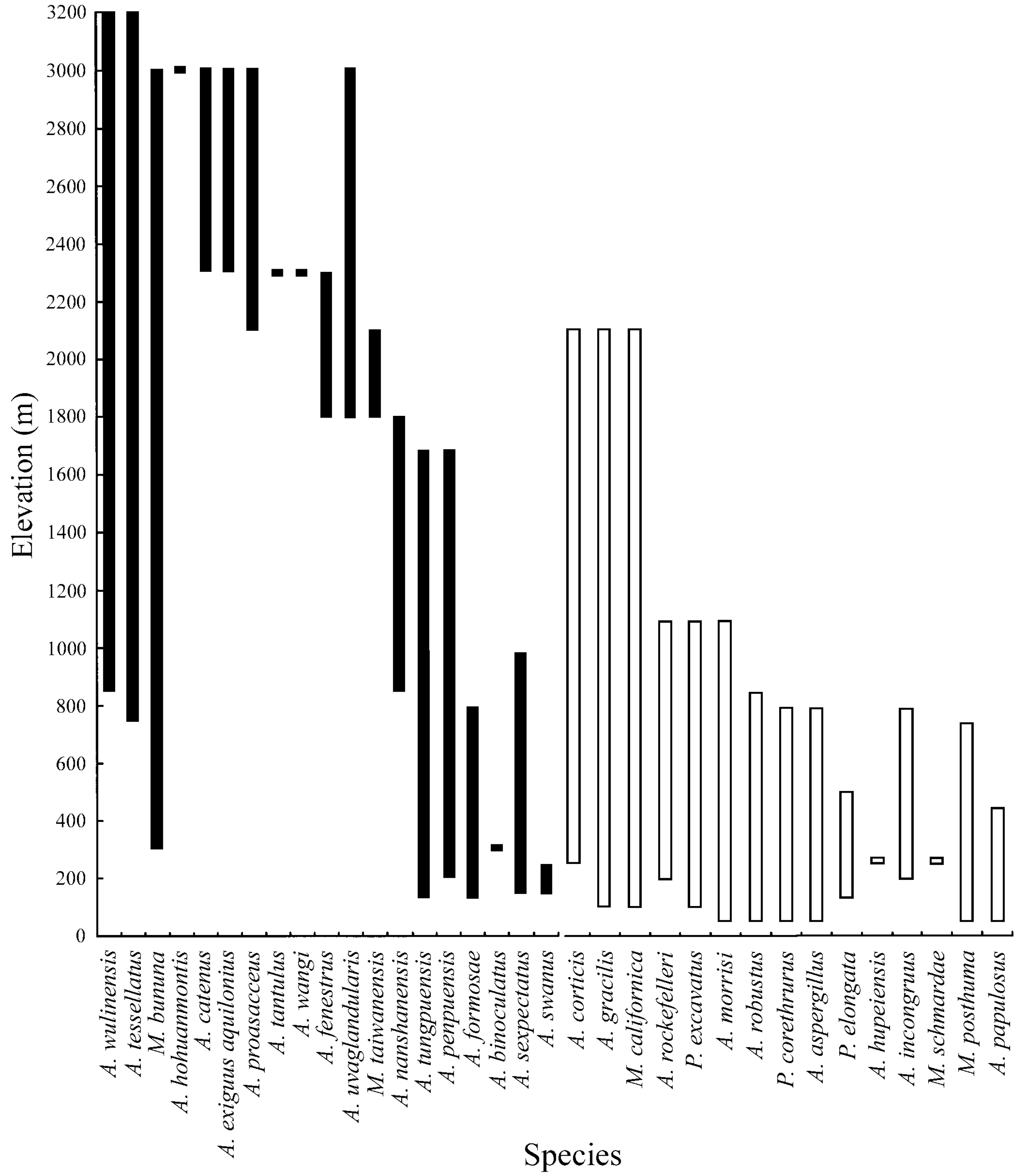

FIGURE 2. Altitudinal ranges in distribution of the native species (solid columns) and the exotic species (open columns) of megascolecid earthworms in the centro-western Taiwan updated and modified from Fig. 2 in Tsai *et al*. (2004).

Additionally, *Pheretima hatomajimensis* from Hatomajima, Iriomote described by Ohfuchi (1957a) was synonymized with *A. corticis* by both Easton (1981) and Blakemore (2003; 2012b) with a question mark, in spite of their disparate papilla arrangement around the male porophore (Tsai *et al*. 2007). Also, the reproductive organs of *A. hatomajimensis* are normal without any sign of degeneration (Tsai *et al*. 2007) and the paired genital papillae on presetal VII–IX often observed in *A. corticis* are absent from *A. hatomajimensis*.

Besides, Easton (1981), Blakemore (2003) and Blakemore *et al*. (2006) considered *Dichogaster hatomaana* from Hatomajima near Iriomote described by Ohfuchi (1957a) identical to *Dichogaster saliens* (Beddard, 1892). Then Blakemore (2012b, p. 17) ambiguously synonymized *Di. hatomaana* with *Di. saliens* and also with *Di. bolaui* both with a question mark. Notwithstanding the similarities among these species, *Di. hatomaana* differs clearly from *Di. saliens* in having a single, mid-ventral female pore and a narrow genital zone commenced from segment XV and ended in segment XVII without any marking or papilla as described and illustrated by Ohfuchi (1957a). *Di. hatomaana* seems more similar to *Di. bolaui*, but yet the former is biprostatic (a pair of prostate glands in XVII) while the latter is quadriprostatic (a pair of prostate glands in each of XVII and XIX). In fact, *Di. hatomaana* should be maintained as a valid species.

The biogeographical picture of the Ryukyu Archipelago was first distorted by Ohfuchi who misidentified his specimens as *A. papulosus*, *M. houlleti* and *Metaphire peguana* (Rosa, 1890) which are tropical species. As mentioned previously, *A. papulosus* has an island-wide distribution in Taiwan but was not collected in Matsu. It is possible for *A. papulosus* to be present in islands of the southern part of the Ryukyu Archipelago, namely Iriomote, Ishigaki and Miyako, but no specimen was found from this region so far. On the other hand, *A. papulosus* should be absent from Okinawa and islands north of Okinawa because Okinawa is about the same latitude as Matsu. Also, it is unlikely for *M. houlleti* to appear in the Ryukyu Archipelago since it occurs in southern Taiwan only. As to *M. peguana*, it has never been found throughout mainland China or Taiwan, not to mention the Ryukyu Islands. To summarize, erroneous identifications of specimens and false synonymies by subsequent authors have led to a "banalization" of the fauna, because what seem to be endemic species were identified as peregrine ones. Obviously, the biodiversity of the local earthworm fauna of the Ryukyu Archipelago has been underestimated.

In the following, I compare the descriptions of "*Pheretima peguana*" and "*Pheretima leucocirca*" in Ohfuchi (1956) with the original descriptions and with those of other members of *Amynthas* having three pairs of spermathecal pores in 6/7–8/9, and I conclude that *Ph. peguana* and *Ph. leucocirca* sensu Ohfuchi (1956) should be recognized as two new species. They are named *Amynthas ishigakiensis* **sp. nov.** and *Amynthas iriomotensis* **sp. nov.**, respectively, and their descriptions, cited at full length from Ohfuchi (1956) with slight modifications, are given below.

After all the revisions and corrections, a total of 28 earthworm species have been recorded hitherto from the Ryukyu Archipelago (Table 3). Albeit Ohfuchi (1957b) claimed that a total of 25 earthworm species (with eight species and one variety being new to science) were found from various parts of Okinawa, Miyako, Ishigaki and Iriomote, the actual number should be corrected to a total of 19 species, with eight of them new to science (endemic) being reported by Ohfuchi (1956; 1957a). Compared with Ohfuchi's (1956; 1957a) findings, the earthworm biogeographical picture of the Ryukyu Archipelago has changed little since then. Some of the conclusions drawn by Ohfuchi (1957b) are worth mentioning: (1) no species in the collection has complicated intestinal caeca like those in the Japanese *Pheretima*; the simple intestinal caeca in earthworms examined are more similar to those of the species living in the Oriental region and not to those of Kyushu, Shikoku and Honshu, Japan, (2) the more cosmopolitan species such as *Aporrectodea caliginosa* (Savigny, 1826) and *Eisenia fetida* (Savigny, 1826) are not found in the collection (both are of temperate origin), and (3) species commonly distributed everywhere on the mainland of Japan are not found in the collection, suggesting evident differences between the earthworm fauna of the Ryukyu Islands and that of the mainland of Japan.

Contrasting with the dissimilarity between the earthworm fauna of the Ryukyu Islands and that of the mainland of Japan, *Metaphire riukiuensis* (Ohfuchi, 1957) from Iriomote and Ishigaki islands shows great morphological similarity to members of the *Metaphire formosae* species-group proposed by Chang *et al*. (2008; 2014). The *M. formosae* species-group is a monophyletic group consisting of 15 species and subspecies of giant earthworms endemic to Taiwan, and most species of this group are allopatrically distributed with isolation by mountains and/or rivers (Chang *et al*. 2008; 2014). Both *M. riukiuensis* and members of the *M. formosae* species-group share the following combination of characters: (1) large body size with lengths around 30 cm and widths about 1 cm, (2) four pairs of morphologically similar spermathecae in VI–IX, (3) absence of preclitellar genital markings, (4) short, stout, muscular and rather straight prostatic ducts, and (5) simple intestinal caeca. The close resemblance between *M. riukiuensis* and *Metaphire formosae* (Michaelsen, 1922) was also noted by Ohfuchi (1957a).

TABLE 1. Misidentifications and controversial taxa in Ohfuchi (1956; 1957a) together with their taxonomic history.

Author's opinion	Taxonomic history
Amynthas asacceus (Chen, 1938)	Ohfuchi 1956, p. 138: *Pheretima pusilla* nov. sp. Sims & Easton 1972, p. 236, 245; Easton 1981, p. 54: *Amynthas pusillus* (Ohfuchi, 1956) Tsai *et al*. 2001, p. 284; 2002, p. 757, 761: = *Amynthas asacceus* (Chen, 1938) Blakemore 2003, p. 7, 36; 2012b, p. 20: = *Amynthas assacceus* (Chen, 1938)
Amynthas glabrus (Gates, 1932)	Ohfuchi 1956, p. 140: *Pheretima papilio* Gates Gates 1972, p. 205: Identification of specimens as *Ph. papilio* not justified due to contradictions in color, locations of spermathecal pores and of intestinal origin Easton 1981, p. 50; Blakemore 2003, p. 6, 19; 2012b, p. 18: *Amynthas glabrus* (Gates, 1932)
Amynthas morrisi (Beddard, 1892)	Ohfuchi 1956, p. 142: *Pheretima exiloides* Chen Easton 1981, p. 55; Blakemore 2003, p. 7, 22; 2012b, p. 18: *Amynthas morrisi* (Beddard, 1892)
Amynthas morrisi (Beddard, 1892)	Ohfuchi 1956, p. 148: *Pheretima elongata* (E. Perrier) Gates 1972, p. 182: Identification of specimens as *Ph. elongata* not justified due to disagreement in genital markings, male porophores, muscularization of septum 8/9, intestinal origin and intestinal caeca Easton 1981, p. 55; Blakemore 2003, p. 7, 22; 2012b, p. 18: *Amynthas morrisi* (Beddard, 1892)
Polypheretima elongata (Perrier, 1872)	Ohfuchi 1956, p. 151: *Pheretima biserialis* (E. Perrier) Gates 1972, p. 182; Easton 1981, p. 61; Blakemore 2003, p. 7, 35; 2012b, p. 20: = *Polypheretima elongata* (Perrier, 1872)
Metaphire californica (Kinberg, 1867)	Ohfuchi 1956, p. 154: *Pheretima sonaiensis* nov. sp. Sims & Easton 1972, p. 239, 246: *Metaphire sonaiensis* (Ohfuchi, 1956) Easton 1981, p. 57; Blakemore 2003, p. 7, 26; 2012b, p. 19: *Metaphire californica* (Kinberg, 1867)
Amynthas robustus (Perrier, 1872)	Ohfuchi 1956, p. 155: *Pheretima lauta* Ude Easton 1981, p. 56; Blakemore 2003, p. 7, 24; 2012b, p. 18: = *Amynthas robustus* (Perrier, 1872)
Amynthas robustus (Perrier, 1872)	Ohfuchi 1956, p. 160: *Pheretima masatake* (Beddard) Easton 1981, p. 56; Blakemore 2003, p. 7, 24; 2012b, p. 18: = *Amynthas robustus* (Perrier, 1872)
Amynthas morrisi (Beddard, 1892)	Ohfuchi 1956, p. 162: *Pheretima* (*Ph.*) *corrugata* Chen Easton 1981, p. 56; Blakemore 2003, p. 7, 24; 2012b, p. 18: = *Amynthas robustus* (Perrier, 1872) This study: Misidentification of *A. morrisi* according to text-fig. 12 in Ohfuchi (1956)
Amynthas gracilis (Kinberg, 1867)	Ohfuchi 1956, p. 164: *Pheretima papulosa* (Rosa), var. *sauteria* Michaelsen Gates 1972, p. 207: Identification of specimens as *Ph. papulosa sauteria* not justified due to disagreement in muscularization of septum 8/9 and other characters Easton 1981, p. 56; Blakemore 2003, p. 7, 23; 2012b, p. 18: *Amynthas papulosus* (Rosa, 1896) This study: Misidentification of *A. gracilis* according to text-fig. 13 in Ohfuchi (1956)
Amynthas bidenryoanus (Ohfuchi, 1956)	Ohfuchi 1956, p. 169: *Pheretima houlleti* (E. Perrier), var. *bidenryoana* var. nov. Gates 1972, p. 192: Inclusion of the variant in *Ph. houlleti* not justified due to thickly muscularized septum 8/9 and other characters Sims & Easton 1972, p. 237, 241: *Amynthas bidenryoanus* (Ohfuchi, 1956) (elevation to species rank) Easton 1981, p. 50; Blakemore 2003, p. 17: ? = *Amynthas flavescens* (Goto & Hatai, 1898) Blakemore 2003, p. 6; 2012b, p. 18: = *Amynthas flavescens* (Goto & Hatai, 1898)
Amynthas ishigakiensis **sp. nov.**	Ohfuchi 1956, p. 171: *Pheretima peguana* (Rosa) Gates 1972, p. 208–209: Identification of specimens as *Ph. peguana* not justified due to disagreement in muscularity of septum 8/9, the genital markings and the intestinal origin Easton 1981, p. 58; Blakemore 2003, p. 7, 33; 2012b, p. 19: *Metaphire peguana* (Rosa, 1890) This study: *Amynthas ishigakiensis* **sp. nov.**
Amynthas iriomotensis **sp. nov.**	Ohfuchi 1956, p. 174: *Pheretima leucocirca* Chen Easton 1981, p. 50; Blakemore 2003, p. 6, 18; 2012b, p. 18: ? = *Amynthas flavescens* (Goto & Hatai, 1898) This study: *Amynthas iriomotensis* **sp. nov.**
Amynthas noharuzakiensis (Ohfuchi, 1956)	Ohfuchi 1956, p. 175: *Pheretima noharuzakiensis* nov. sp. Sims & Easton 1972, p. 237, 244: *Amynthas noharuzakiensis* (Ohfuchi, 1956) Easton 1981, p. 50; Blakemore 2003, p. 18: ? = *Amynthas flavescens* (Goto & Hatai, 1898) Blakemore 2003, p. 6; 2012b, p. 18: = *Amynthas flavescens* (Goto & Hatai, 1898)

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TABLE 1. (Continued)

Author's opinion	Taxonomic history
Amynthas micronarius (Goto & Hatai, 1898)	Ohfuchi 1957a, p. 244: *Pheretima obtusa* nov. sp. Sims & Easton 1972, p. 235, 244: *Amynthas obtusus* (Ohfuchi, 1957) Easton 1981, p. 55; Blakemore 2003, p. 7, 21: ? = *Amynthas micronarius* (Goto & Hatai, 1898) Blakemore 2012b, p. 18: = *Amynthas micronarius* (Goto & Hatai, 1898)
Amynthas corticis (Kinberg, 1867)	Ohfuchi 1957a, p. 251: *Pheretima heterochaeta* (Michaelsen) Easton 1981, p. 49: = *Amynthas corticus* (Kinberg, 1867) Blakemore 2003, p. 6, 14; 2012b, p. 18: = *Amynthas corticis* (Kinberg, 1867)

TABLE 2. A comparison of characters among *Amynthas flavescens*, and *Amynthas bidenryoanus* (= *Pheretima houlleti bidenryoana*), *Amynthas iriomotensis* **sp. nov.** and *Amynthas noharuzakiensis* described in Ohfuchi (1956).

Character	*A. flavescens* (Goto & Hatai 1898)	*A. bidenryoanus* (Ohfuchi 1956)	*A. iriomotensis*[1] **sp. nov.**	*A. noharuzakiensis* (Ohfuchi 1956)
Locality	Tokyo, Japan	Iriomote, the Ryukyus	Iriomote, the Ryukyus	Ishigaki, the Ryukyus
Body length (mm)	120	70–85	130–155	78–95
Diameter (mm)	6	2.5–3.5	5–6	3–4
Segment number	126	73–85	110–130	85–110
First dorsal pore	13/14	12/13 or 13/14	11/12 or 12/13	12/13
Setal number	40–50 per segment			
V	–	30	29–33	28–32
VII	–	42	42–46	40–44
VIII	–	45	46–48	47–52
XX	–	51	55–60	60–65
between male pores	7	13–14	14–16	14–16
Male porophore	surrounded by 2 presetal and 2 postsetal papillae	surrounded by 1 postsetal papilla	surrounded by 1 presetal and 1 postsetal papillae	simple
Genital papillae	4 pairs from postsetal VII to presetal IX	absent	absent	absent
Spermathecae	ampulla large with short duct and vestigial diverticulum	ampulla large with long duct and long diverticular stalk	ampulla large with short duct, long diverticular stalk and large seminal chamber	ampulla small with short duct and short diverticular stalk
Sperm sacs	X, XI	small, X, XI	X, XI	X, XI
Seminal vesicles	XI, XII	well-developed XI, XII	well-developed XI, XII	well-developed XI, XII
Prostate glands	large in XVII–XIX	large in XVI–XX	large in XVI–XX	small
Prostatic ducts	–	short, C-shaped	long, U-shaped	S-shaped
Accessory glands	–	–	present	absent

[1] Specimens misidentified as *Pheretima leucocirca* in Ohfuchi (1956).

Taxonomy

Amynthas ishigakiensis sp. nov.
(Figure 3A)

Pheretima peguana (Rosa): Ohfuchi 1956, p. 171, text-fig. 16.

Holotype: Specimen illustrated in Ohfuchi (1956, text-fig. 16) and identified as *Pheretima peguana* (Rosa).

Description. All details from Ohfuchi (1956) with slight modifications. External: Body length 95–110 mm, greatest diameter 4–5 mm, number of segments 95–120. Color in formalin, dorsally yellowish to reddish brown and ventrally much lighter, clitellum chocolate or purplish. Prostomium epilobous. Clitellum annular, extending from XIV to XVI without setae or dorsal pores but with intersegmental furrows. Setae beginning on segment II. Setal numbers: 32–37/V, 40–45/VI, 44–47/VII, 46–50/VIII and 60–66/XX, more usual setal number: 34/V, 42/VI, 45/VII, 48/VIII, 64/XX. First dorsal pore in 12/13 in all the specimens, sometimes with a distinct but nonfunctional pore-like depression in 11/12. Spermathecal pores three pairs in 6/7, 7/8 and 8/9, ventro-lateral. One pair of fig-shaped genital papillae about 0.5 mm at largest diameter near to the ventromedian line close to the male pores at anterior of the setal line. Male porophores large, eye-like, situated on the setal circle close to the lateral border of XVIII, region around each porophore glandular and very much elevated (each porophore surrounded by a whitish thick patch), separated by 13 or 15 setae.

Internal: Septa 6/7, 7/8 and 8/9 thickened, 9/10 absent, 10/11, 11/12 and 12/13 very thin. Intestine enlarged from XIV, intestinal caeca simple, originating in XXVII and extending anteriorly into about XXV, not serriformed in both ventral and dorsal margins. Three pairs of spermathecae in VII, VIII and IX. Ampulla slightly flattened in dorso-ventrally, about 2 mm in length, 1.8 or 2 mm in breadth, continuous to a very short and stout duct about 0.8 mm in length. Spermathecal diverticulum usually arising from the inner face of the spermathecal duct, much longer than the combined length of the duct and ampulla, about 1.7 mm long. Its end forming a large seminal chamber about 1.4 mm in length. The ovisac present in segment XIV. Prostate gland very large and divided into three main lobes, muscular duct long and thick, looped in U-shaped appearance and shining. The ectal end of the duct with slightly decreasing thickness passing into the body wall to open directly to the exterior through a depression as a primary male pore. Seminal vesicles well-developed in XI and XII. Testis sacs in X and XI as in other species of this genus.

Etymology. The name *ishigakiensis* is given to this species with reference to its type locality in Ishigaki Island, the Ryukyus.

Remarks. *M. peguana* has male pores each within a transversely slit-like lumen (Gates 1972), two pairs of large, round genital markings across 17/18 and 18/19, coiled or S-shaped prostatic ducts confined to segment XVIII, and diverticulum with a heavily twisted stalk (Rosa 1890, Figs. 6–8). However, specimens from Ishigaki Island, the Ryukyus described by Ohfuchi (1956) as "*Pheretima peguana*" have superficial male pore in large eye-like male porophore surrounded by whitish, thick and elevated skin, one pair of presetal genital papillae in the male pore region, long, U-shaped prostatic duct occupying about two segments, and diverticulum with a simple, long stalk and a large seminal chamber (Ohfuchi 1956, p. 172, text-fig. 16). Consequently, the correct identity of Ohfuchi's (1956) specimens certainly is not *M. peguana*. Also, no similarity is found when compared with the other members of *Amynthas* having three pairs of spermathecal pores in 6/7–8/9. Ohfuchi's (1956) specimens should belong to a new species. The whereabouts of the type material is currently unknown. The designation of the holotype is in accordance with the rules of the International Code of Zoological Nomenclature (Articles 72.5.6. and 73.1.4.) (ICZN 1999).

***Amynthas iriomotensis* sp. nov.**

(Figure 3B)

Pheretima leucocirca Chen: Ohfuchi 1956, p. 174, text-fig. 17.

Holotype: Specimen illustrated in Ohfuchi (1956, text-fig. 17) and identified as *Pheretima leucocirca* Chen.

Description. All details from Ohfuchi (1956), with slight modifications. External: Body length 130–155 mm, greatest diameter 5–6 mm, number of segments 110–130. Color in formalin, brownish dorsally and ventrally lighter than the dorsal, clitellum light chocolate. Prostomium epilobous. Clitellum annular, in XIV–XVI, without setae or dorsal pores. Setae beginning on segment II, setal numbers: 29–33/V, 34–38/VI, 42–46/VII, 46–48/VIII, 55–60/XX. Ventral setae longer than the dorsal ones, midventral break distinct, no difference in length and interval between dorsal and ventral ones. First dorsal pore in 11/12 or 12/13. Spermathecal pores three pairs in 6/7, 7/8 and 8/9, ventro-lateral, the openings very distinct. No genital papillae found near this region. Male pores on ventro-lateral extremities of XVIII, in setal line, about 1/3 body circumference ventrally apart, the porophore a teat-like protuberance with several circular wrinkles around. Male openings characteristic: in XVIII the male pore situated at the extreme lateral side within a large round elevated disc, two round papillae immediately medial to each male pore, one presetal and the other postsetal, projecting prominently from the body surface. Number of setae between male pores 14 or 16.

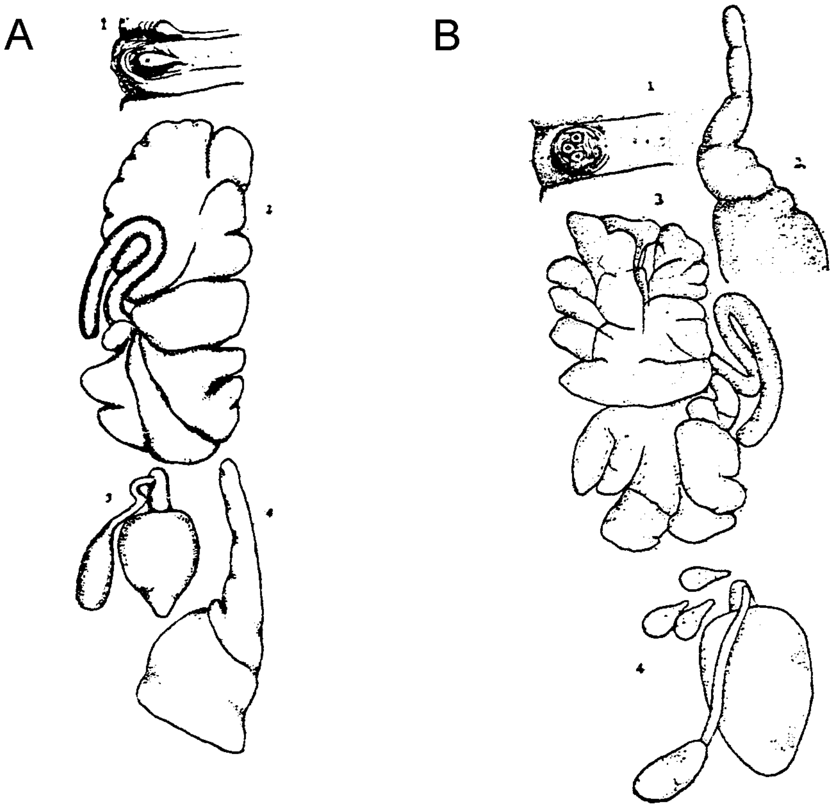

FIGURE 3. *Amynthas ishigakiensis* **sp. nov.** (**A**) and *Amynthas iriomotensis* **sp. nov.** (**B**). **A.** Text-fig. 16 in Ohfuchi (1956). **1.** Ventral view of the genital marking on the right side of the segment XVIII. **2.** Prostate gland with its duct. **3.** Spermatheca and the ampulla. **4.** Intestinal caecum in lateral view from the left side. **B.** Text-fig. 17 in Ohfuchi (1956). **1.** Ventral view of the genital marking on the right side of the segment XVIII. **2.** Intestinal caecum in lateral view from the left side. **3.** Prostate gland with its duct. **4.** Spermatheca, ampulla and its neighboring capsulogenous glands.

Internal: Septa 6/7, 7/8 and 8/9 much thickened, 9/10 absent, 10/11, 11/12 and 12/13 thin. The septum usually thin. Intestine enlarged from XVI, intestinal caeca simple, originating in XXVII, extending anteriorly to XXIV, not serriformed in both ventral and dorsal margins. Three pairs of spermathecae in VII, VIII and IX. Ampulla slightly flattened in dorso-ventrally, about 3 mm in length, 2 mm wide, continuous to the very short and stout duct. Spermathecal diverticulum with its end forming a large seminal chamber about 2 mm in length. Three or four capsulogenous glands near the spermathecae. Prostate gland very large, extending from XVI to XX, and divided into three main lobes, muscular duct very long, bending into ear-capsule-like shape. Seminal vesicles well-developed in XI and XII. Testis sacs in X and XI as in the other species of this genus.

Etymology. The name *iriomotensis* is given to this species with reference to its type locality in Iriomote Island, the Ryukyus.

Remarks. Specimens from Iriomote, the Ryukyus described by Ohfuchi (1956) as "*Pheretima leucocirca*" are fairly similar to *Amynthas leucocircus* (Chen, 1933) from central China in body size, segment number, setal number, papilla arrangement around male pore and in having three pairs of spermathecal pores in 6/7–8/9. However, *A. leucocircus* has pre-clitellar genital papillae in postsetal, medio-ventral position in VII and VIII, small seminal vesicles, short and stout prostatic duct confined to segment XVIII, large, compact, round or kidney-shaped accessory gland associated with each papilla, and short diverticulum (Chen 1933, Figs. 22 & 23), whereas Ohfuchi's (1956) specimens have no pre-clitellar genital papillae and have well-developed seminal vesicles, long, U-shaped prostatic duct occupying about two segments, and long diverticulum (Ohfuchi 1956, p. 175, text-fig. 17). Ohfuchi (1956) mentioned accessory glands (= capsulogenous glands) in the spermathecal region but not in segment XVIII and hence, glands might be absent or too small to be noticed in segment XVIII. These specimens were uncertainly considered synonymous with *A. flavescens* by Easton (1981) and Blakemore (2003; 2012b), but the presence or absence of papillae in the pre-clitellar region, papilla arrangement in the male pore region and the structure of diverticulum are different (Table 2). No other members of *Amynthas* having three pairs of spermathecal pores in 6/7–8/9 are more similar to Ohfuchi's (1956) specimens than *A. leucocircus*. Ohfuchi's (1956) specimens should belong to a new species. The whereabouts of the type material is currently unknown. The designation of the holotype is in accordance with the rules of the International Code of Zoological Nomenclature (Articles 72.5.6. and 73.1.4.) (ICZN 1999).

TABLE 3. Earthworms reported from the Ryukyu Archipelago.

Species	Ohfuchi (1940)	Kobayashi (1941)	Ohfuchi (1956)	Ohfuchi (1957a)	Ishizuka *et al.* (2000)	Blakemore *et al.* (2006)	Oba *et al.* (2015)
Amynthas asacceus			+				
Amynthas bidenryoanus			+				
Amynthas corticis		+		+			
Amynthas glabrus[1]		+	+				
Amynthas gracilis		+	+				
Amynthas hatomajimensis				+			
Amynthas hupeiensis		+					
Amynthas illotus			+				
Amynthas iriomotensis			+				
Amynthas ishigakiensis			+				
Amynthas kunigamiensis					+		
Amynthas micronarius				+			
Amynthas morrisi		+	+				
Amynthas noharuzakiensis			+				
Amynthas robustus		+	+				
Amynthas yambaruensis					+		
Amynthas zoysiae		+					
Metaphire californica		+	+				
Metaphire parvula			+				
Metaphire riukiuensis				+			
Metaphire schmardae		+					
Polypheretima elongata	+	+	+				
Pithemera bicincta				+			
Pontodrilus litoralis							+
Dichogaster bolaui		+					
Dichogaster hatomaana				+			
Ocnerodrilus occidentalis		+					
Pontoscolex corethrurus						+	

[1] *Ph. vieta* in Kobayashi (1941).

Further taxonomic issues

If the distributional aspect of each species could be taken into consideration, lots of false synonymies could have been avoided even without DNA data. Furthermore, it is not uncommon that errors or mistakes arise from secondary citation. In the following I discuss errors of identification and/or synonymization of a number of East

Asian earthworm species, some of them with long-standing taxonomic confusions which in my view could be easily resolved from a distribution-based perspective:

TABLE 4. A comparison of characters between *Amynthas asacceus* and *Amynthas proasacceus*.

Character	*A. asacceus* (Chen, 1938)	*A. proasacceus* Tsai *et al*., 2001
Locality	Hainan Island, southern China	central Taiwan
Elevation (m)	–	2100–3000
Length (mm)	35–60	39–76
Segment number	69–90	57–106
Clitellum width/ Diameter (mm)	2–2.5	2.9–3.99
First dorsal pore	12/13	11/12
Setal number		
VII	37 (VI)	33–40
VIII	42	–
XVII	32	–
XX	–	43–51
XXV	32	–
between male pores	1	6–9
Male porophore	roundish, dark-colored, glandular, 0.7 mm in diameter	round or oval, smooth, 0.45–0.65 mm in diameter
Genital papillae		
preclitellar	absent	absent
postclitellar	absent	absent
Spermathecae	absent	2–6 in VI–VIII
Intestinal caeca	XXVII–XXV	XXVII–XX, XXVII–XXIII
Sperm sacs	small, X, XI	small to large, X, XI
Seminal vesicles	small, XI, XII	small to large, XI, XII
Prostate glands	large, XVI–XXII	absent to large (XVI–XXI)
Prostatic ducts	long, coiled	C-shaped
Accessory glands	absent	absent

Amynthas asacceus **(Chen, 1938) and** ***Amynthas proasacceus*** **Tsai** ***et al*****., 2001.** Blakemore (2003; 2010; 2012b) placed *A. proasacceus* in provisional synonymy with *A. asacceus* (synonymy with a question mark). *A. proasacceus* is only found in the mountainous area with elevations higher than 2100 m in central Taiwan (Tsai *et al.* 2001 and unpublished data), an area which might be covered with snow in winter, whereas *A. asacceus* is from Hainan, a tropical island with a highest elevation below 1900 m in southern China. A synonymy of both taxa is therefore highly improbable and not supported by morphology, either: The simple, smooth male porophore and short, C-shaped prostatic duct of *A. proasacceus* vary greatly from the dark-colored, glandular male porophore and long, coiled prostatic duct of *A. asacceus* (Table 4). Also, none of the individuals of *A. proasacceus* is athecal whereas *A. asacceus* has no spermatheca (Table 4). The synonymy of both taxa is therefore rejected here. The similarities and differences in characters between *A. proasacceus* and *A. asacceus* were elaborated by Tsai *et al.* (2001) who consider that the former is a more primitive species while the latter species is at the most advanced (final) stage of spermathecal degeneration. Nomenclatural note: Although Chen (1938) corrected the name "*assaccea*" to "*asaccea*" and this was reaffirmed by Tsai *et al*. (2001), the correct spelling has often been ignored (Sims & Easton 1972; Blakemore 2003; 2010; 2012b; Nguyen *et al*. 2016).

Amynthas asiaticus **(Michaelsen, 1900).** The occurrence of this species in Taiwan was reported in Kuo (1987) and Chang (1992). The so-called "Taiwan red earthworm (*Pheretima asiatica*)" in Kuo (1987) was purchased from a vermiculture farm in central Taiwan. Kuo (1987) mentioned that the earthworms were easy to raise and propagate and useful for manure decomposition, and suggested that mass rearing of this earthworm is feasible since the subtropical weather here is suitable for the growth of the earthworm. As for the other record in Taiwan, the "local earthworm (*Pheretima asiatica*)" used in Chang's (1992) experiment, worms were fed on soil mixed with pig manure and were identified by T.-H. Tan. Alongside this, Wong and Griffiths (1991) used earthworms imported from the Philippine Earthworm Center in their feeding trials for testing waste treatment ability and concluded that "the ability of *Pheretima asiatica* to tolerate growth in and, at the same time, consume fresh pig manure makes this worm a candidate for further investigation particularly as the other worm genus investigated in Hong Kong, *Eisenia fetida*, died on exposure to raw, unwashed pig manure". However, *A. asiaticus* is an earthworm reported from Tientsin, northern China (Michaelsen 1900a) and Tibet (Michaelsen 1902) only prior to the above studies in the tropical and subtropical regions. Compared with those cosmopolitan species originated in cooler parts of Asia and found in North America (Chang *et al*. 2016), such as *Amynthas agrestis* (Goto & Hatai, 1899), *Amynthas carnosus* (Goto & Hatai, 1899) and *A. corticis*, *A. asiaticus* is apparently not a peregrine species adapted to man-made environments, since there are only two records from the temperate zone, northern China and Tibet, by Michaelsen (1900a; 1902) for this species up to date. It has never appeared in the checklist of Japanese earthworms (Easton 1981; Blakemore 2003; 2012b). How come such an earthworm can be massively reared and used in manure decomposition in tropical or subtropical regions? Based on the author's survey on earthworm farms and bait shops around Taiwan, only *M. posthuma*, *Perionyx excavatus* Perrier, 1872, *E. fetida*/*Eisenia andrei* Bouché, 1972 and recently *Eudrilus eugeniae* (Kinberg, 1867) are cultivated and sold (unpublished data). Similar circumstances should also be found in the neighboring areas. On top of that, no morphological description or any clue to the identification was given in the papers by Kuo (1987), Chang (1992) and Wong and Griffiths (1991) and none of these authors or identifiers worked on earthworm taxonomy. Kuo (1995) even misidentified *A. rockefelleri* as a new species from northern Taiwan (Shen *et al*. 2003a). All available evidence suggests that *A. asiaticus* mentioned in these papers is a misidentification. Accordingly, Tsai *et al*. (2009) delete this species from the earthworm checklist of Taiwan. On the contrary, Blakemore (2010) maintains it, but without further evidence.

***Amynthas carnosus* (Goto & Hatai, 1899).** The type locality of *A. carnosus* is Tokyo, Japan (Goto & Hatai 1899). It is a temperate species widely distributed in Japan, Korea and central and northern China (Kobayashi 1936a), and was recently recorded in North America (Chang *et al*. 2016). Records of the species from northern Taiwan in Shen *et al*. (2005b) have been proven to be misidentifications and those specimens should belong to a new species, *Amynthas yizhou* Blakemore, 2013. Matsu Islands lie southeast of China with a distance of about 10 km east of Fujian Province, China and about 210 km northwest of Taiwan (Shen *et al*. 2014) (Fig. 1). Despite the fact that the earthworm fauna of Matsu Islands is found to be more closely related to that of warm temperate China than to Taiwan or tropical southern China, no specimens of *A. carnosus* were collected there among a total of 931 earthworms obtained in the surveys (Shen *et al*. 2015). In view of the small area of Matsu Islands (< 30 km^2) (Shen *et al.* 2014), the surveys are rather comprehensive. Consequently, areas south of Matsu (located approximately at 26°N, 120°E), including Taiwan, should be excluded from the distributional ranges of *A. carnosus*. The absence of *A. carnosus* from Okinawa and from other Ryukyu Islands southwest of Okinawa (Table 3) further supports the above conclusion since Okinawa is about the same latitude as Matsu as mentioned previously. The synonymies of the four species, *Amynthas monsoonus* James *et al.*, 2005 from tropical southern Taiwan, *Amynthas fuscus* Qiu & Sun, 2012 from Hainan Island, southern China, *Amynthas taiwumontis* Shen *et al*., 2013 from Kinmen, southwest of Matsu, and *Amynthas penpuensis* Shen *et al.*, 2003 from Taiwan, with *A. carnosus* by Blakemore (2013a, b, c) are therefore questionable. In fact, all the four species are morphologically distinguishable from *A. carnosus*: *A. monsoonus* has small prostate gland and diverticulum much longer than ampulla (James *et al*. 2005) while *A. carnosus* has large prostate gland and short diverticulum (Goto & Hatai 1899; Kobayashi 1936a); *A. fuscus* has coiled diverticulum (Sun *et al*. 2012) while that of *A. carnosus* is simple and straight (Goto & Hatai 1899; Kobayashi 1936a); *A. taiwumontis* has long diverticulum and much higher setal number with approximately 70–100 setae per segment (Shen *et al*. 2013) whereas *A. carnosus* has short diverticulum and lower setal number about 30–60 setae per segment (Kobayashi 1936a); *A. penpuensis* has large seminal vesicle and first dorsal pore in 5/6 or 6/7 (Shen *et al.* 2003b) whereas *A. carnosus* has small seminal vesicle and first dorsal pore in 12/13 or 13/14 (Kobayashi 1936a). Blakemore (2013a, p. 26) states that "ICZN requires consistency across names and treatments regardless of where specimens occur". Nevertheless, where specimens occur matters a lot. At least two of the species, *A. penpuensis* and *A. taiwumontis*, have been sequenced and the results support the validity of the species (Shen *et al.* 2014, p. 498, Figure 2). Since type localities of *A. monsoonus* and *A. fuscus* in the tropical zone are further south of those of *A. penpuensis* and *A. taiwumontis*, it is even more improbable that *A. monsoonus* and *A. fuscus* are synonymous with *A. carnosus*. As a corollary, the specimens underlying the record of Nguyen *et al.* (2016) from Vietnam should be reinvestigated. All the aforesaid taxonomic confusion is partly attributable to lack of awareness of the concept of biogeography.

Amynthas hupeiensis **(Michaelsen, 1895).** The type locality of *A. hupeiensis* is Wuchang, Hubei (= Hupei) Province, central China (Michaelsen 1895) (Fig. 1). It is a warm-temperate species distributed in Japan, Korea and China and was introduced into North America and New Zealand (Easton 1981; Blakemore 2010). Gates (1982) indicates that there is no scientific record of its occurrence in the tropics. As mentioned earlier, *A. hupeiensis* is common in northern Taiwan, seldom found in central Taiwan and has never been collected in southern Taiwan, and hence, the presence of *A. hupeiensis* in Vietnam as reported by Blakemore (2010) and Nguyen *et al.* (2016) is questionable. Gates (1972, p. 213) states that *A. hupeiensis* has been mistaken for *M. posthuma*. The latter is a tropical species originated from Southeast Asia and so it is probable for *M. posthuma* to be misidentified as *A. hupeiensis*. Specimens underlying the records of *A. hupeiensis* collected from Vietnam should be reinvestigated; they may belong to some other species, or maybe new species.

Amynthas micronarius **(Goto & Hatai, 1898) and *Amynthas zhuya* Blakemore, 2013 (= *Amynthas montanus* Qiu & Sun, 2012).** The type locality of *A. micronarius* is Tokyo, Japan (Goto & Hatai 1898), and that of *A. zhuya* is Hainan Island, southern China (Sun *et al.* 2012). Blakemore (2012b; 2013a) considers a possible synonymy of both nominal species. *A. micronarius* has never been found throughout mainland China and Taiwan with all records from Japan (Easton 1981) and Korea (Blakemore 2013a). Therefore, from a biogeographical perspective, a synonymy of both species is unlikely. [Nomenclatural note: *A. zhuya* was originally described as *A. montanus* Qiu & Sun, 2012, but this name is preoccupied (Blakemore 2013c)].

Amynthas morrisi **(Beddard, 1892).** Type specimens of *A. morrisi* were from Penang, Malaysia (Beddard 1892). Regarding the Japanese records of *A. morrisi*, Easton (1981) mistook "Ōshima" listed in Table 5 in Kobayashi (1941) for Izuōshima south of Kanagawa in the Kantō region of Honshu. Blakemore (2003, p. 22) apparently followed this erroneous record by Easton (1981) and stated that "In Japan, known from Kanagawa (Oshima) to Okinawa". Numerous places are named "Ōshima" throughout Japan. However, except Okinawa which is in Okinawa Prefecture, all the other localities listed in the first half of Table 5 in Kobayashi (1941, p. 378) belong either to Kagoshima or to Miyazaki Prefecture, southern Kyushu. These localities were arranged approximately from north to south according to their geographical positions. Ōshima was placed between Yakushima and Okinawa, so it should be Amami Ōshima which also belongs to Kagoshima Prefecture of Kyushu (Fig. 1), not Ōshima in the Kantō region, Honshu. Gates (1982) states that "*P. morrisi*, like *P. californica* and *hawayana*, is originally from a temperate zone, Chinese portion of the *Pheretima* domain". Blakemore (2010) also indicates that this species is "originally from China/Japan". However, the above statements are contradictory to the limited distribution in southern islands of Japan and prevalence in tropical southern China and Southeast Asia of *A. morrisi* (Gates 1972; Shen & Yeo 2005). This species is probably originated from southern China.

Amynthas papulosus **(Rosa, 1896) and *Amynthas rockefelleri* (Chen, 1933).** The type locality of *A. papulosus* is Sumatra, Indonesia (Rosa 1896) and that of *A. rockefelleri* is in Zhejiang (= Chekiang) Province, central China (Chen 1933). As mentioned previously ("Geography and earthworm species distribution in Taiwan and its adjacent islands"), *A. papulosus* originated from the tropics and is not found in Matsu, whereas *A. rockefelleri* from central China has never been collected in southern Taiwan (more precisely, south of Tropic of Cancer). The Japanese records of *A. papulosus* in Easton (1981) were cited from Kobayashi (1941) and Ohfuchi (1956). However, not *papulosus* but *rockefelleri* was listed in Table 5 in Kobayashi (1941), and *A. papulosus* in Ohfuchi (1956, p. 164, text-fig. 13) is a misidentification of *A. gracilis* (Table 1). *A. papulosus* and *A. rockefelleri* can be easily distinguished since the size, number and arrangement of their papillae differ considerably (Shen *et al.* 2003a) (Table 5). Tsai *et al.* (2009) considered *A. papulosus* and *A. rockefelleri* two valid species based on morphological, distributional and molecular evidences. Also, *A. papulosus* is present in Kinmen but absent from Matsu as mentioned above. *A. papulosus* and *A. rockefelleri* have been wrongly synonymized for more than fifty years (Gates 1959; 1972; Easton 1981; Blakemore 2003; 2010; 2012b). False synonymy confounds the real distributional range of the two species and misguides contemporary earthworm taxonomists. Type specimens of *A. rockefelleri* preserved at the Smithsonian National Museum of Natural History (No. 20176), Washington, D.C., USA were examined by the author in 2001.

TABLE 5. A comparison of characters between *Amynthas papulosus* and *Amynthas rockefelleri*.

Character	*A. papulosus* (Rosa, 1896)	*A. rockefelleri* (Chen, 1933)
Locality	Sumatra, Indonesia	Chekiang, central China
Body length (mm)	45–50	85–130
Segment number	110–115	108–142
First dorsal pore	12/13	11/12
Setal number		
III	–	38–54
VI	54 (V)	58–70
VIII	–	58–75
XII	66 (XIII)	46–68
XIV (clitellum)	2	6–8
XV (clitellum)	4	10–14
XVI (clitellum)	4–5	12–16
XXV	60	52–62
between male pores	11	12–16
Spermathecal pores	3 pairs (5/6–7/8)	3 pairs (5/6–7/8)
Spermathecae	ampulla spindle-shaped, diverticulum slender, zigzag in the terminal portion	ampulla pear-shaped, diverticulum slender, loosely looped and slightly dilated in the terminal portion
Genital papillae	small, numerous	large
preclitellar	–	widely paired in presetal VIII, occasionally with an additional pair in postsetal VIII
postclitellar		
XVII	2 presetal and 2 postsetal transverse rows	2–4 in postsetal XVII, medial to male pores
XVIII	1 presetal transverse row	absent
XIX	1 presetal transverse row	absent
Seminal vesicles	small	small
Prostate glands	small	absent in most cases, normal in one side occasionally
Accessory glands	–	large, compact mass

***Metaphire hilgendorfi* (Michaelsen, 1892).** The type locality of *M. hilgendorfi* is Hakodate, northern Japan (Michaelsen 1892). It is a temperate species distributed in Japan and Korea and also commonly found in the United States (Gates 1982; Chang *et al*. 2016). *M. hilgendorfi* has not been recorded in China or Taiwan and thus, it is unlikely for this species to occur in Vietnam (Blakemore 2010; Nguyen *et al*. 2016). *M. hilgendorfi* has a cluster of small genital markings within a round, unpaired, presetal patch in mid-ventrum of some or all of segments VIII–IX and XVII–XVIII (Gates 1982; Chang *et al*. 2016). Nevertheless, it was stated in the "Remarks" section of *M. hilgendorfi* in Nguyen *et al*. (2016) that "Le (1995a) noted that the population recorded in Vietnam has stable characters for *M. hilgendorfi*, for example: two pairs of spermathecal pores in 6/7/8, a pair of large genital markings behind the setal ring of xviii". Since the characters of size, number, position and arrangement of genital markings depicted are in disagreement with those of *M. hilgendorfi*, these Vietnamese authors obviously misidentified their specimens, which should belong to some other species, perhaps a new one. Specimens of *M. hilgendorfi* deposited at the Smithsonian National Museum of Natural History, Washington, D.C., USA and at the Natural History Museum, London were examined by the author in 2001 and 2014, respectively.

***Metaphire houlleti* (Perrier, 1872) and *Metaphire guillelmi* (Michaelsen, 1895).** The type locality of *M. houlleti* is Calcutta, India (Perrier 1872) and that of *M. guillelmi* is Wuchang, Hubei (= Hupei) Province, central China (Michaelsen 1895) (Fig. 1). Since both species have slit-like, C-shaped opening of the copulatory pouch, they were considered synonyms by Michaelsen (1897; 1899; 1900b). Beddard (1900) and Stephenson (1925) follow Michaelsen's viewpoint although Beddard (1900, p. 614) was doubtful. Both Chen (1933) and Gates (1935) consider these two species to be specifically different based on reasons summarized in Shen *et al*. (2005a). Chen (1933) also indicates that "More recent studies of the species of the earthworms in this region have led me to believe that *P. houlleti* is not found in Central China". According to Gates (1972), *M. houlleti* is widely distributed in Southeast Asia; it is primarily a lowland tropical species and its original home is probably in Southeast Asia. It is consistent with this view that he rejected *Pheretima houlleti* var. *bidenryoana* Ohfuchi, 1956 from the Ryukyu Islands to belong to *M. houlleti* albeit his arguments were purely morphological (1972, p. 192). As to the confusing taxonomic history of *Amynthas bidenryoanus* (Ohfuchi, 1956), first recognized as a species of its own by Sims and Easton (1972), see above ("Earthworms of the Ryukyu Archipelago").

Shen *et al*. (2005a) retained *M. guillelmi* as a valid species separable from *M. houlleti* due to differences in the structure of opening of copulatory pouch and the geographical distribution (Table 6). Blakemore (2010) continued to list *M. guillelmi* as a synonym of *M. houlleti* without response to the evidences brought forward by Chen (1933), Gates (1935; 1972) and Shen *et al*. (2005a), but he circumscribed the distribution of *M. houlleti* as "Indigenous to Myanmar and southeast Asia" (Blakemore 2010, p. 450), excluding the area of *M. guillelmi*. *M. guillelmi* and *M. houlleti* are morphologically fairly similar, but besides the aforementioned differences, the former has no setae or setal pits on the clitellum and the coiled end of its diverticulum is tapering, not enlarged to form an ovate mass (Michaelsen 1895, Fig. 7) (Table 6). The author examined specimens of *M. guillelmi* from central China and *M. houlleti* from Thailand and Myanmar preserved at the Smithsonian National Museum of Natural History, Washington, D.C., USA in 2001 and paratypes of *M. guillelmi* from Wuchang, Hubei, central China (1903.4.28.18-19) and specimens of *M. houlleti* from various parts of Southeast Asia (north to Myanmar and south to Java) deposited at the Natural History Museum, London in 2014.

Since *M. houlleti* has never appeared in central or northern Taiwan despite years of surveys by different research groups (Shen *et al*. 2005a), it is now clear that the distributional range of this species should be restricted to south of the Tropic of Cancer. In consequence, records of *M. houlleti* found north of this line (Blakemore 2016, p. 23, Figure 10) are questionable. As for *M. guillelmi*, it is a warm-temperate species distributed in north and central China (Chen 1933) and was not found in Matsu (Shen *et al*. 2015), not to mention Taiwan. It is therefore not likely for *guillelmi* to be present in Vietnam (Nguyen *et al*. 2016). Specimens collected from Vietnam should be reinvestigated; they are probably misidentifications of *M. houlleti*. The genus for *guillelmi* has been changed from *Perichaeta* (Michaelsen 1895) over *Pheretima* (Michaelsen 1931) to *Metaphire* (Sims & Easton 1972). However, in a recent paper of Zhang *et al*. (2018), *Pheretima guillelmi* and *Metaphire guillelmi* were considered two ecophysiologically distinct species with the former being endogeic and the latter anecic! Consequently, data and results presented in Zhang *et al*. (2018) are erroneous and not reliable.

***Metaphire peguana* (Rosa, 1890).** The type locality of *M. peguana* is Rangoon, Myanmar (= Burma) (Rosa 1890). This species occurs in most places of Southeast Asia (Gates 1972) and has never been found in mainland China or Taiwan. Easton (1981) and Blakemore (2003; 2012b) included *M. peguana* in the Japanese earthworm fauna based on the record from Ishigaki Island, the Ryukyus by Ohfuchi (1956), although both of them mentioned Gates' (1972) disapproval of Ohfuchi's (1956) identification. Specimens from the Ryukyus should be assigned to a new taxon with a name as *Amynthas ishigakiensis* **sp. nov.**, see above ("Earthworms of the Ryukyu Archipelago"). *M. peguana*, a tropical species, should be removed from the Japanese earthworm checklist. Specimens of *M. peguana* from Myanmar deposited at the Smithsonian National Museum of Natural History, Washington, D.C., USA and from Vietnam at the Natural History Museum, London were examined by the author in 2001 and 2014, respectively.

***Metaphire tschiliensis* (Michaelsen, 1928).** The type locality of *M. tschiliensis* is Tschili (= Hebei) in northern China (Michaelsen 1928). Like *M. guillelmi*, this is a warm-temperate species widely distributed in north and central China (Chen 1933) and has never been found in southern China or Taiwan. Accordingly, it is very unlikely for *M. tschiliensis* to be found in Vietnam (Nguyen *et al*. 2016). Nguyen *et al*. (2016) placed *tschiliensis* under the genus *Amynthas* after examination of a total of nine clitellates and five aclitellates. However, *tschiliensis* has copulatory pouches (Chen *et al*. 1975) and hence, it should belong to *Metaphire*. Evidently, Nguyen *et al*. (2016) misidentified their specimens, which should belong to some other species, possibly a new one. Specimens of *M. tschiliensis* from central China preserved at the Smithsonian National Museum of Natural History, Washington, D.C., USA and from northern China at the Natural History Museum, London were examined by the author in 2001 and 2014, respectively.

TABLE 6. A comparison of characters between *Metaphire guillelmi* and *Metaphire houlleti*.

Character	*M. guillelmi* (Michaelsen, 1895)	*M. houlleti* (Shen *et al*. 2005a)[1]
Locality	Hupei, central China	Pingtung, southern Taiwan
Elevation (m)	–	200–300
Number of specimen	1	6
Body length (mm)	100	107–118
Segment number	108	86–102
Clitellum width (mm)	7	2.39–3.6
First dorsal pore	12/13	9/10
Setal number		
VII	39 (V)	30–36
XIII	52	–
XIV (clitellum)	absent	about 40 setal pits
XV (clitellum)	absent	about 40 setal pits
XVI (clitellum)	absent	about 40 setal pits
XX	–	50–52
XXV	56	–
between male pores	17	9–10
Copulatory pouch	C-shaped opening in the outer side	C-shaped opening in the inner side
Spermathecal pores	3 pairs (6/7–8/9)	3 pairs (6/7–8/9), deep slits
Spermathecae	ampulla oval, large; diverticulum with a slender stalk and a tapering, greatly coiled end	ampulla oval, large; diverticulum with a slender stalk and an enlarged, greatly coiled end
Genital papillae		
preclitellar	absent	absent
postclitellar	absent	absent
Preclitellar accessory glands	stalked, next to spermathecal ducts	stalked, connecting to spermathecal ducts
Hearts	4 pairs in X–XIII	4 pairs in X–XIII
Intestine enlarged from	XV	XV
Intestinal caeca	XXVII–XXIV (miscounted as XXVI–XXIII)	XXVII–XXIV
Testes	X, XI	X, XI
Seminal vesicles	XI, XII	small, XI, XII
Prostate glands	large, XV–XXII	large, XVI–XXII or XVI–XXIII
Accessory glands in XVIII	–	white patch, sessile

[1] Reference in parenthesis after scientific name.

***Perichaeta acincta* Goto & Hatai, 1899, *Pheretima phaselus* Hatai, 1930, *Pheretima maculosus* Hatai, 1930, *Pheretima kamitai* Kobayashi, 1934, *Pheretima yezoensis* Kobayashi, 1938 and *Pheretima mutica* Chen, 1938.** In the following the original combinations *Perichaeta acincta* and *Pheretima maculosus* are used to avoid confusion since the genus for *acincta* has been changed from *Amynthas* (Sims & Easton 1972) over *Metaphire* (Blakemore *et al*. 2010, p. 16) to *Duplodicodrilus* (Blakemore 2012c), and *maculosus* has been placed under *Metaphire* (Sims & Easton 1972) and then *Amynthas* (Blakemore 2012c). Easton (1981) listed *phaselus*, *maculosus* and *kamitai* as synonyms of *acincta* with question marks. Blakemore (2003) again followed Easton (1981) and further added *mutica* in synonymy without a question mark. Later, Blakemore (2012c) included *yezoensis* in synonymy without a question mark and stated on p. 106 that "Here the erstwhile synonym *Amynthas phaselus* (Hatai, 1930) is restored, debatably keeping some of its synonyms (*e.g.*, *Pheretima maculosa* Hatai, 1930 and *P.*

mutica Chen, 1938 that are both treated below), while the synonym *P. yezoensis* is reaffirmed". Nevertheless, Blakemore (2012c, p. 113–114) assigned *phaselus*, *maculosus* and *kamitai* to the genus *Amynthas*, separating them from *acincta* but without mentioning *mutica* at all. The type locality of *acincta* is Tokyo, Japan (Goto & Hatai 1899), that of *kamitai* and *yezoensis* is Keijo (= Seoul), South Korea (Kobayashi 1934) and Hakodate, Japan (Kobayashi 1938a), respectively, while *mutica* is from Hainan Island, southern China (Chen 1938). As for *phaselus* and *maculosus*, Hatai (1930) did not indicate specifically where their type locality is but mentioned "This is a very common earthworm living chiefly in gardens in Sendai and the northern parts of Japan" for *phaselus* and "Widely distributed in Aomori prefecture, Sapporo and Sendai" for *maculosus*, respectively. All these places mentioned by Hatai (1930) are in northern or northeastern parts of Japan. Neither *acincta*, *phaselus*, *maculosus*, *kamitai* nor *yezoensis* was recorded in the Ryukyu Archipelago (Table 3), Matsu Islands (Shen *et al*. 2015), Taiwan or mainland China, so it is unlikely that these species will be found in Hainan Island. As a result, *mutica* should not be considered a synonym of any of the above-mentioned species.

***Drawida barwelli* (Beddard, 1886).** The original description of *Drawida barwelli* by Beddard (1886) was based on the examination of about 20 specimens obtained from the neighborhood of Manila, Philippines. However, Beddard (1888; 1891) mistook *Drawida beddardii* (Rosa, 1890) from Burma for *Dr. barwelli* (see Shen 2018), and the misidentification continued in his subsequent papers (Beddard 1893; 1895) which causes further confusion (see Shen *et al*. 2015; 2018). Moreover, the incorrect synonymy of *Drawida glabella* Chen, 1938 with *Dr. barwelli* by Blakemore (2010), Blakemore and Kupriyanova (2010) and Blakemore *et al*. (2014) and the so-called *Drawida* cf. *barwelli* found in Korea (Blakemore *et al*. 2012; 2014), a misidentification of *Drawida eda* Blakemore, 2010 (see Shen *et al*. 2018), have blurred the actual distributional range of this species. *Dr. barwelli* has been reported from Southeast Asia, Pacific Islands, Central America and Australia (see Shen 2018), and so it is not likely that this tropical species would be found from frozen, icy soil in Korea (Blakemore *et al*. 2012; 2014). *Dr. barwelli* was collected from coastal plains and hills below 1000 m in elevation in central, southern and Hualien and Taitung (including Lanyu) counties in eastern Taiwan, and has never been found in northern Taiwan (Shen 2018). Since *Dr. barwelli* is absent from the earthworm fauna of Kinmen (Chang *et al*. 2012), Matsu (Shen *et al*. 2015) and Japan (Blakemore 2012b; Blakemore *et al*. 2014), the island of Taiwan should be the northernmost range of this peregrine species (Shen 2018).

Critique of erecting sympatric subspecies

Morphological and genetic differentiation and allopatric speciation due to complex topography can be best revealed by geographic subspecies. Examples discovered from Taiwan and Matsu islands are as follows: (1) *Metaphire paiwanna paiwanna* Tsai *et al.*, 2000 from west and *Metaphire paiwanna liliumfordi* Tsai *et al.*, 2000 from east Taiwan divided by the Central Mountain Range (Tsai *et al.* 2000b), (2) *Amynthas tessellatus tessellatus* Shen *et al.*, 2002 at elevations of 1000–3200 m and *Amynthas tessellatus paucus* Shen *et al.*, 2002 at elevations of 700–1100 m from central Taiwan (Shen *et al.* 2002), (3) *Metaphire nanaoensis nanaoensis* Chang & Chen, 2005 and *Metaphire nanaoensis truku* Chang & Chen, 2014 isolated by Heping River in northeastern Taiwan (Chang *et al*. 2014), (4) *Metaphire taiwanensis taiwanensis* Tsai *et al.*, 2004 from central and *Metaphire taiwanensis tsaii* Chang & Chen, 2014 from northern Taiwan separated by Hsuehshan and Central mountain ranges (Chang *et al.* 2014), and (5) *Amynthas nanganensis nanganensis* Shen & Chang, 2015 from the island of Nangan, Matsu and *Amynthas nanganensis beiganensis* Shen & Chang, 2015 from the island of Beigan, Matsu (Shen *et al.* 2015) (Note: In Chinese, "Nan" means south and "Bei" means north). Each subspecies of the above examples are morphologically recognizable, so one can tell where the specimens are from simply by their appearance. This is the biogeographical significance these subspecies stand for. In contrast, the sympatric subspecies dealt with in the following cases are either synonymous or they should be elevated to species rank:

***Amynthas carnosus* (Goto & Hatai, 1899).** Blakemore and Lee (2013) published *Amynthas carnosus roki* with the holotype from Incheon Great Park located in northwestern South Korea. They also made the following statements on p. 132: "In particular, sample IV0000261266 (providing DNA w57) was collected at the same time as *A. carnosus roki* Holotype (w56) yet it complies with Kobayashi (1936) textfig. types IX & III of *A. carnosus carnosus*. Whereas IV0000261263 (providing DNA w55) also from Incheon Great Park but found crawling on the surface at dusk, complies with Kobayashi's types VI & VIII and is almost exactly the same as *A. carnosus* neotype

TABLE 7. A comparison of characters between *Amynthas monstriferus* and *Amynthas carnosus roki*.

Character	*A. monstriferus* (Kobayashi, 1936)	*A. carnosus roki* Blakemore, 2013
Locality	Korea	Korea
Number of specimen	4	2
Body length (mm)	235	175–300
Segment number	137	136
Greatest diameter (mm)	8.5	–
First dorsal pore	12/13	12/13
Prostomium	epilobous	epilobous
Setal number		
VII	38	–
X	55	–
XI	63	–
XII	64	about 60
XIII	68	–
XVII	66	–
XX	73	–
XXX	73	–
between male pores	14	14
Genital papillae		
preclitellar	1 pair on postsetal VIII	absent
postclitellar	absent	absent
Male pores	each on a small, circular, slightly protuberant porophore with circumferential furrows	each on a small mound within concentric rings
Spermathecal pores	4 pairs on anterior VI–IX, each pore on a half-ring-like papilla immediately posterior to the intersegmental furrow	4 pairs post-intersegmental in U-shaped hemispheres on 5/6–8/9
Spermathecae	ampulla elongated oval, diverticulum with a slender stalk and an elongated oval seminal chamber	ampulla elongated oval, diverticulum with a slender stalk and an oval seminal chamber
Hearts	4 pairs in X–XIII	last hearts in XIII
Testes	X, XI	X, XI
Seminal vesicles	each small with a large dorsal lobe, in XI and XII	XI, XII
Prostate glands	small in XVII–XVIII	racemose in XVIII
Accessory gland	whitish glandular mass	–

(Tokyo NMST An435)". It is unlikely that different subspecies are sympatric in a park! *A. carnosus roki* was erected based on two specimens with following statement made in the "Remarks" section (Blakemore & Lee 2013, p. 131): "This taxon is particularly similar to *A. monstriferus* (Kobayashi, 1936), differing not least on the lack of markings on segment 8, and possibly they should be merged. Pending further research, *A. carnosus monstriferus* is reduced to sub-species status as it complies with Kobayashi's (1936) types XII & I of *A. carnosus*!". The only difference between *A. monstriferus* and *A. carnosus roki* is presence or absence of genital papillae on segment VIII (Table 7). All the other "distinctive characters" of *A. carnosus roki* mentioned by Blakemore and Lee (2013, p. 130) are also possessed by *A. monstriferus*, such as large body size and U-shaped post-intersegmental spermathecal papillae. When the illustrations of *A. carnosus roki* (Blakemore & Lee 2013, Fig. 3. A & B) and *A. monstriferus* (Kobayashi 1936b, text-fig. 11) are compared, they are indistinguishable. Since both taxa are erected based on few specimens (Table 7) and presence or absence of genital papillae is subjected to individual variation, the two taxa should be merged as indicated above by Blakemore and Lee (2013, p. 131). *A. monstriferus* was first listed as one of the synonyms of *A. carnosus* by Blakemore (2012a) and then considered a subspecies of *A. carnosus* in Blakemore and Lee (2013). According to Kobayashi (1936a), *A. carnosus* usually has pre-intersegmental spermathecal papillae and pre-clitellar genital papillae in presetal VIII and IX. Therefore, Blakemore and Lee (2013, p. 130) state "On these characters the present subspecies appears to differ from the nominal taxon's neotype and from other synonyms in Blakemore (2012a: 36), also supported with definitive DNA barcode data from its primary type (w56 in Appendix). It shows only 91% similarity to other *A. carnosus* specimens". The validity of *A. monstriferus* is thus established by both molecular and morphological evidences presented in Blakemore and Lee (2013). In other words, the identity of the holotype of *A. carnosus roki* (NIBR-IV0000261264 providing DNA w56) from Incheon Great Park where *A. carnosus* individuals are also collected should be *A. monstriferus*, a valid species separable from *A. carnosus*.

Meanwhile, Blakemore (2013c) proposed *Amynthas carnosus naribunji* from Ulleung-do, South Korea and states in the abstract that "No attempt is made to fully resolve numerous Japanese synonyms of *A. carnosus*…nor Korean synonyms". The single specimen of the so-called *A. carnosus naribunji* was originally identified as "?*Amynthas pingi* (Stephenson, 1925)" in Blakemore (2013b, p. 60) with following statement made in the "Remarks" section: "This Ullong-do specimen requires comparison with the type of *A. pingi* and with other synonyms in chronological order". However, such a comparison was not made, and the name *A. carnosus naribunji* was given to this specimen in Blakemore (2013c). Without discernible morphological characteristics and as stated in Blakemore (2013c, p. 103), *A. carnosus naribunji* is a mostly molecular taxon. Its status remains questionable unless it is morphologically distinguished from all the synonymous taxa listed in Blakemore (2010; 2012a,b,c; 2013a,b), because one of the synonyms may have priority. *A. carnosus naribunji* is therefore considered as *subspecies inquirenda*.

***Amynthas gracilis* (Kinberg, 1867).** *A. gracilis* is a cosmopolitan species with large intraspecific variation, and more than a dozen of synonyms can be found in Blakemore (2010). Blakemore (2013a, p. 26) lists *Amynthas gracilis gracilis* based on a single specimen, IV000251208 from Cheonji-yeon Falls, Jeju Island, South Korea, 13th June, 2012. It was a mature specimen with DNA sample labeled as w63. Blakemore (2013a, p. 28) states in the "Remarks" section that "a potential sub-species is tentatively described below that differs from the more familiar concept of the cosmopolitan *A. gracilis*, yet its DNA - at least for the part of the COI gene - agrees 100% with the current specimen". The so-called "potential sub-species" was named *Amynthas gracilis insularum* which was also based on a single specimen numbered as IV0000251309, holotype providing DNA sample (WO55 resampled as w31), and collected from Cheonji-yeon Falls, Seogwipo, Jeju Island, South Korea, 13th June, 2012. Undisputedly, it is meaningless to create a "potential sub-species", *A. gracilis insularum*, collected from exactly the same locality and on the same day with *A. gracilis gracilis*. Especially w63 and w31 are 100% identical genetically (Blakemore 2013a, Appendix, p. 54)! All the morphological differences between *A. gracilis insularum* and *A. gracilis gracilis* are slight and are merely individual variation, such as the more anteriorly placed first dorsal pore in 10/11 in *A. gracilis insularum* [first dorsal pore in 11/12 in *A. gracilis gracilis* as mentioned in Blakemore (2013a, p. 26)]. Blakemore (2013 a, p. 28) also states in the "Remarks" section of *A. gracilis insularum* that "the current name awaits confirmation from further data and comparison with the fifteen or so historical names included, in whole or in part, in the nominal taxon's synonymy". However, no such a comparison was made in the study or in subsequent studies. In addition, the erection of *A. gracilis insularum* was based on a single specimen, apparently neglecting individual variation; especially *A. gracilis* is a variable species. The papilla arrangement as a triumvirate in the male pore region, regarded as distinct by Blakemore (2013 a, p. 28), is also observed in *A. gracilis* individuals from various parts of Taiwan. These individuals were sympatric with other individuals showing other types of papilla arrangements. It means that such a papilla arrangement is individual variation and not characteristic of individuals from Jeju Island, South Korea. The subspecies category can be deleted for this nominal species due to lack of molecular and morphological distinction and biogeographical significance.

Pertaining to the position of first dorsal pore, Blakemore (2013c, p. 116) also made the following conflicting statement: "However, any of these specimens with spermathecal pores in 5/6/7/8/9 **not** on papillae/porophores described for *A. carnosus* probably equate more to *A. corticis*, as indeed does *A. penpuensis* Shen *et al.*, 2003 as **syn. nov.** since all that currently separates it is its dorsal pores slightly more in advance (from 5/6 or 6/7 rather than from 11/12 abouts), this single character is doubtfully adequate for species level separation". Generally, one- or two-segment difference in the position of first dorsal pore among individuals is normal in many earthworm species, but it makes a real difference if this position varies by at least four segments. *A. penpuensis* has been proven to be a valid species as mentioned earlier.

Drawida koreana **Kobayashi, 1938.** Blakemore *et al*. (2014) erected three subspecies, *austri*, *nanjiro* and *shindo*, of *Drawida koreana*. It was stated in the "Remarks" section of *Dr. koreana nanjiro* that "It is especially close morphologically and is sympatric to the *D. koreana austri* Incheon paratype as well as to *Drawida koreana shindo* **sp. nov.** but is clearly separated from both by characteristics noted and marginally on its DNA data [in Appendix, Fig. 1 where BLAST WO22 (*D. k. nanjiro*) vs. WO27 (*D. k. shindo*) Identities=640/658 (97%), i.e., 3% different with 18 nucleotide bases exchanged; WO22 (*D. k. nanjiro*) vs. WO23 (*D. k. austri*) =596/660 (90%)]". The holotype of *Dr. koreana nanjiro* was found together with the paratype of *Dr. koreana austri* from Incheon, South Korea [see also the "Material" sections of *Dr. koreana austri* and *Dr. koreana nanjiro* in Blakemore *et al*. (2014)]. However, to collect different subspecies together at the same time ignores the biogeographical connotation of the subspecies concept. Furthermore, and as reported by Blakemore *et al*. (2014), *Dr. koreana austri* has long, coiled sperm ducts, *Dr. koreana nanjiro* has moderately long, coiled sperm ducts and those of *Dr. koreana shindo* are short though the former two are poorly illustrated (Blakemore *et al*. 2014, Figs. 11 and 12, respectively), whereas *Dr. koreana* was originally described as having short sperm ducts (Kobayashi 1938b). Molecular and morphological differences as well as the sympatric occurrence of *Dr. koreana nanjiro* and *Dr. koreana austri* suggest the elevation of *Dr. koreana austri* to species rank.

Conclusion

The importance of the following statements made by Tsai *et al*. (2007, p. 377) needs to be reemphasized: "Using speculative synonyms with question marks (without reasoning) to deny the specific status of nominal species (Easton 1981; Blakemore 2003; Blakemore *et al.* 2006), and arbitrarily consider parthenogenetic nominal species as reproductively degenerated morphs (Blakemore 2003) to reject their specific status undoubtedly underestimate the biodiversity of the earthworm fauna of Japan, and create confusion in oligochaete taxonomy". Tsai *et al*. (2007) also point out that synonyms with question marks are not the synonym defined by the International Commission on Zoological Nomenclature (1999, p. 117): "each of two or more names of the same rank used to denote the same taxonomic taxon". Albeit synonyms with question marks are not forbidden by the ICZN, their proliferation is harmful to taxonomy. It is not a clearly exposed hypothesis but only some sort of doubt, which all too often converts into established fact in subsequent publications. Consequently, synonyms with question marks should simply be disregarded.

As for erecting sympatric subspecies, regardless of being a common practice in earthworm taxonomy (Christian & Zicsi 1999), this action ignores the biogeographical connotation of the concept. Earthworm taxonomy should come of age and adopt the meaning of subspecies that is accepted in the rest of biodiversity research.

An integrative taxonomic approach to the identification of earthworm species has recently been advocated (Boyer *et al*. 2011; Chang *et al*. 2014). As indicated in Chang *et al*. (2014, p. 331), the studies regarding the *Metaphire formosae* species-group, a group of giant earthworms endemic to Taiwan, published after 2000 have in fact collectively demonstrated an integrative taxonomic approach through which hypotheses regarding species are tested using morphological, molecular, biogeographical and, to some extent, ecological data. Using a single character, such as papilla arrangement, for species identification and synonymization is highly unreliable. For example, the male pore structure and variable papilla arrangements in the male pore region of *Amynthas tsou* Shen and Chang, 2016 look fairly similar or even identical to those of *Amynthas mutabilitas* Shen, 2012 (see Shen 2012, p. 2272, Figure 2C and Shen *et al.* 2016, p. 1899, Figure 4b). However, the two species are genetically distinguishable (Shen *et al.* 2016, p. 1892, Figure 1), the characters of their reproductive organs are distinctively different and *A. tsou* is from southwestern while *A. mutabilitas* is from eastern Taiwan with the Central Mountain Range as a major geographical barrier. When molecular data are not available, as in the case of *A. monsoonus* and *A. fuscus* mentioned in the "*Amynthas carnosus* (Goto & Hatai, 1899)" section, distributional data may give a hint concerning the possibility of synonymy of morphologically similar species. Misidentification and mis-synonymization or even misinterpretation exemplified in this study provoke not only taxonomic but also distributional confusion of related species. The meaning of biogeography each species/subspecies stands for should be carefully considered, not ignored.

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