

## Native and Exotic Species of Terrestrial Earthworms (Oligochaeta) in Taiwan with Reference to Northeast Asia

Chu-Fa Tsai\*, Huei-Ping Shen and Su-Chen Tsai

Habitat and Ecosystem Division, Taiwan Endemic Species Research Institute, Chichi, Nantou, Taiwan 552, R.O.C.

(Accepted May 15, 2000)

**Chu-Fa Tsai, Huei-Ping Shen and Su-Chen Tsai (2000)** Native and exotic species of terrestrial earthworms (Oligochaeta) in Taiwan with reference to Northeast Asia. *Zoological Studies* 39(4): 285-294. Of the 35 nominal species of terrestrial earthworms (Oligochaeta) reported from Taiwan, there are 30 species of the Megascolecidae, two species of the Lumbricidae, and 1 species each for the Moniligastridae, Glossoscolecidae, and Octochaetidae. The genera *Amyntas* and *Metaphire* of the Megascolecidae are dominant and include 27 species, of which 12 species are native. Among these 35 species, the 12 native species occur primarily in hills and mountains of the island, where natural environments (forests) still remain, or in areas relatively less disturbed by humans. The other 23 species are exotic, including 4 species with presumed origins from America and Europe, four species from Southeast Asia, and 15 species from southern China. They occur in disturbed environments (urban areas and cultivated lands) on the plains and in some hill and mountainous areas. Endemism based on the nominal species in Taiwan is 34.3%, which is much lower than 74.2% for Hainan Island, 78.1% for China, 65.0% for Japan, 60.0% for Korea, and 37.0% for the Ryukyus. The native species of *Amyntas* and *Metaphire* in Taiwan are apparently offshoots of the oligochaete fauna of southern China, resulting from dispersion differentiation.

**Key words:** Endemism, Distribution, Biogeography.

Earthworms have feeble powers of travel and are easily isolated geographically. However, many species of earthworms disperse widely with assistance from nature, such as on tree trunks floating downstream and in earth between the hooves of animals (Stephenson 1929), and/or as the result of human activities, such as in earth on roots of introduced plants for horticulture, agriculture, and botanical gardens (Beddard 1912, Gates 1972, Lee 1985). Based on the distribution and dispersion mechanism, terrestrial earthworms in a geographical area may consist of both native and exotic species. A native species is generally a species that naturally occurs in a restricted geographical area. It is certainly speciated locally and is thus autochthonous (= endemic, indigenous) (Gates 1972). In contrast, an exotic species is a foreign species introduced to a particular geographical area. It is equivalent to a peregrine species, that is a species of wide distribution in Michaelsen's term (Edwards and Bohlen

1996), but more commonly characterized as an anthropochorous species, defined as a species transported by humans, usually unintentionally (Gates 1972).

In this study we reviewed the literature to determine the native or exotic status of the terrestrial earthworms in Taiwan, and their endemism and geographic affinities, as compared to those in other geographical areas of Northeast Asia, including mainland China, Hainan Island, the Ryukyu Islands and other Japanese islands, the Korean Peninsula, and Manchuria.

### RESEARCH IN TAIWAN

Investigation of the earthworm fauna in Taiwan began at the end of the 19th century, when Goto and Hatai (1898) described new and imperfectly known species of earthworms in the Japanese Empire. In

\*To whom correspondence and reprint requests should be addressed. Tel: 886-4-9761-331 ext. 256. Fax: 886-4-9764-600.

this report they described *Pheretima takatorii* and *P. candida* from Taipei. Michaelsen (1922) examined the specimens of earthworms collected by Hans Sauter from the locality presently called Chiahsien in Kaohsiung. He described a new species, *P. formosae*, and also reported a nominal species, *P. papulosa* Rosa. Kobayashi (1938a,b,d) made a general survey in Hsinchu and added 10 nominal species: *Drawida japonica* Michaelsen, *Bimastos parvus* Eisen, *P. californica* Kinberg, *P. hawayana* (Rosa) (= *Amyntas gracilis* (Kinberg)), *P. morrissi* (Beddard), *P. rockefelleri* Chen (= *A. papulosa* (Rosa)), *P. diffringens* (Baird) (= *A. corticus* (Kinberg)), *P. hupeiensis* (Michaelsen), *Perionyx excavatus* Perrier, and *Dichogaster bolau* (Michaelsen). Kobayashi (1941b) added *P. zoysiae* Chen (= *A. minimus* (Horst)).

After World War II, Gates (1959) examined the specimens collected by D. E. Beck on the plains of Taiwan, including the Taipei City; Chaochow, Pingtung County; and Suao, Ilan Co. He listed 10 nominal species of *Pheretima* earthworms, including *P. bicincta* (Perrier), *P. elongata* (Perrier), *P. incongrua* Chen, and *P. posthuma* (Vaillant) as new records. A few years later Tsai (1964) collected earthworms in the Taipei area, and recorded the 3 nominal species, *P. schmardae* (Horst), *P. lauta* (Ude), and *P. robusta* (Perrier), and described 4 new species, namely *P. yushi*, *P. swanus*, *P. taipeiensis*, and *P. polyglandularis*.

Sims and Easton (1972) considered *Amyntas polyglandularis* of Taiwan (Tsai 1964) to be a subspecies of *A. omeimontis* of Mt. Omei in Sichuan, China (Chen 1934), and called it *A. omeimontis polyglandularis*. They also included 2 additional subspecies, *A. omeimontis kinfumontis* of Mt. Kinfu in Sichuan (Chen 1946) and *A. omeimontis kinabalu* of North Borneo (Sims and Easton 1972). However, based on figure 3 of Sims and Easton (1972), their locations and patterns of genital papillae differ so greatly that specific distinction is possibly permissible. Therefore, in this study we retain *A. polyglandularis* as a valid species.

Recently, Kuo (1995) described a new species, *P. hsinpuensis*, from Hsinchu, Taiwan. Chen and Shih (1996) made an earthworm survey in the Fushan Botanical Garden (elevation 1000 m) in Ilan of northeastern Taiwan. They reported 6 nominal species: *P. taipeiensis*, *P. diffringens*, *P. hawayana*, *P. formosae*, *P. rockefelleri*, and *P. polyglandularis*. Shih et al. (1999) reviewed the literature on Taiwan's earthworms and listed 26 nominal species.

For the past 100 yr, faunal surveys of earthworms in Taiwan have been conducted primarily on

the plains of northern and western Taiwan. The exceptions were Michaelsen (1922) whose materials were collected from a peripheral hill of southwestern Taiwan, and Chen and Shih (1996) who surveyed a botanical garden in the mountains of northeastern Taiwan.

Since 1998 we have conducted an earthworm survey for the island with particular attention to hill and mountainous areas. We have described 7 new species: *Amyntas tungpuensis* and *A. sexpectatus* from Nantou County, *A. tayalis* from Taipei Co., *A. binoculatus* from Taichung Co., *Metaphire puyuma* from Taitung Co. (Tsai et al. 1999), *M. paiwana* from Pingtung and Hualien Cos., and *M. bununa* from Nantou and Taitung Cos. (Tsai et al. 2000b). We also added *Pontoscolex corethrurus* (Müller) (Tsai et al. 2000a) and *Metaphire hesperidum* (Beddard) as new exotic species to the fauna of Taiwan. We found that *P. yushi* described from Taipei (Tsai 1964) is a junior synonym of *A. formosae* described by Michaelsen (1922). *A. lautus* (Ude) and *A. robustus* (Perrier) are considered as 2 valid species (Tsai 1964), however, Easton (1980) considered the former to be a junior synonym of the latter.

To date, there are 35 nominal species of terrestrial earthworms in Taiwan, of which 12 species are native (Table 1). They are classified according to the Reynolds and Cook System (Edwards and Bohlen 1996) for families, and according to Sims and Easton (1972) and Easton (1979) for the genera of the *Pheretima* species complex of the Megascolecidae.

## LIST OF TAIWAN EARTHWORMS

### Order Moniligastrida

#### Family Moniligastridae

1. *Drawida japonica* Michaelsen

### Order Haplotaenida

#### Suborder Lumbricina

#### Superfamily Lumbricoidea

##### Family Lumbricidae

2. *Allolobophora trapezoides* Duges
3. *Bimastos parvus* Eisen

#### Superfamily Glossoscolecoidae

##### Family Glossoscolecidae

4. *Pontoscolex corethrurus* (Müller)

#### Superfamily Megascolecoidae

##### Family Megascolecidae

5. *Amyntas aspergillus* (Perrier)
6. *Amyntas binoculatus* Tsai, Shen and Tsai
7. *Amyntas candidus* (Goto and Hatai)
8. *Amyntas corticus* (Kinberg)

9. *Amyntas formosae* (Michaelsen)  
 10. *Amyntas gracilis* (Kinberg)  
 11. *Amyntas hsinpuensis* (Kuo)  
 12. *Amyntas hupeiensis* (Michaelsen)  
 13. *Amyntas incongruus* (Chen)  
 14. *Amyntas lautus* (Ude)  
 15. *Amyntas morrisi* (Beddard)  
 16. *Amyntas polyglandularis* (Tsai)  
 17. *Amyntas papulosus* (Rosa)  
 18. *Amyntas robustus* (Perrier)  
 19. *Amyntas sexpectatus* Tsai, Shen and Tsai  
 20. *Amyntas swanus* (Tsai)  
 21. *Amyntas taipeiensis* (Tsai)  
 22. *Amyntas tungpuensis* Tsai, Shen and Tsai  
 23. *Amyntas tayalis* Tsai, Shen and Tsai  
 24. *Amyntas minimus* (Horst)  
 25. *Metaphire bununa* Tsai, Tsai and Liaw  
 26. *Metaphire californica* (Kinberg)  
 27. *Metaphire hesperidum* (Beddard)  
 28. *Metaphire paiwana* Tsai, Tsai and Liaw  
 29. *Metaphire posthuma* (Vaillant)  
 30. *Metaphire puyuma* Tsai, Shen and Tsai

**Table 1.** Terrestrial earthworms reported from Taiwan and their occurrence in China, the Ryukyus, Japan, Korea, and Southeast (SE) Asia

Species	Taiwan	China	Ryukyus	Japan	Korea	SE Asia
<b>Native species</b>						
<i>Amyntas candidus</i> (Goto and Hatai)	+	–	–	–	–	–
<i>Amyntas formosae</i> (Michaelsen)	+	–	–	–	–	–
<i>Amyntas swanus</i> (Tsai)	+	–	–	–	–	–
<i>Amyntas polyglandularis</i> (Tsai)	+	–	–	–	–	–
<i>Amyntas hsinpuensis</i> (kuo)	+	–	–	–	–	–
<i>Amyntas tungpuensis</i> Tsai, Shen and Tsai	+	–	–	–	–	–
<i>Amyntas tayalis</i> Tsai, Shen and Tsai	+	–	–	–	–	–
<i>Amyntas sexpectatus</i> Tsai, Shen and Tsai	+	–	–	–	–	–
<i>Amyntas binoculatus</i> Tsai, Shen and Tsai	+	–	–	–	–	–
<i>Metaphire puyuma</i> Tsai, Shen and Tsai	+	–	–	–	–	–
<i>Metaphire bununa</i> Tsai, Tsai and Liaw	+	–	–	–	–	–
<i>Metaphire paiwana</i> Tsai, Tsai and Liaw	+	–	–	–	–	–
<b>Exotic species</b>						
<i>Pontoscolex corethrurus</i> (Müller)	+	–	–	–	–	+
<i>Dichogaster bolau</i> Michaelsen	+	–	–	+	–	+
<i>Allolobophora trapezoides</i> Duges	+	+	–	+	+	+
<i>Bimastos parvus</i> Eisen	+	+	–	+	+	+
<i>Perionyx excavatus</i> Perrier	+	–	–	–	–	+
<i>Metaphire posthuma</i> (Vaillant)	+	+	–	–	–	+
<i>Polypheretima elongata</i> (Perrier)	+	–	+	–	–	+
<i>Pithemera bicincta</i> (Perrier)	+	–	+	+	–	+
<i>Amyntas aspergillus</i> (Perrier)	+	+	–	–	–	–
<i>Amyntas taipeiensis</i> (Tsai)	+	+	–	–	–	–
<i>Amyntas incongruus</i> (Chen)	+	+	–	–	–	–
<i>Amyntas lautus</i> (Ude)	+	+	+	–	–	–
<i>Metaphire hesperidum</i> (Beddard)	+	+	–	–	–	+
<i>Amyntas papulosus</i> (Rosa)	+	+	+	–	–	+
<i>Metaphire schmardae</i> (Horst)	+	+	+	+	–	+
<i>Amyntas hupeiensis</i> (Michaelsen)	+	+	+	+	+	+
<i>Amyntas gracilis</i> (Kinberg)	+	+	+	+	–	+
<i>Amyntas morrisi</i> (Beddard)	+	+	+	+	–	+
<i>Amyntas robustus</i> (Perrier)	+	+	+	+	–	+
<i>Metaphire californica</i> (Kinberg)	+	+	+	+	–	+
<i>Amyntas corticus</i> (Kinberg)	+	+	+	+	+	+
<i>Amyntas minimus</i> (Horst)	+	+	+	+	–	+
<i>Drawida japonica</i> Michaelsen	+	+	–	+	+	+

Key: +, present; –, absent.

31. *Metaphire schmardae* (Horst)
  32. *Perionyx excavatus* Perrier
  33. *Pithemera bicincta* (Perrier)
  34. *Polypheretima elongata* (Perrier)
- Family Octochaetidae
35. *Dichogaster bolau* (Michaelsen)

## RESEARCH IN OTHER AREAS OF NORTHEAST ASIA

### Mainland China

Stephenson (1925) described a new species, *Pheretima pingi*, and reported a nominal species, *P. houletti* Perrier, from Nanjing. Later Michaelsen (1929) listed 20 nominal species from various parts of China proper (Fujian, Chihli, Yunnan, Hubei, Anhui, and Hongkong). They included 6 native species of the Megascolecidae and 16 exotic species of the Moniligastridae, Lumbricidae, Megascolecidae, and Acanthodrilidae. He mentioned that no native Oligochaeta are known from Tibet or Mongolia bordering China.

After that time, great efforts were made by Dr. Y. Chen of National Central Univ. until the end of World War II. He investigated the provinces of the lower Yangtze River valley, including Jiangsu, Zhejiang, Anhui, Jiangxi, Hubei, and Hunan (Chen 1930 1933), as well as the province of Sichuan (Chen 1931 1936 1946), and the coastal areas of southern China, Fujian Prov. (Chen 1935a), and Hongkong (Chen 1935b). After the Second World War, he seemingly ceased his investigations. In his latest paper, he described 7 new species from various parts of China (Chen et al. 1975). Among these 7 species we consider that *Pheretima heterogens* Chen and Hsu from Fujian is *Amyntas taipeiensis* of Taiwan (Tsai 1964).

In addition to Chen's work, Gates (1935a,b 1939) examined specimens collected from Sichuan by Dr. D. C. Graham of the American Baptist Foreign Mission Society in 1921-1926, and deposited in the United States National Museum. He described 41 species, of which 19 are new.

According to the above studies, there is a total of 105 nominal species of terrestrial earthworms from mainland China. They include 81 native species, of which 51 species are from mountainous regions of Sichuan Prov. (Chen 1931 1936 1946, Gates 1935b 1939).

Chen (1938) also investigated the earthworm fauna of Hainan Island off the coast of South China, where he found 31 species, of which 23 species are native.

### Japanese islands

Horst (1883) described *Perichaeta sieboldii* (= *Metaphire sieboldi*), the oldest nominal species of earthworm in Japan from the collections in the Leyden Museum. Goto and Hatai (1898 1899) described 28 new species of *Perichaeta* (= *Pheretima*) from Honshu, Shikoku, and Tokyo. Later faunal surveys of earthworms were conducted primarily by Dr. S. Hatai of Tohoku Univ., Dr. S. Ohfuchi of the Saito Ho-on Kai Museum, and Dr. S. Kobayashi of Keijo Second Higher Common School (Hatai 1930a,b, Ohfuchi 1935 1937a,b 1938a,b 1941, Hatai and Ohfuchi 1936 1937, Kobayashi 1941a,b). The investigations were interrupted from the beginning of the Second World War until 1980, when Easton reviewed the Japanese earthworm fauna.

Based on Easton's (1980) account, the Japanese islands (excluding the Ryukyu Islands) have 71 species of terrestrial earthworms, under which he lists 21 synonymous species but with question marks. We feel that until their doubtful species statuses as suggested by Easton (1980) are verified, they should remain as valid species. Recently, Ishizuka (1999) described 11 new species in the genus *Pheretima* with manicate intestinal caeca from the Tokyo area. He stated that of the more than 70 species collected in the area, about 50 species are undescribed. Based on Easton (1980) (including the synonyms with question marks) and Ishizuka (1999), there is a total of 103 nominal species in Japan, of which 67 are native.

### Ryukyu Islands

Kobayashi (1941b) listed 10 species from Okinawa. Ohfuchi (1956 1957) described 25 species based on the specimens collected from the islands of Okinawa, Miyako, Ishigaki, Iriomote, Hatoma, and Kobana. Among them 10 species are native.

### Korea and Manchuria

Kobayashi (1934 1936 1938c 1940a) listed 45 species from Korea, of which 27 species are native. Kobayashi (1940b) listed 19 species from Manchuria, of which 5 species are native (Table 1).

## NATIVE SPECIES

For the 12 native Taiwanese species of earthworms reported, nine belong to the genus *Amyntas* and 3 to the genus *Metaphire* (Table 1).

*Amyntas candidus* was described by Goto and Hatai (1898) from a single specimen collected from Taipei. Since then it has not been found. We suspect that this species once living on the plains of Taipei has probably become extinct due to the intensive urbanization of the area.

The type locality of *A. swanus* is the campus of National Taiwan Univ. in Taipei (Tsai 1964). It is probably a plains-dwelling species, whose habitat has apparently been ruined by recent construction of buildings on the campus.

*A. formosae* was described by Michaelsen (1922) from specimens collected from the mountain area of Chiahsien, Kaohsiung Co. It was later found in Hsinchu (Kobayashi 1938a), Pingtung (Gates 1959), Taipei (= *Pheretima yushi*) (Tsai 1964), and Ilan (Chen and Shih 1996). According to our present survey, this species is one of the large earthworms of the island, commonly found in the peripheral hills to mountains at 1000 m in elevation in the northern and western portions of the Central Mountain Range.

The type locality of *A. tungpuensis* is Tungpu, Nantou Co. in the Central Mountain Range at an elevation of 1000 m (Tsai et al. 1999). It is also found in the Mt. Wushekeng area (elevation 1000 m), Taichung Co., and also in Mt. Shinan (elevation 2000 m), Kaohsiung Co. It is apparently a common medium-sized earthworm in mountains at elevations between 1000 and 2000 m.

The other 5 species of *Amyntas* are known only from their type localities in the peripheral hills of the Central Mountain Range in western Taiwan. They are *A. polyglandularis* from Taipei (Tsai 1964), *A. hsinpuensis* from Hsinpu, Hsinchu Co. (Kuo 1995), *A. tayalis* from Shijr, Taipei Co., *A. sexpectatus* from Koshin, Nantou Co., and *A. binoculatus* from Wufeng, Taichung Co. (Tsai et al. 1999).

For the 3 native species of *Metaphire*, *M. puyuma* is known from a single specimen collected from the shore of Monhuan Lake south to the city of Taitung in southeastern Taiwan (Tsai et al. 1999). It is apparently a plains dweller. *M. bununa* is a common, large mountain earthworm distributed on the western side of the Central Mountain Range at elevations from 150 (Tsai et al. 2000b) to 3000 m in Nantou Co. It also is found on the eastern side of the Central Mountain Range in Taitung Co. *M. paiwana* is found in the mountains of Pingtung Co. in southwestern Taiwan and also in the Coastal Mountain Range of Hualien and Taitung Cos. in eastern Taiwan (Tsai et al. 2000b).

For the 23 species of exotic earthworms in Taiwan (Table 1), *Pontoscolex corethrurus*, *Bimastos parvus*, *Dichogaster bolau*, and *Allolobophora trapezoides* are cosmopolitan in distribution. The original ranges have been suggested to be in tropical America for *P. corethrurus*; either tropical America or Africa for *D. bolau* (Gates 1972); the cold eastern part of North America for *B. parvus*; and the Palearctic (Europe) for *A. trapezoides* (Easton 1980). These 4 species are known to have been transported by man to many parts of the America, Africa, and Asia (Gates 1972, Easton 1980, Lee 1985, Edwards and Bohlen 1996). They commonly occur in tropical regions of South and Southeast Asia (Michaelsen 1934, Gates 1972).

*P. corethrurus* and *D. bolau* are tropical species. In Northeast Asia the former is found only in Taiwan (Tsai et al. 2000a), and the latter occurs in Taiwan and the Ryukyus (Kobayashi 1941a,b). These 2 species have not been found in China, Korea, or Japan. *B. parvus* and *A. trapezoides* are cold-tolerant species. They are distributed widely in Northeast Asia, including China (Michaelsen 1929, Chen 1931 1933), Taiwan (Kobayashi 1938b 1941b, Kuo 1995), Japan (Easton 1980), Korea (Kobayashi 1940a), and Manchuria (Kobayashi 1940b) (Table 1).

*Perionyx excavatus*, *Polypheretima elongata*, *Pithemera bicincta*, and *Metaphire posthuma* are also common exotic species in Taiwan. The original ranges have been suggested to be in the eastern Himalayas (India and Burma) for *P. excavatus*; Borneo, Celebes, and the Philippines for *P. elongata*; and Thailand and Indochina for *M. posthuma* (Gates 1972, Easton 1976 1979). Because of similarities in the distribution between *P. bicincta* and *P. elongata* (Table 1), in this study the original range of *P. bicincta* is also presumed to be in the area similar to or near to that of *P. elongata*. These 4 species are cosmopolitan, and have been transported by man from Southeast Asia to many parts of the world (Gates 1972).

In Northeast Asia, *Perionyx excavatus* is found only in Taiwan (Kobayashi 1938b,d, Gates 1959); *Metaphire posthuma* in Yunnan Prov. of China (Michaelsen 1929) and Taiwan (Gates 1959, Tsai 1964); and *Polypheretima elongata* and *Pithemera bicincta* in Taiwan (Gates 1959) and the Ryukyus (Ohfuchi 1956 1957, Easton 1980). Except for *M. posthuma* in Yunnan, the other species of *P. excavatus*, *P. elongata*, and *P. bicincta* have not been found in China.

The remaining 15 species, including 11 species of *Amyntas*, three species of *Metaphire*, and 1 species of *Drawida*, are exotic in Taiwan, presumably

## EXOTIC SPECIES

originating from mainland China. They show various distribution ranges in Northeast Asia (Table 1) and other parts of the world.

*Amyntas aspergillus*, *A. incongruus*, *A. taipeiensis*, and *A. lautus* have a limited range of distribution in Taiwan, southern China, and occasionally in the Ryukyu Islands. *A. aspergillus*, *A. incongruus*, and *A. taipeiensis* occur only in Taiwan (Kobayashi 1938a, Gates 1959, Tsai 1964) and southern China (Michaelsen 1929, Chen 1933, Gates 1935a, Chen et al. 1975); while *A. lautus* is in Taiwan (Tsai 1964), southern China (Chen 1933), and the Ryukyus (Ohfuchi 1956). Michaelsen (1929) considered *A. aspergillus* to be a peregrine species to a small extent.

*A. hesperidum*, *A. papulosus* (Rosa), *A. hupeiensis*, and *Metaphire schmardae* are distributed primarily in southern China and Taiwan, but are also found sporadically in some other areas of Northeast Asia, Southeast Asia, and other parts of the world. *A. hesperidum* occurs primarily in southern China (Michaelsen 1929, Chen 1931 1933) and Taiwan based on our recent survey, and has been also recorded from Burma, Hawaii (Gates 1972), and Barbados (Beddard 1892). *A. papulosus* occurs in Taiwan (Kobayashi 1938a) and southern China (Chen 1933), also in the Ryukyu Islands (Ohfuchi 1956), Burma, Thailand, and Sumatra (Gates 1972). *M. schmardae* and *A. hupeiensis* are widely distributed in Taiwan (Kobayashi 1938a, Tsai 1964), southern China (Michaelsen 1929, Chen 1931 1933 1935a, b 1936), the Ryukyus (Kobayashi 1941a,b), and other areas of Japan (Easton 1980). *M. schmardae* also occurs in Hawaii and Barbados; and *A. hupeiensis* in North America and New Zealand (Easton 1980).

*A. gracilis*, *A. morrisoni*, *A. robustus*, *A. corticus*, *A. minimus*, *M. californica*, and *Drawida japonica* are cosmopolitan in distribution. They are abundant in Taiwan (Kobayashi 1938a,b, Tsai 1964), southern China (Michaelsen 1929, Chen 1931 1933 1935a,b 1936 1938, Gates 1935a), the Ryukyu Islands (Ohfuchi 1956), and some are found in Japan (Easton 1980) and Korea (Kobayashi 1938c 1940a) in Northeast Asia (Table 1). They are also very common in Southeast Asia and other parts of the world (Gates 1972).

## ENDEMISM

Based on the literature, the numbers of native species and exotic species by genera and families in Taiwan, Hainan I., China, the Ryukyus, Japan, Korea, and Manchuria are summarized in table 2.

Endemism of earthworm fauna in the geographical areas studied was estimated as the fractional number of native species out of the total number of species reported for a geographical area.

Hainan is an island separated from mainland China by a narrow (about 30 km) strait, but the earthworm faunas in both areas are highly distinctive (Chen 1938). The endemism is 74.2% in Hainan and 78.1% in China. The genera, *Amyntas* and *Metaphire*, are dominant and together comprise 71.0% of the earthworm fauna in Hainan, and 81.9% in China. The native species of these 2 genera comprise 82.6% of the total native species in Hainan and 85.4% in China, indicating the dominance of these 2 genera in the endemism of both areas.

A fairly similar case to that of Hainan and China is found for Japan and Korea. Japan is separated from Korea by a strait, and the earthworm faunas in both areas are also highly distinctive. Endemism is 65.0% in Japan and 60.0% in Korea. *Amyntas* and *Metaphire* are dominant and occupy 73.8% of the earthworm fauna in Japan and 66.7% in Korea. The native species of these 2 genera occupy 88.1% of the total native species in Japan and 81.5% in Korea, respectively.

Twenty-seven species of the earthworms have been reported for the Ryukyu Islands which have 37% endemism. All 10 native species belong to the genera *Amyntas* and *Metaphire*.

Manchuria (a historical region comprising Northeast China) is the northern range of the family Megascolecidae in Asia. Only 3 exotic species have been found: *A. hupeiensis* and *A. tschiliensis* from China, and *M. aggera* from Korea (Kobayashi 1940b). On the other hand, like Korea and Japan, Manchuria has a highly diverse fauna of the families Moniligastridae and Lumbricidae (16 species). All native species belong to the genera *Allolobophora* and *Drawida* with endemism of 26.3%.

Like the cases for China, Hainan I., Japan, Korea, and the Ryukyus, the earthworm fauna of Taiwan is dominated by *Amyntas* and *Metaphire*, occupying 77.1% of total species of earthworms. Endemism is 34.3% which is much lower than values found in the other 6 geographical areas of Northeast Asia, except for Manchuria (Table 2). Like the Ryukyus, all 12 native species belong to these 2 genera. When the areas, climate, and topography are compared among Hainan I., the Ryukyus, China, Japan, and Korea, the low number of species with low endemism found in Taiwan is more likely due to limited sampling of its earthworm fauna in the past than due to the geologically younger age of the island.

## HABITAT

In Taiwan, habitats and distributions of earthworms show obvious differences between native and exotic species. The native species of *Amyntas* and *Metaphire* occur almost solely in the hills and mountains where natural environments remain or have not been seriously disturbed by humans. Today the native species are almost absent from the plains where dense urbanization and intensive agriculture exist.

In contrast to the native species, the exotic species are found almost exclusively in disturbed environments on the plains, such as agricultural land, fruit orchards, banana plantations, betel nut plantations, botanical gardens, and city parks. In the hills and mountains, they are also commonly found in areas where there is cultivation.

It is reasonable to speculate that the plains and mountains of Taiwan were once covered with thick jungles before the rapid increase in Chinese immi-

**Table 2.** Numbers of native (N) and exotic (E) species of terrestrial earthworms (Oligochaeta) reported from Taiwan, China, Hainan I., the Ryukyus, Japan, Korea, and Manchuria

	Taiwan		China		Hainan		Ryukyus		Japan		Korea		Manchuria	
	N	E	N	E	N	E	N	E	N	E	N	E	N	E
<b>Monilogastridae</b>														
<i>Drawida</i>	–	1	7	2	1	–	–	–	4	4	4	1	1	4
<i>Desmogaster</i>	–	–	1	–	–	–	–	–	–	–	–	–	–	–
<b>Enchytraeidae</b>														
<i>Fridericia</i>	–	–	–	–	1	–	–	–	–	–	–	–	–	–
<b>Lumbricidae</b>														
<i>Allolobophora</i>	–	1	–	2	–	–	–	–	–	2	–	2	4	–
<i>Bimastos</i>	–	1	–	1	–	–	–	–	–	1	–	3	–	2
<i>Dendrobaena</i>	–	–	–	–	–	–	–	–	–	2	–	–	–	–
<i>Eisenia</i>	–	–	–	–	–	–	–	–	–	3	–	4	–	4
<i>Octolasion</i>	–	–	–	–	–	–	–	–	–	–	–	–	–	1
<b>Biwadrilidae</b>														
<i>Biwadrilus</i>	–	–	–	–	–	–	–	–	1	–	–	–	–	–
<b>Glossoscolecidae</b>														
<i>Pontoscolex</i>	–	1	–	–	–	–	–	–	–	–	–	–	–	–
<b>Microchaetidae</b>														
<i>Glyphidrilus</i>	–	–	–	–	–	1	–	–	–	–	–	–	–	–
<b>Megascolecidae</b>														
<i>Amyntas</i>	9	11	51	11	17	3	7	9	49	13	16	7	–	3
<i>Filodrilus</i>	–	–	–	–	1	–	–	–	–	–	–	–	–	–
<i>Lampito</i>	–	–	–	1	–	1	–	–	–	–	–	–	–	–
<i>Metaphire</i>	3	4	19	5	2	–	3	3	10	4	6	1	–	–
<i>Perionyx</i>	–	1	–	–	–	–	–	–	–	–	–	–	–	–
<i>Pheretima</i>	–	–	–	–	–	–	–	–	–	2	–	–	–	–
<i>Planapheretima</i>	–	–	3	–	–	–	–	–	–	–	–	–	–	–
<i>Pithemera</i>	–	1	–	–	–	–	–	1	–	1	1	–	–	–
<i>Polypheretima</i>	–	1	–	–	–	–	–	1	1	1	–	–	–	–
<b>Acanthodrilidae</b>														
<i>Microscolex</i>	–	–	–	–	–	–	–	–	–	1	–	–	–	–
<i>Pontodrilus</i>	–	–	–	–	–	1	–	–	–	1	–	–	–	–
<b>Octochaetidae</b>														
<i>Dichogaster</i>	–	1	–	–	1	1	–	2	–	2	–	–	–	–
<i>Howascolex</i>	–	–	1	–	–	–	–	–	–	–	–	–	–	–
<b>Ocnerodrilidae</b>														
<i>Ocnerodrilus</i>	–	–	–	1	–	1	–	1	–	1	–	–	–	–
Total (N or E)	12	23	82	23	23	8	10	17	67	36	27	18	5	14
Combined total (N + E)	35		105		31		27		103		45		19	
Endemism [N/ (N + E)] x 100%	34.3		78.1		74.2		37.0		65.0		60.0		26.3	
<i>Amyntas</i> + <i>Metaphire</i>	12	15	70	16	19	3	10	12	59	17	22	8	0	3
Native A. + M./ Total native (%)	100	–	85.4	–	82.6	–	100	–	88.1	–	81.5	–	0	–

gration 300-500 yr ago. As mentioned previously, there is a distinctive difference in habitat preference between native and exotic species. Also, there is high endemism of *Amyntas* and *Metaphire* earthworms in most of the geographical areas of North-east Asia, particularly for Hainan Island and mainland China. When we consider the above phenomena, it is reasonable to assume that the jungles previously covering both the plains and mountains of Taiwan were once inhabited entirely or nearly entirely by native species alone. Since then jungles of the plains have been cleared and those lands have been transformed into urban areas and farmlands. In these areas, natural habitats have been destroyed, and almost all native species of earthworms on the plains are no longer found. A few native species, e.g., *A. candidus*, *A. swanus*, and *M. puyuma*, found on the plains at present may be the relicts of such the original native forms. With habitat transformation, exotic species took over the areas disturbed by man over most of the plains, and also many parts of the hills and mountains, where the native fauna once lived.

## BIOGEOGRAPHY

Taiwan is an island situated on the continental slope of mainland China between the Ryukyu Arc and the Luzon Arc in the Western Pacific Ocean (Yu and Chow 1997). It is separated from mainland China by the 150-km-wide Taiwan Strait. The depth of the strait is about 60 m, and areas deeper than 100 m are found only in a trench between the Pescadores (Penghu) and southwestern Taiwan and in the waters north of Keelung (Lin 1957). Because of the relatively shallow strait, Taiwan is known to have been connected by a landbridge to mainland China several times during the Pleistocene. In the last Wurm Glacial period (10 000 to 56 000 yr ago), sea levels decreased by 80 m to 150 m (Lin 1957 1966).

The islands of Japan are separated from the Korean peninsula by the Korean Strait, which has a water depth of about 100 m (Kim et al. 1991). During the Pleistocene glacial periods, a landbridge was also present between Korea and Japan (Lin 1957). For the Ryukyu Islands, the biogeographical evidence indicates that the Miyako and Yaeyama Islands at the southern end of the Ryukyu Archipelago were connected with Taiwan in the early Pleistocene, while Okinawa and Amami Islands have been isolated from the continent since the Pliocene (Hikida and Ota 1997). Furthermore, Taiwan is separated

from the Philippines by a deep strait, the Bashi Channel, also the location of part of the so-called Wallace's Line (Lin 1957). Based on the above geohistorical and biogeographical evidences, the terrestrial fauna of Taiwan is known to belong to the "Oriental Province" north of Wallace's Line, and is closely related to that of China proper (Hikida and Ota 1997, Lin and Wu 1997, Tzeng et al. 1997).

All native terrestrial earthworms that have been found in Taiwan belong to the 2 genera, *Amyntas* and *Metaphire*. These 2 genera are highly diverse (numbers of species) with the highest endemism in mainland China, followed by Hainan I., Japan, Korea, the Ryukyus, and Taiwan (Table 2). It is considered that *Amyntas* and *Metaphire* are more advanced genera in the *Pheretima* auct. complex (Sims and Easton 1972), and an offshoot of the Malayan oligochaete fauna with the root of the genus *Archipheretima* in Borneo and the Philippines (Michaelsen 1929, Easton 1979). It is hypothesized that the native species of *Amyntas* and *Metaphire* in Taiwan are the results of dispersion differentiation with their ancestral forms from southern China.

## REFERENCES

- Beddard FE. 1892. On some species of the genus *Perichaeta*. Proc. Zool. Soc. London **1892**: 153-172.
- Beddard FE. 1912. The Oligochaeta terricolae of the Philippines. Part 1. The genus *Pheretima*. Phil. J. Sci. **7**: 79-203.
- Chen JH, HT Shih. 1996. A preliminary study of earthworms in Fushan Botanical Garden. Chin. Biosci. **39**: 52-59. (in Chinese).
- Chen Y. 1930. On some new earthworms from Nanking, China. Sci. Rep. Natl. Cent. Univ. Nanking **1**: 11-37.
- Chen Y. 1931. On the terrestrial Oligochaeta from Szechuan with description of some new forms. Contrib. Biol. Lab. Sci. Soc. China (Zool.) **7**: 117-171.
- Chen Y. 1933. A preliminary survey of the earthworms of the Lower Yangtze valley. Contrib. Biol. Lab. Sci. Soc. China (Zool.) **9**: 178-296.
- Chen Y. 1935a. On two new species of Oligochaeta from Amoy (*Pheretima wui* sp. n. and *Howascolex sinicus* sp. n.). Contrib. Biol. Lab. Sci. Soc. China (Zool.) **11**: 109-122.
- Chen Y. 1935b. On a small collection of earthworms from Hongkong with descriptions of some new species. Bull. Fan Meml. Inst. Biol. **6**: 33-59.
- Chen Y. 1936. On the terrestrial Oligochaeta from Szechuan II with the notes on Gates' types. Contrib. Biol. Lab. Sci. Soc. China (Zool.) **11**: 269-306.
- Chen Y. 1938. Oligochaeta from Hainan, Kwangtung. Contrib. Biol. Lab. Sci. Soc. China (Zool.) **12**: 375-427.
- Chen Y. 1946. On the terrestrial Oligochaeta from Szechuan III. J. West China Border Res. Soc. **16**: 83-141.
- Chen Y, CF Hsu, T Yang, HY Fong. 1975. On some new earthworms from China. Acta Zool. Sinica **21**: 89-99.
- Easton EG. 1976. Taxonomy and distribution of the *Metapheretima elongata* species-complex of Indo-Australian



- earthworms (Megascolecidae: Oligochaeta). Bull. Br. Mus. Nat. Hist. (Zool.) **30**: 31-53.
- Easton EG. 1979. A revision of the 'acaecate' earthworms of the *Pheretima* group (Megascolecidae: Oligochaeta): *Archipheretima*, *Metapheretima*, *Planapheretima*, *Pleionogaster* and *Polypheretima*. Bull. Br. Mus. Nat. Hist. (Zool.) **35**: 1-126.
- Easton EG. 1980. Japanese earthworms: a synopsis of the Megadrile species (Oligochaeta). Bull. Br. Mus. Nat. Hist. (Zool.) **40**: 33-65.
- Edwards CA, PJ Bohlen. 1996. Biology and ecology of earthworms. New York: Chapman and Hall, 426 pp.
- Gates GE. 1935a. On some Chinese earthworms. Lingnan Sci. J. **14**: 445-458.
- Gates GE. 1935b. New earthworms from China with notes on the synonymy of some Chinese species of *Drawida* and *Pheretima*. Smithsonian. Misc. Collns. **93**: 1-19.
- Gates GE. 1939. On some species of Chinese earthworms, with special reference to specimens collected in Szechwan by Dr. D. C. Graham. Proc. U.S. Natl. Mus. **85**: 405-507.
- Gates GE. 1959. On some earthworms from Taiwan. Am. Mus. Novit. **1941**: 1-19.
- Gates GE. 1972. Burmese earthworms: an introduction to the systematics and biology of Megadrile Oligochaetes with special reference to Southeast Asia. Trans. Am. Phil. Soc. **62**: 1-326.
- Goto S, S Hatai. 1898. New or imperfectly known species of earthworms. No. 1. Annot. Zool. Jpn. **2**: 65-78.
- Goto S, S Hatai. 1899. New or imperfectly known species of earthworms. No. 2. Annot. Zool. Jpn. **3**: 13-24.
- Hatai S. 1930a. On *Drawida hattamimizu* sp. nov. Sci. Rep. Tohoku Univ. **5**: 485-508.
- Hatai S. 1930b. Note on *Pheretima agrestis* (Goto and Hatai), together with the description of four new species of the genus *Pheretima*. Sci. Rep. Tohoku Univ. **5**: 651-667.
- Hatai S, S Ohfuchi. 1936. Description of one new species of the genus *Pheretima*. Sci. Rep. Tohoku Univ. **10**: 767-772.
- Hatai S, S Ohfuchi. 1937. On one new species of earthworm belonging to the genus *Pheretima* from northeastern Honshu, Japan. Res. Bull. Saito Ho-on Kai Mus. **12**: 1-11.
- Hikida T, H Ota. 1997. Biogeography of reptiles in the subtropical East Asian islands. In KY Lue, TH Chen, eds. The symposium on the phylogeny, biogeography and conservation of fauna and flora of East Asian region. Taipei: National Taiwan Normal Univ., pp. 11-27.
- Horst R. 1883. New species of the genus *Megascolex* Templeton (*Perichaeta* Schmarda) in the collections of the Leyden Museum. Notes Leyden Mus. **5**: 182-196.
- Ishizuka K. 1999. New species of the genus *Pheretima* s. lat. (Annelida, Oligochaeta, Megascolecidae) from Tokyo, Japan – species with manicate intestinal caeca. Bull. Natl. Sci. Mus. Tokyo Ser. A. **25**: 33-57.
- Kim K, KR Kim, HK Rho, R Limeburner, RC Searsley. 1991. Identification of water masses in the Yellow Sea and the East China Sea by cluster analysis. In K Takano, ed. Oceanography of Asian marginal seas. Amsterdam: Elsevier Oceanography Series **54**: 253-265.
- Kobayashi S. 1934. Three new Korean earthworms belonging to the genus *Pheretima*, together with the wider range of the distribution of *Pheretima hilgendorfi* (Michaelsen). J. Chosen Nat. Hist. Soc. **19**: 1-11.
- Kobayashi S. 1936. Earthworms from Koryo, Korea. Sci. Rep. Tohoku Univ. **11**: 140-184.
- Kobayashi S. 1938a. Earthworms found in Hsinchu, Taiwan I. Zool. Mag. (Jpn.) **51**: 659-660. (in Japanese).
- Kobayashi S. 1938b. Earthworms found in Hsinchu, Taiwan II. Zool. Mag. (Jpn.) **51**: 777-779. (in Japanese).
- Kobayashi S. 1938c. Earthworms of Korea I. Sci. Rep. Tohoku Univ. **13**: 89-170.
- Kobayashi S. 1938d. Occurrence of *Perionyx excavatus* E. Perrier in North Formosa. Sci. Rep. Tohoku Univ. **13**: 201-204.
- Kobayashi S. 1940a. Earthworms of Korea II. Sci. Rep. Tohoku Univ. **16**: 147-156.
- Kobayashi S. 1940b. Terrestrial Oligochaeta from Manchoukuo. Sci. Rep. Tohoku Univ. **15**: 261-315.
- Kobayashi S. 1941a. On the terrestrial earthworms from Shikoku, Chieukoku, Kinki and the central region of Japan. Zool. Mag. (Jpn.) **53**: 258-266. (in Japanese).
- Kobayashi S. 1941b. The distribution of Oligochaeta in western Japan. Zool. Mag. (Jpn.) **53**: 371-384. (in Japanese).
- Kuo TC. 1995. Ultrastructure of genital markings in some species of *Pheretima*, *Bimastos* and *Perionyx* in northern Taiwan. Natl. Hsinchu Teacher's College J. **8**: 181-199.
- Lee KE. 1985. Earthworms: their ecology and relationships with soils and land use. New York: Academic Press, 411 pp.
- Lin CC. 1957. Discuss Taiwan island and China mainland from the stand point of geology. Hist. Res. Cons.: Taiwan Province Press, 39 pp. (in Chinese).
- Lin CC. 1966. An outline of Taiwan's quaternary geohistory with a special discussion of the relation between natural history and culture history in Taiwan. Bull. Dept. Archaeol. Anthropol. **28**: 7-44. (in Chinese).
- Lin CC, WJ Wu. 1997. Systematic and zoogeographic study of the ant tribe Dacetini in East Asia (Hymenoptera: Formicidae). In KY Lue, TH Chen, eds. The symposium on the phylogeny, biogeography and conservation of fauna and flora of East Asian region. Taipei: National Taiwan Normal Univ., pp. 135-150. (in Chinese).
- Michaelsen W. 1922. Oligochaeten aus dem Rijks-Museum van Natuurlijke Historie zu Leiden. Capita Zool. J. **1**: 1-67.
- Michaelsen W. 1929. The Oligochaeta fauna of China. Lingnan Sci. J. **8**: 157-166.
- Michaelsen W. 1934. Oligochaeten von Französisch-Indochina. Archs. Zool. Exp. Gen. **76**: 493-546.
- Ohfuchi S. 1935. On some new species of earthworms from northeastern Hondo, Japan. Sci. Rep. Tohoku Univ. **10**: 409-415.
- Ohfuchi S. 1937a. Descriptions of three new species of the genus *Pheretima* from northeastern Honshu, Japan. Res. Bull. Saito Ho-on Kai Mus. **12**: 13-29.
- Ohfuchi S. 1937b. On the species possessing four pairs of spermathecae in the genus *Pheretima*, together with the variability of some external and internal characteristics. Res. Bull. Saito Ho-on Kai Mus. **12**: 31-136.
- Ohfuchi S. 1938a. New species of earthworms from northeastern Honshu, Japan. Res. Bull. Saito Ho-on Kai Mus. **15**: 33-52.
- Ohfuchi S. 1938b. New and little known forms of earthworms, *Pheretima* from Nippon. Res. Bull. Saito Ho-on Kai Mus. **15**: 53-66.
- Ohfuchi S. 1941. The cavernicolous Oligochaeta of Japan. Sci. Rep. Tohoku Univ. **16**: 243-256.
- Ohfuchi S. 1956. On a collection of the terrestrial Oligochaeta obtained from the various localities in Riu-Kiu Islands, together with the consideration of their geographic distribution (Part I). J. Agric. Sci. Tokyo Nogyo Daigaku **3**: 131-176.

- Ohfuchi S. 1957. On a collection of the terrestrial Oligochaeta obtained from the various localities in Riu-Kiu Islands, together with the consideration of their geographic distribution (Part II). *J. Agric. Sci. Tokyo Nogyo Daigaku* **3**: 243-261.
- Shih HT, HW Chang, JH Chen. 1999. A review of the earthworms (Annedida: Oligochaeta) from Taiwan. *Zool. Stud.* **38**: 435-442.
- Sims RW, EG Easton. 1972. A numerical revision of the earthworm genus *Pheretima* auct. (Megascolecidae: Oligochaeta) with the recognition of new genera and an appendix on the earthworms collected by the Royal Society North Borneo Expedition. *Biol. J. Linn. Soc.* **4**: 169-268.
- Stephenson J. 1925. Oligochaeta from various regions, including those collected by the Mount Everest expedition 1924. *Proc. Zool. Soc.* **1925**: 879-907.
- Stephenson J. 1929. Oligochaeta: in reports of expedition to Brazil and Paraguay, 1926-27. *J. Linn. Soc. (Zool.)* **37**: 291-325.
- Tsai CF. 1964. On some earthworms belonging to the genus *Pheretima* Kinberg collected from Taipei area in North Taiwan. *Quart. J. Taiwan Mus.* **17**: 1-35.
- Tsai CF, HP Shen, SC Tsai. 1999. On some new species of the pheretimoid earthworms (Oligochaeta: Megascolecidae) from Taiwan. *J. Natl. Taiwan Mus.* **52**. (in press).
- Tsai CF, HP Shen, SC Tsai. 2000a. Occurrence of the exotic earthworm *Pontoscolex corethrurus* (Müller) (Glossoscolecidae: Oligochaeta) in Taiwan. *Endemic Species Res.* **2**: 68-73.
- Tsai CF, SC Tsai, GJ Liaw. 2000b. Two new species of protandric pheretimoid earthworms belonging to the genus *Metaphire* (Megascolecidae: Oligochaeta) from Taiwan. *J. Nat. Hist.* **34**: 1731-1741.
- Tzeng CS, CY Wang, SC Shen. 1997. Phylogeography of crossostomid fishes. In KY Lue, TH Chen, eds. The symposium on the phylogeny, biogeography and conservation of fauna and flora of East Asian region. Taipei: National Taiwan Normal Univ., pp. 101-115. (in Chinese).
- Yu HS, J Chow. 1997. Cenozoic basins in northern Taiwan and tectonic implications for the development of the eastern Asian continental margin. *Palaeogeogr. Palaeoclimatol. Palaeoecol.* **131**: 133-144.

## 臺灣陸生蚯蚓之特有性及外來現象與其他東北亞地區之比較

蔡住發<sup>1</sup> 沈慧萍<sup>1</sup> 蔡素蟾<sup>1</sup>

臺灣有記錄的陸生蚯蚓為 35 種，以 *Amyntas* 及 *Metaphire* 這兩屬為優勢，共有 27 種，其中 12 種為特有種，主要分布於人為干擾較少的山區。其餘 23 種外來種，有 4 種來自美洲及歐洲，4 種來自東南亞，15 種來自中國大陸，分布於遭受人為開發的平原與山區。依此種類記錄，臺灣陸生蚯蚓的特有種比例為 34.3%，較海南島 74.2%、中國大陸 78.1%、日本 65.0%、韓國 60% 及琉球 37.0% 為低。至於臺灣之蚯蚓相顯然是由南中國蚯蚓相衍生出的分支。

**關鍵詞：**特有性，分布，生物地理。

<sup>1</sup> 行政院農業委員會特有生物研究保育中心棲地生態組