New *Polypheretima* and *Pithemera* (Oligochaeta: Megascolecidae) species from the Mt. Malindang Range, Mindanao Island, Philippines

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We describe four new pheretimoid earthworm species, one in *Polypheretima* and three in *Pithemera*, from Mt. Malindang, Misamis Occidental Province, Mindanao Island, Philippines, and provide diagrams of external morphology and internal anatomy. *Polypheretima mindanaoensis* sp. nov. belongs to the *Po. elongata* species group, characterised by having genital markings on xix and successive segments and pairs of spermathecal batteries in vi and/or vii. It differs from the other members of the *Po. elongata* species group in having no copulatory bursae. This species shows individual variation in the number of spermathecae in each battery. Individuals that lack spermathecae are presumed to reproduce parthenogenetically. *Pithemera malindangensis* sp. nov. and *Pi. duminagati* sp. nov. belong to the *Pt. bicincta* species group, characterised by having the first spermathecal pores in 4/5. These two species differ in size and in the distance between male pores. *Pithemera donvictorianoi* sp. nov. belongs to the *Pt. pacifica* species group, characterised by having the first spermathecal pores in 5/6. This is the only member of this species group so far reported from the Philippines, and this is the only Philippine *Pithemera* species whose clitellum covers two rather than two and a half segments. Current studies show that worldwide, the Philippines has the highest diversity for *Pithemera*, with 13 species, followed by Papua New Guinea and the Pacific Islands, each area with six species. Indonesia has the highest diversity for *Polypheretima*, with 18 species, followed by Vietnam with 13 species, and then Papua New Guinea and the Philippines, each area with eight species. These findings indicate a high degree of endemicity within these areas, suggesting that many species remain to be detected in the Philippines.

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**Keywords:** *Pithemera; Polypheretima; Mindanao; Philippines; new species*

**Introduction**

Mt. Malindang Range Natural Park (MMRNP) comprises a complex of inactive volcanoes located at the foot of the Zamboanga Peninsula, which extends westward from central Mindanao Island, Philippines. Comprising an area of 533,000 km\(^2\), the Park ranges in altitude from 600 m above sea level (a.s.l.) in the lowlands to 2404 m a. s.l. at the top of the highest peak, Mt. Malindang (8.2166°N, 123.6333°E). About 330,000 km\(^2\) remain covered with relatively undisturbed primary forest, while the rest
includes bushland, denuded land and cultivated land. The complex topography includes a 60-km² crater lake (Lake Duminagat), two other sunken crater areas of more than 200 km² each, and numerous canyons and ravines.

Due to its rugged topography, altitudinal extent and tropical location, MMRNP has a diverse flora and fauna including species endemic to the Mt. Malindang Range, especially among vertebrates (Arances et al. 2006). To date, however, the faunal diversity of the Mt. Malindang Range has been only patchily inventoried, with most attention to vertebrates (amphibians, reptiles, birds and mammals) and much less to invertebrate groups that nonetheless are functionally important members of tropical forest ecosystems. One such latter group is the earthworms, which play important functional roles that affect soil properties and have community-wide effects (e.g. Anderson 1988; Fragoso and Lavelle 1992; Jouquet et al. 2006; Lavelle et al. 2006; Boniao et al. 2012). Studies of earthworm taxonomy in the Philippines over the past decade (James 2004a, 2005, 2006, 2009; James et al. 2004; Hong and James 2004, 2008a, 2008b, 2008c, 2009, 2010, 2011a, 2011b; Aspe and James 2014) have indicated high diversity and possibly high local endemicty, and suggest that many species remain to be discovered. This series of reports describing new earthworm species focused on various sites on Luzon Island, with studies on Mindanao Island conducted only at Mt. Kitanglad (James 2004a) and Mt. Malindang (Aspe and James 2014).

A study of the diversity and distribution of earthworms on Mt. Malindang detected 23 species, including 18 species in *Pheretima*, three in *Pithemera*, one in *Polypheretima* and the introduced species *Pontoscolex corethrurus* Müller, 1857 (Aspe 2006; Aspe et al. 2009). The 18 *Pheretima* species from Mt. Malindang were recently described by Aspe and James (2014). The present paper provides descriptions of four new species in *Pithemera* and *Polypheretima*.

**Material and methods**

**Site description**

Samples were collected from 9 to 15 October 2003 in primary and disturbed forests at different elevations in Barangay [= Precinct] Lake Duminagat in the municipality of Don Victoriano, Barangay Small Potongan in the municipality of Concepcion, and Barangays Sibucal and Toliyok in Oroquieta City (Figure 1B). All are in Misamis Occidental Province. The primary forest had remained largely undisturbed by human activities. The vegetation was dense and lush; trees were stout and thickly covered with moss, ferns and lichens. The ground was also thickly covered with moss, roots and leaf litter. Trees in the disturbed forest, regrown after deforestation by humans, were dominated by dipterocarps, tended to be more closely spaced than in the primary forest and tended to have more undergrowth (saplings, shrubs and tree ferns). The ground was also covered with thick leaf litter, roots, bryophytes and lichens. The terrain in the forested areas was very rugged, with steep grades and many cliff faces, making access very difficult. Surrounded by humid primary forest in Barangay Lake Duminagat is a crater lake about 60 km² in area called Lake Duminagat. The geographical coordinates of collecting sites were determined by global positioning system (GPS; Magellan Map410); elevations were determined by GPS if a satellite signal was detectable, or with an altimeter if not. The map datum used in the GPS readings was Luzon.
Figure 1. (A) Map of the Philippines showing localities where species of *Polypheretima* (white dots) and *Pithemera* (black dots) have been collected. (B) Map of Mt. Malindang showing the localities where the *Polypheretima* and *Pithemera* species reported in this study were collected.
Sampling
Sampling methods and the locations of sampling sites were previously reported in Aspe (2006) and Aspe et al. (2009). A summary is as follows: in each barangay, six scattered plots 20 m × 20 m in extent were established, with an average distance of 75 m between plots. On each plot, 10 quadrats (0.5 m × 0.5 m square × 0.3 m deep) in randomly selected spots were dug and searched for earthworms. The earthworms collected were preliminarily sorted to species and counted to assess relative abundance. Additional haphazard sampling was done outside the plots to further assess species’ distributions across all sites. Tree bark, ferns, mosses, vines and the insides of rotten logs were also checked for earthworms. Earthworms collected were cleaned in tap water, killed in 10% ethanol, and placed in Saranex sealable plastic bags filled with a volume of 10% formalin that was at least three times the total volume of the earthworms. After 2 days, the formalin was replaced with 80% ethanol for long-term preservation.

Descriptions
The descriptions given below are based on the terminological conventions of Easton (1979), and the classification is that of Sims and Easton (1972). Descriptions of body color are based on living specimens. Body dimensions refer to fixed material. The degree of separation between pores is expressed as a proportion of the circumference of the worm; for example, ‘male pores 0.23 circumference apart ventrally’ means the distance between the pores is 0.23 times the circumference of the worm at that point, with the circumference calculated as \( \pi \) times segment diameter. While many character states are shared among species within genera, generic characters of the three species in *Pithemera* are repeated to aid in identification. All descriptions are based on external examination and dorsal dissection under a stereomicroscope. Illustrations were prepared with Adobe Illustrator v. CS5. Holotypes and some paratypes are deposited in the Annelid Collection of the National Museum of the Philippines (NMA), Manila. Other paratypes are deposited in the Annelid Collection of the Zoological Reference Collection (ZRC.ANN) of the Raffles Museum of Biodiversity Research, Department of Biological Sciences, National University of Singapore, Singapore.

Results
We describe four new species from Mt. Malindang, Mindanao Island: *Polypheretima mindanaoensis* sp. nov., *Pithemera malindangensis* sp. nov., *Pi. duminagati* sp. nov. and *Pithemera donvictorianoi* sp. nov. Figure 1B shows the location in Mt. Malindang where *Polypheretima mindanaoensis* and species of *Pithemera* were collected. Table 1 shows the frequency, site density and relative abundance of the four species at the five collecting sites on Mt. Malindang. The numbers of *Pheretima* individuals (Aspe and James 2014) are also included to indicate the overall relative abundance and frequency of *Polypheretima* and *Pithemera* species in the earthworm community. Among species in the latter two genera, *Pithemera malindangensis* sp. nov. was the most abundant, with a relative abundance of 11.7%, while *Pithemera*
Table 1. Density and frequency of earthworm species found at collecting sites on Mt. Malindang (modified from Aspe et al. 2009, tab. 2). Data are given for only five of nine sites, as no individuals were found at two of the sites (agricultural areas and grasslands in Barangays Small Potongan and Toliyok). + indicates individuals were also collected outside sampling plots. The density value for each site is individuals collected per 4.5 m$^3$ of soil examined on plots. *Aspe and James (2014).

| Barangay Type of forest Elevation (m asl) Species | Primary forest lake Duminagat (1845–2027 m asl) | Disturbed forest lake Duminagat (1479–1662 m asl) | Disturbed forest Sibucal (902–1067 m asl) | Disturbed forest small Potongan (915–1,024 m asl) | Disturbed forest Toliyok (238–271 m asl) | Total (%) individuals on all plots | Frequency of occurrence among sites |
|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|
| *18 Pheretima species                            | 79+                                             | 56+                                             | 46+                             | 38+                             | 12                              | 232 (85)                        | –                               |
| Polypheretima mindanaoensis                      | –                                               | 7                                               | 1                               | –                               | –                               | 8 (2.9)                         | 0.4                             |
| Pithemera                                       | 23                                              | 9                                               | –                               | –                               | –                               | 32 (11.7)                       | 0.4                             |
| Pithemera duminagati                             | +                                               | +                                               | +                               | –                               | –                               | –                               | +                               |
| Pithemera donvictorianoi                         | –                                               | +                                               | –                               | –                               | 1                               | 1 (0.37)                        | 0.4                             |
| Total individuals                                | 102+                                            | 72+                                             | 47+                             | 38+                             | 13                              | 273 (100)                       |                                  |
| Total species                                    | 14                                              | 20                                              | 17                              | 11                              | 3                               | 26                              |                                  |

Note: asl = above sea level.
duminagati sp. nov. showed the highest frequency of occurrence (0.6), though it was only collected through haphazard sampling outside the plots. The sites with the highest species diversity were in disturbed forest in Barangays Lake Duminagat and Sibucal (20 and 17 species, respectively). The sites with highest species diversity and abundance were all above 900 m in elevation. Polypheretima mindanaoensis sp. nov. and the three Pithemera species were not detected in Barangay Small Potongan, and only one individual of Pithemera donvictorianoi sp. nov. was collected in Barangay Toliyok at a lower elevation.

Taxonomy

Family **MEGASCOLECIDAE** Rosa, 1891  
Genus *Polypheretima* Michaelsen, 1934  
*Type species.* *Perichaeta stelleri* Michaelsen, 1892

**Generic diagnosis**

Body cylindrical; setal arrangement perichaetine; annular clitellum covering segments xiv–xvi; pair of male pores in xviii on circular porophores which may be within copulatory bursae; ventral genital markings present or absent; oesophageal gizzard in viii; intestine begins in xv or xvi; nephridia on spermathecal ducts lacking; caeca lacking; male sexual system usually holandric, with testes and funnels enclosed in paired sacs in x and xi; seminal vesicles in xi and xii; spermathecal pores small, spermathecal diverticula simple and usually ectal in origin; prostates racemose; copulatory bursae may or may not be present; ovaries free in xiii; oviducts lead to single or closely paired opening (Easton 1979). Hong and James (2008a) observed that most *Polypheretima* species on Luzon have white pigmentation and are generally smaller than *Pheretima* species.

*Polypheretima mindanaoensis* sp. nov.  
(Figures 2A and 3A)

**Diagnosis**

Body white; stout, adult length 90–118 mm; paired, sublateral genital markings on each of xix to xxvi; intestinal origin in xv; small spermathecae present in batteries or lacking.

**Etymology**

The species is named for Mindanao Island.

**Material examined**

Holotype: adult (NMA 4527), Barangay Lake Duminagat, municipality of Don Victoriano, Misamis Occidental Province, Mt. Malindang Range (8.2986°N,
123.6169°E), 1357 m a.s.l, Mindanao Island, Philippines; coll. Nonillon Aspe, Nolan Aspe and J. Adeva, 9–15 October 2003. Paratypes: one adult, one juvenile (NMA 4545); two adults (ZRC.ANN.0013); same collection data as for holotype.

Description
White, clitellum pinkish-grey. Body stout, adult length 90–118 mm; diameter 5.1 mm at x, 7 mm at xx; 140–141 segments (n = four adults); body cylindrical in cross-section, tail narrowing gradually to sharp point. First dorsal pore at 12/13; spermathecal pores lacking or inconspicuous; female pore single in xiv, male pores on paired low papillae on xviii, 0.23 circumference apart, 10 setae between openings. Clitellum annular, from xiv to xvi. Setae pointed posteriorly, unevenly distributed around segmental equators; 41–53 setae on vii, 44–46 setae on xx; dorsal and ventral setal gaps lacking. Genital markings widely paired on xix to xxv and/or xxvi, between the sixth and seventh setal lines.

Septa 4/5/6/7/8 muscular, 8/9 absent, 9/10 present around dorsal vessel and hearts; 10/11 to 13/14 thickly muscular. Dense tufts of nephridia on anterior faces of 5/6 and 6/7; nephridia of intestinal segments located at septum–body wall junction, mainly on body wall near anterior and posterior faces of septa. Oesophageal gizzard large, extending from viii–x; oesophagus with lamellar inner surface extend from xi–xiii;
Figure 3. Schematic drawings of the internal morphology of (A) *Polypheretima mindanaoensis* sp. nov., (B) *Pithemera malindangensis* sp. nov., (C) *Pithemera duminagati* sp. nov. and (D) *Pithemera donvictorianoi* sp. nov. Abbreviations: s, spermatheca; n, dense tufts of nephridia; h, heart; p, prostate gland; c, caecum. Scale bars: 5 mm.
intestinal origin in xv, caeca lacking; typhlosole a simple fold of about one sixth lumen diameter originating in xvi; intestinal wall without longitudinal blood vessels but with two pairs of vertical vessels per segment.

Hearts in x to xii, oesophageal. Commissural vessels in vi, vii and ix, lateral; lacking in viii. Supra-oesophageal vessel extending from x to xii; extra-oesophageal vessels joining ventral oesophageal wall in x, receiving efferent parieto-oesophageal vessels in xiv.

Ovaries and funnels free in xiii, spermathecae lacking in two adults, one adult individual with five spermathecae closely lining up on the left side of vi, another adult individual with three spermathecae closely lining up on the left side and five spermathecae closely lining up on the right in vi and two spermathecae on left and two on right in vii; spermathecae small, ampulla pyriform, spermathecal duct short, slender; diverticulum stalk long and slender, attached ectally to duct, with one kink, terminating in short, sausage-shaped receptacle; no nephridia on spermathecal ducts. Male sexual system holandric, testes and funnels enclosed in paired ventral sacs in x and xi; seminal vesicles in xi and xii; pseudovesicles in xiii; vasa deferentia slender, free from body wall en route to ental end of prostatic ducts; prostates in xvi to xxi, each prostate racemose, trilobed but compact; copulatory bursae lacking.

**Remarks**

*Polypheretima mindanaoensis* sp. nov., the first member of *Polypheretima* reported from Mindanao Island, belongs to the *Po. elongata* Perrier, 1872 species group of Easton (1979), characterised by having a pair of genital markings in xix, successive segments in line with the male pores, paired batteries of up to 28 spermathecae in vi and/or vii, and shallow copulatory bursae with no stalked glands. Easton (1979) included five species in the group: *Po. elongata*; *Po. everetti*; *Po. kinabaluensis* Beddard and Fedarb, 1895; *Po. phacellotheca* Michaelsen, 1899; and *Po. stelleri* Michaelsen, 1892. *Polypheretima mindanaoensis* markedly differs from *Po. elongata* and *Po. everetti* in size (355 × 4 in *Po. elongata*; 300 × 12 in *Po. everetti*), in the number of segments covered by the genital markings (extending from xix to xxii in *Po. elongata*; xix to xxi in *Po. everetti*) and in the number of setae on vii (usually 80–130 in *Po. elongata*; 130 in *Po. everetti*) (Table 2). *Polypheretima mindanaoensis* (white) differs in colour from *Po. everetti* and *Po. kinabaluensis* (reddish-purple and red, respectively). Those individuals of *Polypheretima mindanaoensis* that have spermathecae have fewer spermathecae in each battery than *Po. kinabaluensis* (6–12 in 5/6/7), *Po. phacellotheca* (9–12 in 5/6) or *Po. stelleri* (up to 28 in 5/6/7), and individuals have fewer setae (41–53) on vii than *Po. phacellotheca* (80) or *Po. stelleri* (130). Finally, *Po. mindanaoensis* differs from all congeners in the *Po. elongata* species group in lacking copulatory bursae. Congeners reported from the Philippines include *Po. fruticosa* Hong and James, 2008a, *Po. perlucidula* Hong and James, 2008a, and *Po. bannaworensis* Hong and James, 2008a, from Banaue, Luzon Island; *Po. pagudpudensis* Hong and James, 2011a from Kalbaryo, Luzon Island; *Po. monticola* Beddard, 1912 from Mt. Pulong (Mt. Pulag), Benguet
Table 2. Comparison of characters among *Polypheretima* species in the Philippines. +, present; -, absent.

| Character                        | *Polypheretima mindanaoesis* sp. nov. | *Polypheretima elongata* Perrier, 1872 | *Polypheretima everetti* Beddard and Fedarb, 1895 | *Polypheretima monticola* Beddard, 1912 | *Polypheretima fruticosa* Hong and James, 2008a | *Polypheretima perlucidula* Hong and James, 2008a | *Polypheretima bannavorensis* Hong and James, 2008a | *Polypheretima pagudpudensis* Hong and James, 2011a |
|----------------------------------|---------------------------------------|----------------------------------------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|
| Body pigmentation               | White                                 | White                                  | Reddish purple ?                              | Brown dorsal                                   | White                                         | Brownish dorsal                               | White                                         | White                                         |
| Length                          | 90–118                                | 355                                    | 300                                           | 130                                           | 39–61                                         | 38–56                                         | 51–74                                         | 56–63                                         |
| Setae vii; xx                   | 41–53; 44–46                          | Usually 80 to 130; ?                   | Numerous, up to 130; ?                        | ?                                             | 44; 41                                        | 50; 23                                        | 39; 46                                        | 63; 27                                        |
| Setae bet. male pores           | 10                                    | ?                                      | 6–12                                          | ?                                             | 9                                            | 12                                            | 6–7                                           | 8                                             |
| Sper. pore spacing              | –                                     | ?                                      | ?                                             | ?                                             | 0.25                                         | 0.28                                          | 0.22–0.25                                     | ?                                             |
| Male pore spacing               | 0.23                                  | 0.25                                   | 0.25                                          | ?                                             | 0.27                                         | 0.32                                          | 0.24                                          | 0.23                                          |
| Location of spermathecae        | 0 or up to 5 spermathecae in each battery in 5/6, or 5/6/7 | Rarely more than 3 spermathecae in each battery in 5/6/7 | Paired in 5/6–8/9 | Paired in 5/6 | Paired in 5/6/7 | Paired in 5/6 | Paired in 5/6/7 | Paired in 5/6/7 |
| Genital markings                | Paired in xix–xxvi                    | Paired in ix–xxii                      | Paired in xix–xxi                             | Paired in ix, xvii, xix–xx                    | Paired in xvii or xix in 5/6–8/9 and 13/14 | –                                             | –                                             | Paired in xvi, xix–xx                        |
| Septa in 5/6–13/14              | + in 4/5; – in 8/9                    | - in 9/10                              | ?                                             | viii                                           | viii                                          | viii                                          | viii                                          | viii                                          |
| Origin of gizzard               | vii                                   | vii                                    | viii                                           | viii                                           | viii                                          | viii                                          | viii                                          | viii                                          |
| Origin of typhlosole            | xvi                                   | ?                                      | ?                                             | ?                                              | xx                                            | xxi                                           | xxi                                           | xxi                                          |
| Prostate glands                 | xvi–xxi                               | ?                                      | ?                                             | ?                                              | xvii–xxii                                     | xvii–xx                                      | xvi–xx                                       | xvii–xxii                                     |
Province, and from Luzon Island; and Po. everetti and Po. elongata, both collected on Balabac Island, Palawan. Polypheretima perlucidula, Po. bannaworensis, Po. pagudpudensis and Po. monticola belong to the Po. bifaria species group of Easton (1979), characterised by having pairs of spermathecae in 5/6–8/9 or only in 6/7 or 7/8, while Po. fruticosa is closely related to Po. voeltzkowi Michaelsen, 1907, characterised by having a pair of spermathecae in only in 5/6. The new species also differs from the other species in the number of setae between male pores, in the genital marking pattern and in the size and segmental position of the prostate glands (Table 2).

Spermathecae function to receive and store sperm released by the male pores of the partner during copulation; loss of spermathecae usually means a loss of male function. Loss of spermathecae, reduction of testes and lack of spermatozoal iridescence in the sperm funnels in earthworms are indicative of reproduction by parthenogenesis (Gates 1972), in which the egg develops into a new individual without being fertilised by sperm. In the case of Po. elongata, which has been introduced into many parts of the world (see Table 4), Easton (1979) observed that atecate individuals are especially numerous in introduced populations, presumably reproducing parthenogenetically.

In one specimen of Po. mindanaoensis sp. nov., the ventral nerve cord has a solid dark core, perhaps related to parasitism. We observed several nematodes near an empty nerve cord swelling in xvii.

**Occurrence**

*Polypheretima mindanaoensis* sp. nov. was found at two of five collecting sites. In all, eight individuals were collected in disturbed forests in Barangays Lake Duminagat and Sibucal at elevations of 902–1662 m a.s.l. The soil it inhabited was covered with thick leaf litter and roots, bryophytes and lichens. We did not observe it on rotten logs.

**Genus Pithemera** Sims and Easton, 1972

*Type species. Perichaeta bicincta* Perrier, 1875

**Generic diagnosis**

Body cylindrical; setae numerous, regularly arranged around each segment; clitellum annular, covering two or two and a half segments from xiv to xv, and/or half of xvi; spermathecal pores small, three to five pairs from 4/5 to 8/9; female pore single or paired in xiv; genital markings present or absent; oesophageal bursae absent; intestinal caeca originating in xxii (in *Pheretima*, caeca originating in xxvii); spermathecal ducts without nephridia (as in *Polypheretima*); male system holandric or metandric; prostate glands racemose; copulatory bursae lacking (Sims and Easton 1972). Hong and James (2008a) observed that *Pithemera* species are generally lighter in pigmentation and smaller in size than *Pheretima* species.
Pithemera malindangensis sp. nov.
(Figures 2B and 3B)

**Diagnosis**
White worm; adult length 91–144 mm; clitellum from xiv through half of xvi; five pairs of spermathecal pores, 4/5–8/9; distance between male pores 0.2 circumference apart; no genital markings; intestinal origin in xiv; prostate glands from xvi–xix.

**Etymology**
The species is named for Mt. Malindang.

**Material examined**
Holotype: adult (NMA 4528), Mt. Malindang Range (8.2986°N, 123.6169°E), Barangay Lake Duminagat, municipality of Don Victoriano, Misamis Occidental Province, Mindanao Island, Philippines; 1357 m a.s.l; coll. Nonillon Aspe, Nolan Aspe and J. Adeva, 9–15 October 2003. Paratypes: three adults (NMA 4547); two adults (ZRC.ANN.0014); all same collection data as for holotype.

**Description**
White, clitellum grey–brown. Adult length 91–144 mm (n = six adults); diameter 4 mm at x, 3.5 mm at xx; body cylindrical in cross-section, tail blunt; 118–126 segments. First dorsal pore at 13/14, inconspicuous in most specimens; paired spermathecal pores 4/5/6/7/8/9, inconspicuous; female pores paired in xiv, male pores on paired circular porophores forming mounds in xviii, 0.2 circumference apart, two to four setae between openings. Clitellum annular, extending from xiv through half of xvi. Setae evenly distributed around segmental equators, 58 setae on vii, 30–40 setae on xx; dorsal setal gap absent, ventral gap present. Genital markings lacking.

Septa 5/6/7/8 muscular, 8/9 absent, 9/10–13/14 muscular. Dense tufts of nephridia on anterior faces of 5/6 and 6/7; nephridia of intestinal segments located at septum–body wall junction, mainly on body wall near anterior and posterior faces of septa. Gizzard large, extending from viii to ix; oesophagus with internal lamellar sections extending from xi to xiii; intestinal origin in xiv; caeca from xxii to xxi; typhlosole a simple fold of about one fifth lumen diameter, originating in xxii; intestinal wall lacks longitudinal blood vessels.

Hearts in x–xii, oesophageal. Commissural vessels in vi, vii and ix, lateral; lacking in viii. Supra-oesophageal vessel extending from x to xii; extra oesophageal vessels joining ventral oesophageal wall in x, receiving efferent parieto-oesophageal vessels in xiv.

Ovaries and funnels free in xiii. Spermathecae five pairs in v to ix; duct short, slender; small, spherical to ovate ampulla greater than duct length; diverticulum stalk short, attached ectally to duct, terminating in short, sausage-shaped receptacle. Male sexual system holandric; testes and funnels enclosed in paired ventral sacs in x and xi; seminal vesicles in xi and xii; vasa deferentia slender, free from...
body wall, those on each side separate until xiv, joining ental end of prostatic ducts; each prostate racemose, broad, multilobed, in xvi–xix; ectal half of duct expands to form muscular spindle; ducts in hairpin loop. Transverse muscle bands present above body wall at 16/17 and 18/19, the latter much larger. Copulatory bursae lacking.

Remarks

*Pithemera malindangensis* sp. nov. belongs to the *Pi. bicincta* (Perrier, 1875) species group of Sims and Easton (1972), which initially comprised two species, *Pi. bicincta* and *Pi. violacea* Beddard, 1895. Michelsen (1910), Ohfuchi (1957) and Shen and Tsai (2002), however, considered *Pi. violacea* to be a junior synonym of *Pi. bicincta*. *Pithemera bicincta*, first collected from Mindoro Island, has the first spermathecal pores in 4/5, and the intestinal caeca are paired and positioned laterally. *Pithemera malindangensis* is similar to *Pi. bicincta* in the arrangement and number of spermathecae and septa, the number and locations of hearts, and the length of the caeca, but the former is larger, lacks genital markings, and has the intestinal origin in xvi rather than xv. Other members of the *bicincta* species group reported from the Philippines (all from Luzon Island except for *Pi. duminagati* sp. nov. described below) include *Pi. rotunda* and *Pi. philippinensis* (James et al. 2004); *Pi. duhuani*, *Pi. fragumae*, *Pi. ifugaoensis* and *Pi. triangulata* (Hong and James 2008a); and *Pi. glandis*, *Pi. fusiformis* and *Pi. levii* (Hong and James 2011a). *Pithemera malindangensis* sp. nov. and *Pi. duminagati* sp. nov. are similar to most or all other members of the *bicincta* group in the origin of the gizzard, number of hearts, and length and location of the caeca, but differ from the others in having the intestinal origin in xvi rather than xv. The Malindang species are also white and lack genital markings. *Pithemera malindangensis* sp. nov. is larger than *Pi. duminagati* sp. nov., the male pores are more distant and it has only two pairs of dense tufts of nephridia (on the anterior faces of 5/6/7), whereas the latter has three pairs (on 5/6/7/8; Table 3).

Occurrence

*Pithemera malindangensis* sp. nov. was the most abundant among the four species, comprising 11.7% of all earthworms collected. It was common in primary and disturbed forests in Barangay Lake Duminagat at elevations of 1479–2027 m a.s.l. The soil it inhabited was covered with thick leaf litter and roots, bryophytes and lichens. We did not observe it on rotten logs.

*Pithemera duminagati* sp. nov.

(Figures 2C and 3C)

Etymology

The species is named for Barangay Lake Duminagat, the type locality.
Table 3. Comparison of characters among *Pithemera* species in the Philippines. +, present; -, absent.

| Character                  | *Pithemera malindangensis sp.* nov. | *Pithemera dumogati sp.* nov. | *Pithemera donvictoriano sp.* nov. | *Pithemera bicincta* Perrier, 1875 | *Pithemera rotunda* James et al. 2004 | *Pithemera philippinensis* James et al. 2004 |
|----------------------------|-----------------------------------|--------------------------------|-----------------------------------|--------------------------------|-----------------------------------|----------------------------------|
| Body pigmentation          | White                             | White                          | White                             | ?                               | White                             | Pigmented                        |
| Length                     | 91–144                            | 36–37                          | 41–58                             | 40–80                           | 31–44                             | 51–54                            |
| Cover of clitellum          | xiv–1/2 xvi                       | xiv–1/2 xvi                    | xiv–xv                            | xiv–1/2xvi                      | xiv–1/2 xvi                       | xiv–1/2xvi                       |
| Spermathecal pores          | 4/5–8/9                           | 4/5–8/9                        | 5/6–8/9                           | 4/5–8/9                         | 4/5–8/9                           | 4/5–8/9                          |
| Setae vii; xx              | 58; 30-40                         | 43–48; 31–43                   | 42–48; 41–57                      | 42; 46                          | 49–54; 48–61                      | 56–68; 49–61                     |
| Male pore setae            | 2–4                               | 0–3                            | 8                                 | ?                               | 9                                 | 9                                |
| Male pore spacing           | 0.2                               | 0.13                           | 0.11                              | 0.2                             | ?                                 | ?                                |
| Female pores               | Paired                            | Paired                         | Paired                            | Paired                          | Paired                            | Paired                           |
| Genital markings           | –                                 | –                              | –                                 | Paired in xviii–xix              | Paired in xviii–xxii              | –                                |
| Septa in 5/6–13/14          | - in 8/9                          | - in 8/9                       | - in 8/9 and 13/14                | - in 8/9                        | - in 8/9                          | - in 8/9                         |
| Dense tufts of nephridia   | 5/6/7                             | 5/6/7/8                        | 5/6/7/8                           | ?                               | ?                                 | ?                                |
| Origin of intestine        | xiv                               | xiv                            | xiv                               | ?                               | ?                                 | ?                                |
| Caeca                      | xxii–xxi                          | xxii–xxi                       | xxii–xxi                          | xxii–xxi                        | xxii–xxi                          | xxii–xxi                         |
| Origin of typhlosole       | xxii                              | xix                            | xxii                              | ?                               | xxii                              | xxii                             |
| Location of hearts         | x–xii                             | x–xii                          | x–xii                             | x–xii                           | x–xii                             | x–xii                            |
| Prostate glands            | xvi–xix                           | xvi–xxi                        | xvi–xix                           | xvi–xix, xx                     | xvi–xx                           | xvii–xix                         |

(Continued)
| Character                  | *Pithemera duhuani* Hong and James, 2008a | *Pithemera fragumae* Hong and James, 2008a | *Pithemera ifugaoensis* Hong and James, 2008a | *Pithemera triangulata* Hong and James, 2008a | *Pithemera glandis* Hong and James, 2011a | *Pithemera fusiformis* Hong and James, 2011a | *Pithemera levii* Hong and James, 2011a |
|---------------------------|------------------------------------------|------------------------------------------|-----------------------------------------------|-----------------------------------------------|---------------------------------------------|---------------------------------------------|---------------------------------------------|
| Body pigmentation         | Brown dorsal                             | White                                    | Light brown                                   | Light brown                                   | Brown dorsal                                | Brown dorsal                                | Brown dorsal                                |
| Length                    | 53–59                                    | 53–101                                   | 38–65                                         | 47–76                                         | 62–108                                      | 20–22                                      | 50–65                                      |
| Cover of clitellum xiv–1/2xvi | xiv–1/2xvi                               | xiv–xvi                                 | xiv–1/2xvi                                   | xiv–1/2xvi                                   | xiv–1/2xvi                                  | xiv–1/2xvi                                  | xiv–1/2xvi                                  |
| Spermathecal pores        | 4/5–8/9                                  | 4/5–8/9                                  | 4/5–8/9                                       | 4/5–6/7                                       | 4/5–8/9                                     | 4/5–8/9                                     | 4/5–7/8                                     |
| Setae vii; xx             | 40; 39                                   | 66; 69                                   | 41; 44                                        | 41; 44                                        | 53; 61                                      | 36; 47                                      | 54; 63                                      |
| Male pore setae           | 6–7                                      | 10–15                                    | 8–10                                         | 1–3                                           | 8–11                                        | 10                                         | 6–7                                        |
| Male pore spacing         | 0.32–0.37                                | 0.24                                     | 0.15–0.24                                    | 0.1                                           | 0.18                                        | 0.31                                        | 0.13                                        |
| Female pores              | Paired                                   | Paired                                   | Paired                                       | Paired                                       | Single                                      | Paired                                     | Paired                                     |
| Genital markings          | Paired in xvii, xix or xviii only        | Paired in xvii – xviii                  | Paired in xx                                  | –                                             | –                                           | Paired in xiv–xx                           | Paired in xvii–xix                          |
| Septa in 5/6–13/14        | - in 8/9                                 | - in 8–10                                | - in 8/9                                      | - in 8/9                                      | - in 8/9 and 13/14                         | - in 8/9                                   | - in 8/9                                   |
| Dense tufts of nephridia  | ?                                       | ?                                        | ?                                            | ?                                            | ?                                          | ?                                          | ?                                          |
| Origin of intestine       | xv                                       | xv                                       | xv                                           | xv                                           | xv                                         | xv                                         | xv                                         |
| Caeca                     | xxii–xxi                                  | xxii                                     | xxii–xxi                                      | xxii–xxi                                      | xxii–xxi                                    | xxii–xxi                                    | xxii–xxi                                    |
| Origin of typhlosole      | xxii                                     | xxii                                     | xxii                                          | xxii                                          | xxii                                        | xxii                                       | xxii                                       |
| Location of hearts        | x–xii                                    | xi–xii                                   | x–xii                                         | x–xii                                         | x–xii                                       | xi–xii                                     | x–xii                                      |
| Prostate glands           | xvi–xix                                  | xvi–xix                                  | xvi–xix                                       | xviii                                         | xvii–xix                                    | xvii–xix                                   | xvii–xix                                   |
Material examined
Holotype: adult (NMA 4529), Mt. Malindang Range (8.2986°N, 123.6169°E), Barangay Lake Duminagat, municipality of Don Victoriano, Misamis Occidental Province, Mindanao Island, Philippines; 1357 m a.s.l; coll. Aspe et al., 9–15 October 2003. Paratypes: two adults (NMA 4548), same collection data as for holotype.

Diagnosis
Very small, white worm; adult length 36–37 mm; clitellum from xiv through half of xvi; five pairs of spermathecal pores, 4/5–8/9; distance between male pores 0.13 circumference apart; no genital markings; intestinal origin in xv; prostate glands from xvi–xxi.

Description
White; clitellum grey–brown. Adult length 36–37 mm (n = three adults); diameter 2.5 mm at x; 2 mm at xx; body cylindrical in cross-section, tail blunt; 88–95 segments. First dorsal pore at 12/13; paired spermathecal pores in 4/5/6/7/8/9, inconspicuous; female pores paired in xiv; male pores on paired porophores in xviii, 0.13 circumference apart, zero to three setae between openings. Clitellum annular, extending from xiv to half of xvi. Setae unevenly distributed, 43–48 setae on vii, 31–43 setae on xx; no dorsal or ventral gaps. Genital markings lacking.

Septa 5/6/7/8 slightly muscular, 8/9 absent, 9/10–13/14 thinly muscular. Dense tufts of nephridia on anterior faces of 5/6/7/8; nephridia of intestinal segments located at septum/body wall junction, mainly on body wall near anterior and posterior faces of septa. Gizzard large, extending from viii to ix; oesophagus with lamellar section from xi to xiii; intestinal origin in xv; caeca from xxii to xxi; typhlosole a simple fold of about one-quarter lumen diameter, originating in xix, full size in xxii; intestinal wall lacks longitudinal blood vessels but has two pairs of vertical vessels per segment. Hearts in x–xii, oesophageal; commissural vessels in vi, vii and ix, lateral; lacking in viii; supra-oesophageal vessel extends from x to xii; extra oesophageal vessels joining ventral oesophageal wall in x, receiving efferent parieto-oesophageal vessels in xiv.

Ovaries and funnels free in xiii; ovisacs in xiv; spermathecae five pairs from v to ix; duct short, slender; small, ovate ampulla; diverticulum stalk short, attached ectally to duct, terminating in short, pyriform receptacle; receptacle a small sphere lacking spermatozoal iridescence. Male sexual system holandric; testes and funnels enclosed in paired ventral sacs in x and xi; seminal vesicles in xi and xii; vasa deferentia slender, free from body wall, joining ental end of prostatic ducts; each prostate racemose, broad, 3- or 4-lobed, present from xvi to xxi; ectal half of duct expands to form muscular spindle; ducts in hairpin loop. Ental portion of duct with two lumens. Copulatory bursae lacking.

Remarks
*Pithemera duminagati* sp. nov. belongs to the *Pi. bicincta* group of Sims and Easton (1972). Although *Pi. duminagati* sp. nov. is similar to *Pi. bicincta* in some
characters, it differs from the latter in size, in lacking genital markings, in the distance between male pores, in the relative size of the prostates and in the origin of the intestine (Table 3). *Pithemera duminagati* sp. nov. is similar to *Pi. rotunda* (James et al. 2004), another member of the bicincta group, in size and in being white, in septal arrangement, in intestinal origin and in the length of caeca, but *Pi. duminagati* sp. nov. has fewer setae between the male pores, lacks genital markings, and has proportionally larger prostate glands. Among the three *Pithemera* species from Mt. Malindang, *Pi. duminagati* sp. nov. is more similar to *Pi. malindangensis* sp. nov. in the extent of the clitellum, number of spermathecae and septal arrangement. Like *Pi. donvictorianoi* sp. nov., *Pi. duminagati* sp. nov. is smaller in body size than *Pi. malindangensis* sp. nov. and has three pairs of dense tufts of nephridia on 5/6/7/8, whereas the latter has only two pairs on 5/6/7.

**Occurrence**

*Pithemera duminagati* sp. nov. was found outside the sampling plots at three of five sites: in primary and disturbed forest in Barangay Lake Duminagat and in disturbed forest in Barangay Sibucal, at elevations of 902–2027 m a.s.l. The soil it inhabited was covered with thick leaf litter and roots, bryophytes and lichens. We did not observe it on rotten logs.

**Pithemera donvictorianoi** sp. nov.

(Figure 2D and 3D)

**Diagnosis**

White worm; adult length 41–58 mm; clitellum annular from xiv to xv; four pairs of spermathecal pores, 5/6–8/9; male pores closely spaced; intestinal origin in xiv; prostate glands from xvi–xix.

**Material examined**

Holotype: adult (NMA 4530), Mt. Malindang Range (8.2986°N, 123.6169°E), Barangay Lake Duminagat, municipality of Don Victoriano, Misamis Occidental Province, Mindanao Island, Philippines; 1357 m a.s.l; coll. Aspe et al., 9–15 October 2003. Paratypes: two adults (NMA 4549 and ZRC.ANN.0015); both same collection data as for holotype.

**Etymology**

The species is named for the municipality of Don Victoriano, the type locality.

**Description**

White; clitellum dark brown. Length 41–58 mm (n = 3 adults); diameter 2.5–3.0 mm. at x; 2.5–3.0 mm at xx; body cylindrical in cross-section, tail blunt; 85–100 segments. First dorsal pore at 12/13; paired spermathecal pores in 5/6/7/8/9, inconspicuous;
female pores paired in xiv; male pores on lateral faces of slightly elevated cones in xviii, 0.11 circumference apart, eight setae between openings. Clitellum annular, extending from xiv to xv. Setae evenly distributed around segmental equators, 42–48 setae on vii, 41–57 setae on xx; no dorsal or ventral gaps. Genital markings lacking.

Septa 5/6/7/8 slightly muscular, 8/9 absent, 9/10–12/13 thinly muscular. Dense tufts of nephridia on anterior faces of 5/6/7/8; nephridia of intestinal segments located at septum/body wall junction, mainly on body wall near anterior and posterior faces of septa. Gizzard large, from viii to ix; oesophagus with lamellar sections from xi to xiii; intestinal origin in xiv; caeca from xii to xxi; typhlosole a simple fold of about one-sixth lumen diameter, originating in xii, maximum diameter in xxiv; intestinal wall without longitudinal blood vessels.

Hearts in x–xii, oesophageal; commissural vessel in vi, vii and ix, lateral; viii extending to gizzard; supra-oesophageal vessel extending from x to xii; extra-oesophageal vessels joining ventral oesophageal wall in x, receiving efferent parieto-oesophageal vessels in xiv.

Ovaries and funnels free in xiii; ovisacs lacking; spermathecae four pairs in vi to ix; duct short, slender; ampulla small, narrow ovate; diverticulum stalk short, attached ectally to duct, terminating in short, ovate receptacle. Male sexual system holandric; testes and funnels enclosed in annular sacs in x and xi; with sacs enclosing hearts; seminal vesicles in xi–xii; vasa deferentia slender, free from body wall, joining ental end of prostatic ducts; prostates in xvi to xix; each prostate racemose, broad, 4-lobed, lobes deeply incised; ectal half of duct expands to form muscular spindle; ducts in hairpin loop. Ental portion of duct with three lumens. Copulatory bursae lacking.

Remarks

*Pithemera donvictorianoi* sp. nov. belongs to the *Pi. pacifica* group of Sims and Easton (1972) and is the only member of this species group so far reported from the Philippines. This group is characterised by having four spermathecae, with the first spermathecal pore in 5/6, in contrast to the *Pi. bicincta* group, members of which have the first pair of spermathecal pores in 4/5. Like the other *Pithemera* species on Malindang, it is white and lacks genital markings, and the caeca extend from xvii to xxi. Like *Pi. duninagati* sp. nov., it has smaller average body size than *Pi. malindangensis* sp. nov., and it has three pairs of dense tufts of nephridia, on 5/6/7/8, whereas *Pi. malindangensis* has only two pairs, on 5/6/7. *Pithemera donvictorianoi* differs from all other Philippine *Pithemera* species in that the clitellum extends from xiv through xv, rather than from xiv through half of xiv (Table 2).

Occurrence

*Pithemera donvictorianoi* sp. nov. was rare, with only one individual collected inside a plot in disturbed forest in Barangay Toliyok, though we also detected it in disturbed forest in Barangay Lake Duminagat. The soil it inhabited was covered with thick leaf litter and roots, bryophytes and lichens. We did not observe it on rotten logs.
Discussion

Blakemore (2007) listed 14 valid *Pithemera* species distributed in East Asia and the Pacific region, described from 1938 to 2004. He also listed 38 valid *Polypheretima* species distributed from East Asia and the Pacific region to South America and Africa, described from 1872 to 1984. In addition, Nguyen et al. (2014, 2015) listed a total of 13 *Polypheretima* species from Vietnam, which includes four recently described species. Prior to 2004, only one *Pithemera* and three *Polypheretima* species were known from the Philippines: *Pithemera bicincta* from Mindoro Island; *Polypheretima monticola* from Benguet Province, Luzon Island; and *Po. elongata* and *Po. everetti*, both from Balabac Island, Palawan Province. From 2004 to present (including this study), 12 *Pithemera* and five *Polypheretima* species were added to the Philippine fauna, bringing the totals to 13 and eight, respectively.

Table 4 shows the diversity of *Polypheretima* and *Pithemera* species reported from the various countries or regions where they occur. The Philippines has the highest diversity of *Pithemera*, with 13 species, followed by Papua New Guinea and the Pacific Islands, each area with six species. For *Polypheretima*, Indonesia has the highest diversity, with 18 species, followed by Vietnam with 13 species and then Papua New Guinea and the Philippines, each area with eight species. Among the species of *Polypheretima*, *Po. elongata* is the most widespread, having been reported from 10 regions around East Asia, the Pacific and Africa. This is followed by *Po. taprobanae* and *Po. everetti*, reported from six and four regions, respectively, around Asia, the Pacific, South America and Madagascar. The most widespread *Pithemera* species is *Pi. bicincta*, which occurs in six regions around East Asia and the Pacific. Among the species in the Philippines, *Po. elongata*,

| Country/region                          | *Polypheretima* | *Pithemera* |
|----------------------------------------|-----------------|-------------|
| Korea                                  | 1               | 1*+         |
| Japan                                  | 1*+             | 1*+         |
| Taiwan                                 | 1*              | 2*          |
| Philippines                            | 8*+             | 13*+        |
| Vietnam                                | 13*+            | –           |
| Thailand                               | 1*              | –           |
| Malaysia                               | 5*              | –           |
| Indonesia                              | 18*+            | 1*+         |
| Papua New Guinea                       | 8*              | 6*          |
| Australia                              | 1*              | –           |
| Pacific Islands (Fiji, Samoa, New Caledonia, Hawaii) | 4*+@           | 6*          |
| Brazil                                 | 1@              | –           |
| Africa                                 | 1*              | –           |
| Madagascar                             | 3@              | –           |
| India                                  | 1@              | –           |
Po. everetti and Pi. bicincta are widely distributed, both locally and globally. Joshi et al. (1999) reported Po. elongata and Pi. bicincta at Ifugao, Luzon Island. The known ranges of the rest of the Pithemera and Polypheretima species are all restricted to the type localities, indicating a high degree of endemism, both among local areas and islands in the Philippines, and in the Philippines as a whole. This pattern suggests that many species remain to be detected in the Philippines.

To facilitate the further study of earthworms at Mt. Malindang and on Mindanao Island, we provide the following key to the species that are from the Mt. Malindang Range. The key also includes the genus Pheretima and the exotic species Pontoscolex corethrurus. The most easily located external features are used at the beginning of the key. Until more is known about the taxonomy and distributions of earthworms on Mindanao and in the rest of the Philippines, however, this key should be used with caution in identifying earthworms from outside the Mt. Malindang Range.

Key to earthworm species from the Mt. Malindang Range

1. Clitellum nine segments, from xiv–xxii, interrupted ventrally, setae lumbricine in arrangement ................................................................. Pontoscolex corethrurus
   – Clitellum three segments, female pore single .............................................. 2
   – Clitellum two or 2½ segments, female pores paired . ...................... Pithemera (3)

2. Body pigmented, genital markings lacking; spermathecae, nephridia on ducts, and caeca present ................................................................. Pheretima
   – Body white, genital markings paired in xix–xxvi, spermathecae lacking or in batteries, caeca absent ................................................................. Polypheretima mindanaoensis

3. Clitellum two segments in xiv–xv, four pairs of spermathecae, 5/6–8/9 .......... Pithemera donvictorianoi
   – Clitellum 2½ segments, five pairs of spermathecae, 4/5–8/9 ....................... 4

4. Intestinal origin in xiv, prostate glands in xvi–xix, male pores more distant, adult length 91–144 mm ................................................................. Pithemera malindangensis
   – Intestinal origin in xv, prostate glands in xvi–xxi, male pores closer, adult length 36–37 mm ................................................................. Pithemera duminagati

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