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# New species of *Pheretima* (Oligochaeta: Megascolecidae) from the Mt. Malindang Range, Mindanao Island, Philippines

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#### Abstract

We provide descriptions, with illustrations of internal structures, for 18 new species of *Pheretima* from Mt. Malindang, Misamis Occidental Province, Mindanao Island, Philippines. Among the 18 species, 11 belong to the *P. sangirensis* species group, characterized by having a pair of spermathecal pores in the intersegmental furrow of 7/8 and lacking penial sheaths in the copulatory bursae: *P. maculodorsalis* **n. sp.**, *P. tigris* **n. sp.**, *P. immanis* **n. sp.**, *P. lago* **n. sp.**, *P. nunezae* **n. sp.**, *P. boniaoi* **n. sp.**, *P. malindangensis* **n. sp.**, *P. misamisensis* **n. sp.**, *P. wati* **n. sp.**, *P. longiprostata* **n. sp.**, and *P. nolani* **n. sp.** One species, *P. longigula* **n. sp.**, belongs to the *P. montana* species group, characterized by having a pair of spermathecal pores in the intersegmental furrow of 7/8 and penial sheaths in the copulatory bursae. Two species, *P. longigula* **n. sp.**, belongs to the *P. montana* species group, characterized by having a pair of spermathecal pores in the intersegmental furrow of 7/8 and penial sheaths in the copulatory bursae. Two species, *P. longigula* **n. sp.**, and *P. nolani* **n. sp.** and *P. concepcionensis* **n. sp.**, are monothecal. Three species, *P. adevai* **n. sp.**, *P. lluchi* **n. sp.**, and *P. potonganensis* **n. sp.**, belong to the *P. darnleiensis* species group, characterized by having either four or five pairs of spermathecae from vi to ix, with a fifth pair variably present in segment v. One species, *P. subanensis* **n. sp.**, is athecate. All species described here from the Mt. Malindang Range are probably native rather than introduced, and probably do not represent range extensions of species known from neighboring islands in Southeast Asia. We provide an identification key to the *Pheretima* species from Mt. Malindang.

Key words: Earthworm, terrestrial, tropical, taxonomy, new species, diversity

#### Introduction

Until recently, knowledge of the native earthworm fauna of the Philippines was very limited. Non-specialist biologists in the Philippines erroneously identified all earthworms there as *Lumbricus terrestris* Linnaeus, 1758, a species common to North America and Europe but not detected in recent studies in the Philippines. Organized research on earthworm diversity in the Philippines began after Lawrence Heaney and collaborators discovered that the Isarog shrew-rat (*Rhynchomys isarogensis* Musser & Freeman, 1981) and *Chrotomys gonzalesi* Rickart & Heaney, 1991 feed exclusively on earthworms. The desire of the mammalogists to identify the worms the rat feeds on led to the discovery of 10 new species collected in 1993, all belonging to perichaetine genera in the *Pheretima* complex (Sims & Easton 1972) in the family Megascolecidae (James 2004).

*Pheretima* Kinberg, 1867, a Southeast Asian group with a range extending from northern Australia to Myanmar and northward to Korea, became the largest genus of earthworms in the Megascolescidae *sensu* Gates (1959). Using computer-based phenetic analyses, Sims & Easton (1972) and Easton (1979) reallocated species in *Pheretima* auct. (pheretimoid species and subspecies) into 'convenient' species groups comprising 10 genera (*Amynthas, Archipheretima, Pheretima, Planapheretima, Metapheretima, Pithemera, Ephemitra, Metaphire, Polypheretima* and *Pleionogaster*). Blakemore (2007) estimated that among more than 1400 nominal taxa of pheretimoid earthworms (which include numerous synonyms, invalid names, and *lapsus*) there are roughly 930 valid species and subspecies in *Pheretima* auct. He acknowledged around 40 valid species of *Pheretima sensu stricto*, with the distributional range restricted to the Indo-Australian archipelago, Sumatra, and the Philippines.

As the result of taxonomic studies in the last decade, around 200 species of native earthworms representing 10 genera are now now identified from the Philippines (Blakemore 2007; James 2004, 2005, 2006, 2009; James *et al.* 

2004; Hong & James 2004, 2008a–c, 2009, 2010, 2011a, b). Among these are 46 new species of *Pheretima sensu* Sims & Easton (1972), reported in studies conducted mostly in mountainous forested areas on Luzon Island (James *et al.* 2004; Hong & James 2008a–c, 2009, 2010, 2011a, b), but also in one study in the Mt. Kitanglad Range, Mindanao Island (James 2004). In the present paper, we describe 18 new *Pheretima* species from Mt. Malindang, Mindanao, and present an identification key to *Pheretima* species from Mt. Malindang.

# Material and methods

**Study area.** The Malindang Range is a large volcanic complex at the base of the Zamboanga Peninsula, western Mindanao Island, Philippines (Fig. 1). The forests in this mountain range are the only remaining natural forests representing the tropical Zamboanga biogeographic zone (Mallari *et al.* 2001), one of 15 such zones in the Philippines. Reaching 2425 m asl., Mt. Malindang (~ 8°18'N, 123°39'E) is the highest mountain on the Zamboanga Peninsula, covering 53,262 ha and consisting of 46% lower montane and upper montane (mossy) forest, 25% bushland, 6% denuded land, and 23% cultivated land (Mallari *et al.* 2001).

We collected earthworms in primary forest, disturbed forest, grassland, and agricultural habitats at various elevations in four geographically separate barangays (= precincts): Barangay (Brgy) Lake Duminagat in the municipality of Don Victoriano; Brgy Sibucal and Brgy Toliyok in Oroquieta City; and Brgy Small Potongan in the municipality of Concepcion. The terrain in the forested areas was very rugged, with steep grades and many cliff faces, making access extremely difficult. Surrounded by humid primary forest in Brgy Lake Duminagat is a crater lake about 9 ha in area called Lake Duminagat. The primary forest in this barangay had never been logged and remained largely undisturbed by human activities. The vegetation was dense and lush; trees were thickly covered with moss, ferns, and lichens, and ground was thickly covered with moss, roots, and leaf litter. The dominant trees included *Viburnum* sp., *Lithocarpus, Caldeluvia, Pometia, Macaranga dipterocarpifolia*, and *Polyosma philippinensis*.

Trees in the disturbed forest, regrown after deforestation by humans, were dominated by dipterocarps (those we identified included *Lithocarpus mindanaensis, L. philippinensis*, and *Polyosma philippinensis*) and tended to be more closely spaced than in the primary forest, and to have more undergrowth (saplings, shrubs, and tree ferns). The ground was covered with thick leaf litter, roots, bryophytes, and lichens.

**Sampling.** The earthworms described in this paper were collected in an ecological and distributional study at Mt. Malindang during the periods 9–15 Oct. 2003 and 18–25 Feb. 2004. 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 x 20 m in extent were established, with an average distance of 75 m between plots. On each plot, 0.075 m<sup>3</sup> (0.5 m x 0.5 m square x 0.3 m deep) of soil was examined from each of 10 quadrats in randomly selected spots. This gave a total of 4.5 m<sup>3</sup> of soil sampled at each of the five collecting sites (see Table 1), which equals a surface area of 15 m<sup>2</sup>. In the Lake Duminagat Disturbed category, two sites were lumped (Disturbed Forest and Logged Over) in Aspe *et al.* (2009: Table 2), and thus represent 12 plots and 9 m<sup>3</sup> of soil sampled, equaling 30 m<sup>2</sup>. The earthworms collected in each quadrat were preliminarily sorted to species and counted. Additional haphazard sampling was done outside the plots to test for patch effects in the quadrats. Tree bark, ferns, mosses, vines, and the insides of rotten logs were also checked for earthworms. Earthworms collected were rinsed 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 two days, the formalin was replaced with 80% ethanol. Elevations were read by GPS (Magellan Map 410; Luzon map datum) if a satellite signal was detectable, or with an altimeter if not. Elevation is expressed in this paper as meters above sea level (m asl).

**Examination and descriptions.** Worms were sorted in the field to putative species using body size, coloration and number of spermathecal pores as identifying characters. Some of the worms were released alive after collection and counting, due to limitations on the total number of specimens we were allowed to take in the collecting agreements with the Protected Area and Wildlife Bureau and the indigenous community. Among the preserved specimens, external and internal characters were examined for a representative subset. Without exception, these examinations confirmed the original assignment of specimens to putative species. We therefore assume that all specimens listed in Table 1 are correctly identified. Some specimens were unfortunately lost from our field collection due to unforeseeable circumstances, and so the number of specimens listed in Table 1 is higher than indicated in the descriptions.



**FIGURE 1.** (A) Map of the Philippines showing localities where new earthworm species described in the last decade were collected. (B) Map of Mt. Malindang showing locations of the barangays where the new *Pheretima* species reported in this study were collected.

All descriptions are based on external examination and on dorsal dissection under a stereomicroscope, following the terminology and conventions of Easton (1979). 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, 'spermathecal pores 0.13 circumference apart ventrally' means the distance between the pores is 0.13 the circumference of the worm at that point, with the circumference calculated as  $\pi$  times segment diameter. The generic diagnosis and assignment to species groups follows Sims & Easton (1972). While the species described share many character states diagnostic for the genus, we include shared characters to facilitate information retrieval from the separate descriptions. Line drawings were prepared with Adobe Illustrator ver. CS5.

While we detected what appear to be 22 previously undescribed *Pheretima* species at Mt. Malindang, we have not formally named and included here species for which the material available for morphological examination was limited to a single specimen. In this paper, we depart from the usual practice of illustrating earthworms with drawings of the external anterior-ventral aspect, but instead present schematic drawings in the dorsal view of the internal morphology showing the structure and location of organs. The reasons for this break from tradition are 1) the most useful first pass at identification involves overall color pattern and the size of mature individuals, neither of which is evident in drawings of external aspect presented at the same size rather than the same scale; 2) the external aspect is quite stereotyped within *Pheretima* species groups (e.g. *Pheretima* species herein do not possess genital markings that vary in pattern); 3) artifacts of preservation and degree of sexual maturity further limit the utility of a single drawing of external morphology in species identification; and 4) most of the characters used in species discrimination are internal, and the large proportion of descriptions typically devoted to internal anatomy reflects this.

Holotypes and some of the paratypes are deposited in the National Museum of the Philippines Annelid Collection (NMA), P. Burgos St., Manila, Philippines. 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 18 new species from Mt. Malindang, Mindanao Island. All of them belong to the subgenus *Pheretima* (*Pheretima*) Kinberg, 1867, distinguished from the other subgenus, *Pheretima* (*Parapheretima*) Cognetti, 1912, by the absence of secretory diverticula on the coelomic surface of the copulatory bursae. Eleven species belong to the *P. sangirensis* (Michaelsen, 1891) species group of Sims & Easton (1972), characterized by having a pair of spermathecal pores in the intersegmental furrow of 7/8 and by lacking penial sheaths in the copulatory bursae: *P. maculodorsalis* **n. sp.**, *P. tigris* **n. sp.**, *P. immanis* **n. sp.**, *P. lago* **n. sp.**, *P. nunezae* **n. sp.**, *P. boniaoi* **n. sp.**, *P. malindangensis* **n. sp.**, *P. misamisensis* **n. sp.**, *P. wati* **n. sp.**, *P. longiprostata* **n. sp.**, and *P. nolani* **n. sp.** One species, *P. longigula* **n. sp.**, belongs to the *P. montana* (Kinberg, 1867) species group, characterized by having a pair of spermathecal pores in the intersegmental furrow of 7/8 and penial sheaths in the copulatory bursae. Two species, *P. vergrandis* **n. sp.**, and *P. concepcionensis* **n. sp.** are monothecal. Three species (*P. adevai* **n. sp.**, *P. lluchi* **n. sp.**, and *P. potonganensis* **n. sp.**) belong to the *P. darnleiensis* (Fletcher, 1887) species group, characterized by having either four or five pairs of spermathecae from segments vi to ix, with a fifth pair variably present in segment v. We also describe an athecate species, *P. subanensis* **n. sp.** In addition to *Pheretima*, our study detected three *Pithemera* and one *Polypheretima* species, which we will describe elsewhere.

Table 1 shows the frequency and relative abundance of *Pheretima* species at the five collecting sites where *Pheretima* was detected. *Pheretima wati*, *P. misamisensis*, and *P. potonganensis* were the most widely distributed among sites (frequency1 for *P. wati* and 0.8 for *P. misamisensis* and *P. potonganensis*). *Pheretima adevai*, *P. wati* and *P. potonganensis* showed the highest relative abundance across all sites and plots (19.4%, 11.8% and 11.2%, respectively, of all individuals collected). The sites with highest species diversity were in disturbed forest in Barangays Lake Duminagat and Sibucal (20 and 17 species, respectively). The four sites where we found *Pheretima* to be species-rich and common were all above 900 m in elevation.

<b>TABLE 1.</b> Population dens: Aspe <i>et al.</i> , 2009). Data are Small Potongan and Toliyol examined on plots, equalling	ity for <i>Pheretima</i> spe given for only five c c). + indicates indivi g a surface area of 1.	ceies at sampling sites of nine sites, as no $Ph$ duals collected outsic $5 \text{ m}^2$ .	s on Mt. Malindang, <i>eretima</i> individuals le sampling plots. D	and frequency of occu were found at four of th ensity values for each s	rrence of species ac ne sites (agricultura ite are individuals (	ross sites (Moc l areas and gras collected per 4.	ified from slands in Brgys 5 m <sup>3</sup> of soil
Barangay Habitat Elevation	Lake Duminagat Primary Forest (1845–2027 m asl)	Lake Duminagat Dist urbed Forest (1479–1662 m asl)	Sibucal Disturbed Forest (902–1067 m asl)	Small Potongan Disturbed Forest (915–1,024 m asl)	Toliyok Disturbed Forest (238–271 m asl)	Total (%) individuals on all plots	Frequency of occurrence among sites
Geographical Coordinates	8°17'55"N 123°37'01"E	8°18'22.1"N 123°37'12.1"E	8°19'31"N 8 123°38'02"E	°24'04"N 123°36'47"E	8°25'51"N 123°42'21"E		
Species							
P. maculodorsalis <b>n. sp.</b>	11	4	I	ı	ı	13 (5.6)	0.4
P. tigris n. sp.	12	+	ı	2	ı	14 (5.9)	0.6
P. immanis n. sp.	+	11	ı	4	ı	15 (6.3)	0.6
P. lago n. sp.	11	2	2		ı	15 (6.3)	0.6
P. nunezae <b>n. sp.</b>	ı	ı	2	3	ı	5 (2.1)	0.4
P. boniaoi n. sp.	ı	+	ı	+	ı	+	0.4
P. malindangensis <b>n. sp</b> .	4	1	8		ı	13 (5.5)	0.6
P. misamisensis n. sp.	+	+	+	+		+	0.8
P. wati n. sp.	1	8	9	13	+	28 (11.8)	1
P. longiprostata <b>n. sp.</b>		ı	+	4		4 (1.7)	0.4
P. nolani <b>n. sp.</b>	14	7	+			21 (8.9)	0.6
P. longigula <b>n. sp.</b>	5	+	ı		ı	5 (2.1)	0.4
P. adevai n. sp.	23	23		+		46 (19.4)	0.6
P. Iluchi n. sp.	+	+	3		·	3 (1.3)	0.6
P. potonganensis n. sp.		+	8	9	12	26 (11.2)	0.8
P. vergrandis n. sp.	ı	+	15	1	,	16 (6.9)	0.6
P. concepcionensis n. sp.	·	+	1	7		8 (3.4)	0.6
P. subanensis n. sp.	ı	ı	ı	+	·	+	0.2
Total individuals	+62	56+	46+	38+	12	232 (100)	
Total species	12	16	15	11	2	22	



FIGURE 2. Photographs of living *Pheretima* worms in dorsal view, showing coloration. (A) *P. maculodorsalis* **n. sp.**; (B) *P. tigris* **n. sp.**; (C) *P. immanis* **n. sp.**; (D) *P. longigula* **n. sp.**; (E) *P. malindangensis* **n. sp.** Scale bars: A–D, 5 cm; E, 3 cm.

# Taxonomy

# Megascolecidae Rosa, 1891

# Pheretima (Pheretima) Kinberg, 1867

#### Type species. Pheretima montana Kinberg, 1867

**Diagnosis.** Body circular in cross section, with numerous setae regularly arranged equatorially around each segment; setae absent on first and last segments. Male pores paired within copulatory bursae opening on segment xviii; one or more pairs of spermathecal pores in intersegmental furrows between 4/5 and 8/9. Clitellum annular, covering three segments (xiv to xvi). Single female pore midventrally on xiv. Genital markings usually absent. Internally, esophageal gizzard usually originating in viii; a pair of caeca originating in xxvii, extending forward; septa in 4/5–7/8, 10/11–12/13, thickened or slightly thickened, lacking in 8/9 or 9/10 in some species. Ovaries and funnels free in xiii. Male sexual system holandric, with paired testes and funnels enclosed in sacs in x and xi, and seminal vesicles in xi and xii. Spermathecae a single pair, multiple pairs, or sometimes single and located midventrally. Nephridia on spermathecal duct present. One pair of prostate glands, racemose. Copulatory bursae present; secretory diverticula on coelomic surface of copulatory bursae lacking.

# Pheretima maculodorsalis n. sp.

(Figs 2A, 3A,B, Table 2)

**Material examined.** Holotype: adult (NMA 4505), Brgy Lake Duminagat, municipality of Don Victoriano, Misamis Occidental Province, Mt. Malindang Range (8°17'55"N, 123°37'01"E), 1500 m asl., Mindanao Island, Philippines, coll. Nonillon Aspe, Nolan Aspe, J. Adeva, Oct. 9–15, 2003. Paratypes: two juveniles (NMA 4531), same collection data as for holotype.

**Etymology.** The species name is derived from the Latin 'macula' (spot) and 'dorsalis' (pertaining to the back) and refers to the oval spots along the dorsal midline.

**Diagnosis.** Large worm, adult length 226–235 mm; dark red stripes in dorsal intersegmental furrows in head region, replaced by oval dots in post-clitellar segments; one pair of spermathecal pores closely spaced at intersegment 7/8; spermatheca with irregularly rounded ampulla, stout muscular duct, stalked diverticulum with 2–3 lobed receptacle; very long caeca extending from xxvii to xxi.

**Description**. In living animals, head segments striped dark red in intersegments, non-pigmented equators; in post-clitellar segments, stripes replaced by dorsal oval dots, which are also of dark red coloration. Length 226–235 mm (n=3 adults, including non-type material); diameter 11–13 mm at x, 9 mm at xx; body cylindrical in cross-section, tail narrowing abruptly in last 8 segments; 115–122 segments. First dorsal pore at 12/13; spermathecal pores one pair at 7/8, 0.09 circumference apart ventrally, with small thickened lips, ventral surface of 1/2 vii–viii thickened. Female pore single in xiv, openings of copulatory bursae paired in xviii, 0.13 circumference apart ventrally, 2–4 setae between openings. Clitellum annular, from xiv to xvi. Setae evenly distributed around segmental equators; 73–74 setae on vii, 63–75 setae on xx, dorsal setal gaps present, no ventral gaps.

Septa 5/6–7/8 and 10/11–13/14 muscular, 8/9 membranous, 9/10 lacking. Dense tufts of nephridia on anterior faces of 5/6 and 6/7; nephridia of intestinal segments located mainly on body near septum/body wall junction. Large gizzard extending from viii to x, esophagus with low vertical lamellae x–xiii, intestinal origin xvii, caeca originating in xxvii, extending forward to xxi, ventral margins slightly incised; typhlosole originates in xxvii, simple fold slightly less than dorsal vessel diameter; intestinal wall with 50–54 longitudinal blood vessels.

Hearts in x to xiii, esophageal; commissural vessels in vi, vii, and ix, lateral; those in viii extend to gizzard; supra-esophageal vessel extends from x to xiii; extra-esophageal vessel joins ventral esophageal wall in xi, receives efferent parieto-esophageal vessel in xiii.

Ovaries and funnels free in xiii. Spermathecae paired, postseptal in viii, with nephridia on ducts; each spermatheca with irregularly rounded ampulla, stout muscular duct, stalked diverticulum attached to duct near ampulla, terminating in 2–3 lobed receptacles, stalks short. Spermathecae contain small, ovate spermatophores with very slender tails about half length of spermatophore body. Male sexual system holandric, testes and funnels enclosed in paired sacs in x, xi; seminal vesicles xi, xii, each with digitate dorsal lobe; vesicles of xi enclosed in testes sac; vasa deferentia slender, free from body wall en route to ental end of prostatic ducts; prostates in xvii to xx, each a single, dense, racemose mass; short straight muscular duct entering posterior margin of copulatory bursa; paired large copulatory bursae extend from xviii to xxi; coelomic surfaces of paired hemispheric copulatory bursae muscular, secretory diverticula lacking; roof of copulatory bursae with two pads, posterior pad bifurcate, both pads with small lumen within glandular tissue; small penis between pads; penial sheaths in copulatory bursae absent. Bursal floor has thick wrinkles, no other projections.

Remarks. Pheretima maculodorsalis n. sp. belongs to the P. sangirensis species group in Sims & Easton (1972), characterized by spermathecal pore(s) opening only in 7/8 and absence of penial sheaths in the copulatory bursae. Members of this group may have no septa in either intersegments 8/9 or 9/10 or both; the caeca are either simple or have short pockets on the ventral margins; the male system is holandric, with paired testis sacs; and the copulatory bursae are simple, with short conical penes. In Sims & Easton (1972), the P. sangirensis group was composed of P. sangirensis, P. ceramensis Cognetti, 1922, and P. crassicystis Michaelsen, 1896. Michaelsen (1900) reassigned P. crassicystis as a subspecies of P. sangirensis. Blakemore (2007) acknowledged Michaelsen's (1900) reassignment of P. sangirensis subspecies: P. s. sangirensis, P. s. crassicystis, and P. s. chica Michaelsen, 1896. The subspecies vary in size (140 mm x 3.5–4.5 mm in P. s. sangirensis; 240 mm x 8 mm in P. s. crassicystis; and 54–120 mm in P. s. chica) and color (dark purple brown in P. s. sangirensis; purplish gray in P. s. crassicystis; and purple in P. s. chica). Also, the first dorsal pore in P. s. sangirensis is located in 11/12 while it is in 12/13 in P. s. crassicystis and P. s. chica. Another species, P. unicystis Lee, 1981 from Vanua Tu, was added to the species group, but *P. unicystis* differs from the other members in the group by having the clitellum located in 1/2 xiv - 1/2 xv and in consistently having only one spermatheca located on the right side of 7/8. Blakemore (2007) considered P. unicystis to be a possible junior synonym of *P. montana* Kinberg, 1867. *Pheretima maculodorsalis* differs markedly from P. sangirensis (and subspecies; see Table 2 for comparison) and P. ceramensis in pigmentation pattern (pigmented over the entire dorsum in P. ceramensis), the distance between male pores and spermathecal pores (about 0.2 circumference apart and slightly closer set, respectively in *P. ceramensis*) (James, 2004), the origin of the intestine (xv in P. ceramensis), and the number of intestinal vessels (36 in P. ceramensis), among other

characters. Pheretima maculodorsalis is similar to P. s. crassicystis in size (240 mm) and the location of the dorsal pore, but the latter is entirely pigmented, has no septum in 8/9, has caeca extending from xxvii-xxii, and has the prostate extending from xvii-xix.

James (2004) reviewed the P. sangirensis group and added to this group 10 new species (P. quincunxia, P. diesmosi, P. monoporata, P. vicinipora, P. baungonensis, P. paucisetosa, P. alba, P. virgata, P. rubida and P. asurgo Blakemore, 2006 (a replacement name for P. rugosa James, 2004 to avoid homonymy with P. houlleti rugosa Gates, 1926) from the Mt. Kitanglad range in Mindanao. Hong & James (2008b) added another two species (P. lagunaensis and P. mariae) to this group from Mt. Makiling on Luzon Island. Pheretima maculodorsalis n. sp. is a large worm, and among the species at Mt. Kitanglad is most similar in size to P. virgata, which reaches 290 mm. The two species differ in the intestinal origin (xvi in *P. virgata*), the pigmentation pattern (stripes in *P. virgata*), the number of intestinal vessels (42 in P. virgata), and the number and shape of pads in the copulatory bursae. Other large worms on Mt. Malindang are P. tigris n. sp., P. immanis n. sp., and P. lago n. sp. Pheretima maculodorsalis differs from them (Table 2) in pigmentation pattern; the length of the caeca; the shape, size and position of prostate glands and copulatory bursae; and the spermathecal pores, which are closer together. *Pheretima maculodorsalis* is the only species of the *sangirensis* group at Mt. Malindang that has the intestinal origin in xvii.

Occurrence. We found *P. maculodorsalis* in primary and disturbed forest at two of five forest sites in Brgy Lake Duminagat, at elevations of 1479–2027 m asl. It occurred in soil and rotting logs (Table 1).



FIGURE 3. (A) Diagrammatic ventral view of *P. maculodorsalis* n. sp. showing the spermathecal pores (sp), clitellum (cl), and male pores (m). (B, C) Schematic drawings of the internal morphology of Philippine Pheretima species, in dorsal view: (B) P. maculodorsalis n. sp.; (C) P. tigris n. sp.; (D) P. immanis n. sp. Abbreviations: s, spermatheca; h, heart; p, prostate gland; cb, copulatory bursa; c, caecum. Scale bars: 10 mm.

# Pheretima tigris n. sp.

(Figs 2B, 3C, Table 2)

Material examined. Holotype: adult (NMA 4506) Brgy Lake Duminagat, municipality of Don Victoriano, Misamis Occidental Province, Mt. Malindang Range (8°17'55"N, 123°37'01"E), 1500 m asl., Mindanao Island, Philippines, coll. Nonillon Aspe, Nolan Aspe and J. Adeva, Oct. 9-15, 2003. Paratypes: three juveniles (NMA 4532), same collection data as for holotype. Other material: two adults (ZRC.ANN.0016), Brgy Small Potongan, municipality of Concepcion, Misamis Occidental Province, Mt. Malindang Range, 8°24'04" N, 123°36'47" E, 848 m asl, coll. Nonillon Aspe, M. Lluch and J. Adeva, Feb. 18-25, 2004.

**Etymology.** The species name is the Latin 'tigris' (tiger), referring to the striped body.

Diagnosis. Large worm with adult length of 230-283 mm; dark red to purple dorsal pigment stripes in

intersegmental furrows, equators non-pigmented; one pair of spermathecal pores at 7/8; spermathecae with ovate to pyriform ampullae; relatively small prostates extending from xvi to xviii; 56–58 intestinal vessels; very large, elongate caeca extending from xxvii to xix; penes absent.

**Description.** Living animals have iridescent, dark red to purple dorsal stripes at intersegmental furrows; pigment almost black in formalin; equators non-pigmented. Length 230–283 mm (n=3 adults); diameter 8–10 mm at x, 11–14 mm at xx; body cylindrical in cross-section, tail narrowing abruptly in last 6 segments; 113–123 segments. First dorsal pore at 12/13; spermathecal pores one pair at 7/8, 0.13 circumference apart ventrally; large indistinct pads paired in viii behind spermathecal pores; female pore single in xiv, openings of copulatory bursae paired in xviii, 0.14 circumference apart ventrally, 0–4 setae between openings. Clitellum annular, extending from xiv to xvi. Setae evenly distributed around segmental equators; 53–66 setae on vii, 48–61 setae on xx, dorsal and ventral gaps absent.

Septa 5/6 and 7/8 slightly muscular, 6/7 and 10/11–15/16 muscular, 8/9 membranous, 9/10 lacking. Dense tufts of nephridia on anterior faces of 5/6 and 6/7; nephridia of intestinal segments located on body wall anterior and posterior to septa. Large gizzard extending from viii to x; esophagus with low vertical lamellae x–xiii; intestinal origin xvi; caeca originate in xxvii, extend forward to xix, broad base diminishes to narrow tip, several small ventral pockets; typhlosole originates in xxvii, three-pronged origin composed of main central ridge with two short branches posterior to beginning of ridge, then simple fold 1/6 lumen diameter; intestinal wall with 56–58 longitudinal blood vessels. Intestine narrow with thick villous lining in xvi–xxvi, intestine much wider after xxvii.

Hearts in x to xiii, esophageal, but x and xi very small; commissural vessels in vi, vii, and ix lateral; those in viii extend to gizzard; supra-esophageal vessel extends from x to xv; extra-esophageal vessels join ventral esophageal wall in x, receive efferent parieto-esophageal vessels in xiii.

Ovaries and funnels free in xiii; spermathecae paired, postseptal in viii, with nephridia on ducts; each spermatheca with large ovate to pyriform ampulla, stout muscular duct, stalked diverticulum attached to duct ental near ampulla, terminating in oblong receptacle wider at distal end; stalk short, thick. One or two spermatophores in each ampulla, nearly spherical, with long curved tail and ragged, 'dirty' end that may have been a plug in spermathecal pore. Male sexual system holandric; testes and funnels enclosed in paired ventral sacs in x and xi; seminal vesicles in xi and xii, that in xii with long flattened dorsal lobe; vesicles of xi in testes sacs; vasa deferentia slender, free from body wall en route to ental end of prostatic ducts; each prostate densely racemose, extending from xvi to xviii, muscular duct attached to surface of hemispheric to elliptical copulatory bursa in xvii to xix, entering posterior dorsal face of copulatory bursa; paired copulatory bursae extend from xvii to xix coelomic surfaces of copulatory bursae muscular, secretory diverticula lacking; floor of bursae with 5 small pads forming U-shaped array around posterior side of opening; pyramidal penial mound directed to opening from posterior bursal roof; penes absent.

**Remarks.** *Pheretima tigris* **n. sp.** belongs to the *P. sangirensis* group in Sims & Easton (1972) but differs from *P. sangirensis* pigmentation pattern, intestinal origin, and number of intestinal vessels, and in lacking penes (Table 2). Anterior septa are present except at 9/10, unlike most other species in the *P. sangirensis* group, where septa 8/9/ 10 are absent. *Pheretima tigris* is a large worm, similar in size to *P. ceramensis* and *P. s. crassicystis* (140–440 mm and 240 mm, respectively) (James, 2004), but the latter two species are entirely pigmented and have shorter caeca (xxvii–xx and xxvii–xxiv, respectively). In addition, *P. ceramensis* has the intestinal origin in xv and has fewer longitudinal blood vessels (36), and *P. s. crassicystis* has no dorsal setal gap and lacks a septum in 8/9. Among the species at Mt. Kitanglad (James 2004), *P. tigris* is most similar to *P. virgata* James, 2004 in size and pigmentation pattern, the origin of the intestine and typhlosole, and the absence of penes, but differs from the latter in the number of setae (76 in vii and 80 in xx in *P. virgata*), the number of longitudinal blood vessels in the intestine (42 in *P. virgata*), the extent of the copulatory bursae (xviii in *P. virgata*), and the number and shape of pads in the copulatory bursae. *Pheretima tigris* differs from *P. maculodorsalis* in pigmentation pattern, the origin of the prostate glands, the absence of penes, and in the number and shape of pads in the copulatory bursae.

**Occurrence.** *Pheretima tigris* was found at elevations of 915–2027 m asl, commonly in primary forest in Brgy Lake Duminagat and less commonly in disturbed forest in Brgy Small Potongan. It occurred in soil and rotting logs (Table 1).

Character	Pheretima sangirensis * (Michaelsen 1891)	Pheretima maculodorsalis n sn	Pheretima tigris <b>n. sp.</b>	Pheretima immanis <b>n. sp.</b>	Pheretima lago <b>n. sp.</b>	Pheretima nunezae <b>n. sp.</b>
Body pigmentation	Dorsally pigmented	Dorsal intersegments	Dorsal	Dorsal	Dorsally	Dorsally pigmented
	all over	with oval dots	intersegments	intersegments with	pigmented	all over
			with stripes	stripes	all over	
Length	54-240	226–235	230–283	365	223 - 315	> 116
Width	4-8	9–13	8-14	18-17	10 - 11	8.5 - 9
Setae vii; xx	40;60+	73-74; 63-75	53-66; 48-61	61-69; 63-68	49; 53	46; 51
Setae bet. male pores	9	2-4	0-4	5	0-2	6
Sper. pores spacing	0.25 - 0.28	0.09	0.13	0.12	0.18 - 0.24	0.28
Male pores spacing	0.17 - 0.25	0.13	0.14	0.14	0.15	0.22
Setal gaps D; V**	- ;-/+	;. +	- - -	- ; -	;. +	;. +
Septa in 5/6-13/14	- in 8/9/10	- in 9/10	- in 9/10	- in 9/10	- in 9/10	+ in 4/5; - in 9/10
Origin of gizzard	viii	viii	viii	viii	ix	ix
Origin of intestine	XV	xvii	xvi	xvi	xiv	XV
Caeca	from xxvii	xxvii–xxi	xxvii–xix	XXVII–XX	xxvii–xxi	XXVII–XXIV
Origin of typhlosole	absent in xxx-xl	xxvii	xxvii	iivxx	XXVII	xxvii/xxvi
Intestinal vessels	36	50 - 54	56–58	28–32	36–38	20–23
Location of hearts	x-xiii	x-xiii	x-xiii	x-xiii	xi–xiii	xi–xiii
Prostate glands	xvii-xix	xvii–xx	xvi–xviii	xvii–xviii	xiv–xviii	xvii–xix
Copulatory bursae	present	xviii–xxi	xvii–xix	xvi–xvii	vii–xx	viii
Penes	+	+		I	+	+
					cont	inued on the next page

**TABLE 2.** Comparison of species in the *Pheretima sangirensis* and *P. montana* groups at Mt. Malindang.

<b>TABLE 2.</b> (Continued)							
Character	Pheretima	Pheretima	Pheretima	Pheretima	Pheretima	Pheretima	Pheretima
	boniaoi <b>n. sp.</b>	malindangensis	misamisensis	wati	longiprostata	nolani	longigula
		n. sp.	n. sp.	n. sp.	n. sp.	n. sp.	n. sp.
Body pigmentation	Dorsal	Dorsally	Dorsally	Dorsally	Dorsally	Dorsally	Dorsally
	intersegments	pigmented	pigmented	pigmented	pigmented	pigmented	pigmented
	with stripes	all over	all over	all over	all over	all over	all over
Length	101 - 133	60 - 81	55-65	67–75	37–41	8997	139–186
Width	5-6	4-5	3-4	3.5-4	3 - 3.5	4.5-5	3.5-4.5
Setae vii; xx	59-78; 62-68	43-47; 50-57	42-51; 43-48	59-71; 52-60	35-40; 37-47	33–48; 42	28-47; 27-51
Setae bet. male pores	0	0	6-7	0	0-5	2	0-4
Sper. pores spacing	0.14	0.16	0.3	0.17	0.16	0.14	0.24
Male pores spacing	0.03	0.11	0.23	0.08	0.16	0.12	0.17
Setal gaps D; V*	; <b>.</b> +	 +	; +	÷	÷	+	
Septa in 5/6-13/14	- in 9/10	- in 8/9/10	- in 9/10	- in 8/9	- in 8/9/10	- in 9/10	- in 8/9/10
Origin of gizzard	viii	viii	viii	viii	viii	viii	viii
Origin of intestine	xvii	xvi	XV	XV	XV	XV	xxi
Caeca	xxvii–xxiv	XXVII–XXIII	xxvi–xxv	xxvii–xxii	xxvii–xxv	xxvii–xxii	xxvii–xxii
Origin of typhlosole	xxvii	xxvii	xxvii	xxvii/xviii	xxvii/xxvi	xxvii/xxvi	xxxiii
Intestinal vessels	33-45	30	32	34–38	20	4244	32–36
Location of hearts	xi–xiii	xi–xiii	x-xiii	x-xiii	x—xiii	x—xiii	x-xiii
Prostate glands	xvi–xxi	xvi–xxi	xvi–xxii	xv–xxii	XV-XXIII	XVXX	xviii–xx
Copulatory bursae	xvii–xx	xvii–xx	xvii–xix	xvii–xxi	xvii–xx	xvii–xix	xvii–xviii
Penes		+	+	I	+	+	+
* including all subspecie	es; data based on M	ichaelsen (1891, 1899	(, 1900)				
**D: dorsal gap; V: ven	tral gap; +: present;	-: absent.					

### Pheretima immanis n. sp.

(Figs 2C, 3D, Table 2)

**Material examined.** Holotype: adult (NMA 4507), Brgy Lake Duminagat, municipality of Don Victoriano, Misamis Occidental Province, Mt. Malindang Range (8°17'55"N, 123°37'01"E), 1500 m asl., Mindanao Island, Philippines, coll. Nonillon Aspe, Nolan Aspe and J. Adeva, Oct. 9–15, 2003. Paratype: one adult, tail end missing (ZRC.ANN.0017), same data as for holotype.

Etymology. The species name is from the Latin 'immanis' (huge, enormous), referring to the large size.

**Diagnosis.** Adults large, reaching 365 mm in length; thick dark purple to black dorsal stripes at intersegmental furrows, equators unpigmented; one pair of spermathecal pores at 7/8; spermathecae, prostate glands and copulatory bursae small relative to body size; penes lacking; 28–32 intestinal vessels.

**Description.** Living animals with iridescent, broad, dark blue-purple to black dorsal pigment stripes at intersegmental furrows; stripes narrow ventrally to fine points, non-pigmented equators widest ventrally. Length 365 mm (n=1 adult), diameter 17 mm at x, 18 mm at xx; body cylindrical in cross-section; 119 segments. First dorsal pore at 12/13; spermathecal pores one pair at 7/8, 0.12 circumference apart ventrally; female pore single in xiv, openings of copulatory bursae paired in xviii, 0.14 mm circumference apart ventrally, 5 setae between openings. Clitellum annular, extending from xiv to xvi. Setae unevenly distributed; 61–69 setae on vii; 63–68 setae on xx; no dorsal or ventral gaps.

Septa 5/6 and 7/8 slightly muscular, 10/11-15/16 muscular, 8/9 thin, 9/10 absent. 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 at anterior and posterior faces of septa. Large gizzard extending from viii to x, esophagus with low vertical lamellae from x to xiii; intestine originates in xvi; caeca originate in xxvii, extend forward to xx; typhlosole originates in xxvii, simple fold  $\frac{1}{4}$  lumen diameter. Intestinal wall with 28–32 longitudinal blood vessels.

Hearts in x to xiii, esophageal; commissural vessels vi, vii and ix lateral; those in viii extend to gizzard; supraesophageal vessel extends from x to xiii; extra-esophageal vessels join ventral esophageal wall in x, receive efferent parieto-esophageal vessels in xiii.

Ovaries and funnels free in xiii; spermathecae paired, postseptal in viii, with nephridia on ducts; each spermatheca with large, rounded rectangular ampulla, stout muscular duct, stalked diverticulum attached to duct near ampulla, terminating in oblong receptacle wider at distal end, attached by its side near narrow ental end; stalks short. Four spermatophores present in each ampulla. Male sexual system holandric; testes and funnels enclosed in paired sacs in x and xi; seminal vesicles xi and xii each with dorsal lobe; vasa deferentia slender, free from body wall en route to ental end of prostatic ducts; each prostate densely racemose, in xvii and xviii, muscular duct attached to surface of hemispheric copulatory bursa, entering posterior dorsal face of copulatory bursa; paired small copulatory bursae extend from xvi to xvii; coelomic surfaces of copulatory bursae muscular, secretory diverticula lacking; floor of bursae with two small pads lateral to opening; penes absent.

**Remarks.** A member of the *P. sangirensis* group, *P. immanis* **n. sp.** is by far the largest of any earthworm species previously known from the Philippines. Other large-sized worms in the Philippines include P. virgata James, 2004 (length 290 mm) from Mt. Kitanglad; P. barligensis Hong & James, 2011b (length 225-255 mm) from Mt. Province on Luzon Island; P. callosa Gates, 1937 (length 330 mm) from Benguet on Luzon Island; and P. maculodorsalis n. sp. (length 226–235 mm), P. tigris n. sp. (length 230–283 mm), and P. lago n. sp. (length 223–315 mm) described herein. *Pheretima immanis* differs from these species in pigmentation pattern; the origins of the intestine; the shape and size of spermathecae, diverticula, prostates and copulatory bursae; and the lengths of the caeca. Pheretima immanis, with one pair of spermathecae in viii, differs from the large worms P. barligensis (4 pairs in 5/6-8/9) and P. callosa (3 pairs in 6/7-8/9). Pheretima immanis is most similar to P. tigris in having dorsal stripes, in the arrangement of septa and the origins of the intestine and typhlosole, and in lacking penes; both also lack setal gaps on the dorsum and ventrum. However, mature individuals of *P. immanis* reach a larger size, and the dorsal stripes are much thicker than those of *P. tigris*. Internally, the two species differ in the extent of the caeca, the size and position of prostate glands and copulatory bursae (Table 2), the number of intestinal vessels, and the shape and size of spermathecae. Other large worms in the *P. sangirensis* group are *P. ceramensis* (140-440 mm) and *P. s.* crassicystis (240 mm), but these two species markedly differ from P. immanis in having pigmentation all over the body. Moreover, P. ceramensis has the intestinal origin in xv and has shorter caeca (xxvii–xxiv); P. crassicystis has no septa in 8/9, the prostate is a bit longer (xvii–xix), and the caeca are shorter (xxvii–xxii). The largest Pheretima

species in the world, which Blakemore *et al.* (2007) identified as *P. darnleiensis*, reaches 700 mm in length; that species differs markedly from *P. immanis* in having 4 or 5 pairs of spermathecal pores located in 5/6–8/9.

**Occurrence.** *Pheretima immanis* was found at elevations of 915–2027 m, but was somewhat more common at elevations above around 1480 m than at lower elevations (Table 1).

Pheretima lago n. sp.

(Fig. 4A, Table 2)

**Material examined.** Holotype: adult (NMA 4508), Brgy Lake Duminagat, municipality of Don Victoriano, Misamis Oriental Province, Mt. Malindang Range (8°17'55"N, 123°37'01"E), 1500 m asl., Mindanao Island, Philippines , coll. Nonillon Aspe, Nolan Aspe, and J. Adeva, Oct. 9–15, 2003. Paratypes: one adult (NMA 4533); two adults (ZRC.ANN.0018), same collection data as for holotype.

Etymology. The species name 'lago' means 'large worm' in the Cebuano dialect of the Philippines.

**Diagnosis.** Worms large, up to 315 mm long; dorsum dark, gradually fading towards ventral side; one pair of spermathecal pores at 7/8; relatively small spermathecae, diverticula with 2–4 chambered receptacles; intestine originating in xiv; hearts in xi to xiii, lacking in x, prostate glands located mostly anterior to copulatory bursae; 36–38 intestinal vessels.

**Description.** Living individuals with dark-brown to black dorsum anteriorly, lighter posteriorly, with gradually widening, non-pigmented equators; head setal rings with very thin non-pigmented area. Length 223–315 mm (n=4 adults); diameter 10–11 mm at x, 10–11 mm at xx; body cylindrical in cross-section, tail narrowing abruptly in last 6 segments; 116–134 segments. First dorsal pore at 12/13; inconspicuous spermathecal pores one pair in 7/8, 0.18–0.24 circumference apart ventrally; female pore single in xiv; openings of copulatory bursae paired in xviii, 0.15 circumference apart ventrally, 0–2 setae between openings. Clitellum annular, extending from xiv to xvi. Setae unevenly distributed; 49 setae on vii, 53 setae on xx, dorsal gap present, ventral gap absent.

Septa 5/6–7/8, 10/11–13/14 muscular, 8/9 thin, 9/10 absent. Dense tufts of nephridia on anterior faces of 5/6 and 6/7; nephridia of intestinal segments sparser on segmental equators. Large gizzard extending from ix to x; esophagus with low vertical lamellae within x to xiii; intestinal origin in xiv; slender caeca originating in xxvii, extending forward to xxi, ventral margins slightly incised; typhlosole originates in xxvii, simple fold of 1/5 lumen diameter; intestinal wall with 36–38 longitudinal blood vessels.

Hearts in xi to xiii, esophageal; hearts in x much reduced, hidden under membrane that is perhaps remnant of septum 9/10; commissural vessels vi, vii, and ix lateral; those in viii extend to gizzard; supra-esophageal vessel extends from xi to xiii; extra-esophageal vessel joins ventral esophageal wall in x, receives efferent parieto-esophageal vessel in xiii, with upper and lower branches.

Ovaries and funnels free in xiii; spermathecae paired, preseptal in vii, with nephridia on ducts; each spermatheca with large irregular rounded ampulla, stout muscular duct, stalked diverticulum attached to duct near ampulla, terminating in 2–4 chambered receptacle; stalks long, muscular. Spermathecal ducts fluted internally and off center from duct axis, ducts bearing rosette-shaped structure engorged with blood. Numerous ovate to pyriform spermatophores in each ampulla, tails longer than spermatophore body. Male sexual system holandric; testes and funnels enclosed in ventrally paired sacs in x and xi; seminal vesicles in xi and xii, each with long digitate dorsal lobe; vasa deferentia slender, free from body wall en route to ental end of prostatic ducts; each prostate racemose, with 6–7 main lobes in xiv to xviii; short, curved muscular duct enters anterior surface of copulatory bursa; paired elongate copulatory bursae extend from xvii to xx, coelomic surface of copulatory bursae muscular, secretory diverticula lacking; posterior portion of bursae filled with solid glandular tissue; long penis in anterior chamber of bursa; half-circle collar around anterior base of penis; copulatory bursae lack penial sheaths. Three long ridges in bursae, lateral to opening, one each on roof, floor, and lateral face of chamber.

**Remarks.** *Pheretima lago* **n**. **sp.** belongs to the *P. sangirensis* group of Sims & Easton (1972) but differs from all subspecies of *P. sangirensis* in having septa in 8/9, preseptal spermathecae in vii, and the intestine originating in xiv. It is a large worm, similar in size to *P. ceramensis* and *P. s. crassicystis*, but *P. ceramensis* has the intestine originating in xv and has shorter caeca (xxvii–xxiv), and *P. s. crassicystis* has no dorsal setal gap, the septum in 8/9 is lacking, and the prostates extend from xvii–xix. *Pheretima lago* is the second largest *Pheretima* species from Mt. Malindang next to *P. immanis* **n. sp.** *Pheretima lago* **n. sp.** differs from *P. immanis* and another large worm, *P. tigris* 

**n. sp.**, in pigmentation pattern, in having a dorsal setal gap, in the origin of the gizzard, in having spermathecal diverticula with chambered receptacles, in the number of hearts, in the extent of the caeca, in the number of intestinal vessels, and in having long penes (Table 2). *Pheretima lago* is similar to *P. callosa* James, 2004 in size, but the latter has 3 pairs of spermathecal pores in 6/7–8/9, the intestinal origin in xv, and prostates confined to xviii.

**Occurrence.** *Pheretima lago* was found at elevations of 900–2030 m asl. It was common at higher elevations in primary forest in Brgy Lake Duminagat, but uncommon at lower elevations (Table 1).



**FIGURE 4.** Schematic drawings of the internal morphology of Philippine *Pheretima* species, in dorsal view: (A) *P. lago* **n. sp.**; (B) *P. nunezae* **n. sp.**; (C) *P. boniaoi* **n. sp.** Abbreviations: s, spermatheca; h, heart; p, prostate gland; cb, copulatory bursa; c, caecum. Scale bars: 10 mm.

#### Pheretima nunezae n. sp.

(Fig. 4B, Table 2)

**Material examined.** Holotype: adult, amputee (NMA 4509), Brgy Sibucal, Oroquieta City, Misamis Occidental Province, Mt. Malindang Range (8°19'31"N, 123°38'02"E), 991 m asl., Mindanao Island, Philippines , coll. Nonillon Aspe, M. Lluch, and J. Adeva, Feb. 18–25, 2004. Paratype: one juvenile (NMA 4534), same data as for holotype.

**Etymology.** The species is named in honor of Dr. Olga Nuneza, one of our collaborators in the Malindang Biodiversity Research Program and a professor at Mindanao State University-Iligan Institute of Technology, Iligan, Philippines.

**Diagnosis.** Large worm, dark gray-brown dorsally, non-pigmented ventrally, clitellum gray; one pair of spermathecal pores at 7/8; septa from 4/5 to 13/14, except for 9/10; relatively small prostates extending from xvii to xix, copulatory bursae confined to xviii; 20–23 intestinal vessels.

**Description.** In living animals, dorsum dark gray-brown anteriorly, fading posteriorly; ventrum nonpigmented; equators non-pigmented; clitellum gray, darker than adjacent segments. Length of posteriorly incomplete worm 116 mm; diameter 8.5 mm at x; 9 mm at xx; body cylindrical in cross-section. First dorsal pore at 12/13; paired spermathecal pores at 7/8, 0.28 circumference apart ventrally; female pore single in xiv; openings of copulatory bursae paired in xviii, 0.22 circumference apart ventrally, 9 setae between openings. Clitellum annular, extending from xiv to xvi. Setae evenly distributed, 46 setae on vii, 51 setae on xx, dorsal gap present, ventral gap absent.

Septa 4/5/6/7/8 slightly muscular, 8/9 membranous, 9/10 absent, 10/11–15/16 slightly muscular. Dense tufts of

nephridia on anterior faces of 5/6 and 6/7; nephridia of intestinal segments located mainly on body wall at anterior and posterior faces of septa, at septum/body wall junction. Large gizzard extending from ix to x; esophagus with wide-angled, chevron-shaped lamellae, extending from x to xiii; intestine originates in xv; caeca originate in xxvii, extend forward to xxiv, with pocketed ventral margin; typhlosole simple fold, about 1/8 lumen diameter, originating at 26/27. Intestinal wall with 20–23 longitudinal blood vessels.

Hearts in xi to xiii, esophageal commissural vessels in vi, vii, and ix lateral; those in viii extend to gizzard; extra-esophageal vessels join ventral esophageal wall in x, receive efferent parieto-esophageal vessels in xiv.

Ovaries and funnels free in xiii; spermathecae paired in vii, one preseptal and the other postseptal; spermathecae irregularly shaped, with nephridia on ducts; each spermatheca with angular, apically attached oval ampulla, short thick muscular duct with slight bulge for diverticulum attachment; single-stalked diverticulum attached to face of duct, terminating in thick, sausage-shaped receptacle, stalk shorter than receptacle. Each spermatheca contains 2 spermatophores. Male sexual system holandric; testes and funnels enclosed in paired sacs in x and xi; seminal vesicles in xi and xii, each with short, spherical dorsal lobe; vasa deferentia slender, free from body wall, passing around lateral face of copulatory bursae en route to ental end of prostatic ducts; each prostate racemose, with three lobes, extending from xvii to xix, wrapped around lateral margins of copulatory bursa; muscular duct attached to surface of copulatory bursa along entire length of latter and enters apex. Ductlets of lobes meet vasa deferentia at common junction with muscular prostatic duct. Copulatory bursae hemispherical in xviii; coelomic surface of bursa muscular, secretory diverticula lacking; bursal floor with 2 pads lateral to center; elongate fold with longitudinal groove extending across medial edges of each pad; opening composed of sphincter valve surrounded by narrow ring; bursal roof with pair of folds or pads medial to small, rounded quadrangular penial projection directed posteriorly; copulatory bursae lacking penial sheaths.

**Remarks.** *Pheretima nunezae* **n. sp.** belongs to the *P. sangirensis* group of Sims & Easton (1972). It differs from all subspecies of *P. sangirensis* in having a septum in 8/9, the gizzard originating in ix, hearts absent in x, and fewer intestinal vessels and setae in xx. It differs from *P. ceramensis* Cognetti, 1922 in the origin of the gizzard (viii in *P. ceramensis*); the number of setae (60 setae per segment in *P. ceramensis*; James 2004); the number of hearts and intestinal vessels (x–xiii and 36, respectively in *P. ceramensis*); and the number of pads on the floor of the copulatory bursae. *Pheretima nunezae* **n. sp.** differs from most of the Malindang species in the *sangirensis* group in size, particularly in width (except that of *P. maculodorsalis* **n. sp.** and *P. tigris* **n. sp.**); in having wide spacing between the spermathecal pores and between male pores, especially in large worms; in the shape of the spermathecae and spermathecal diverticula; in the size and position of the prostate glands and copulatory bursae; in the number of intestinal vessels; and in the length of the caeca. No other species known in the Philippines resembles *P. nunezae*.

**Occurrence.** A few *Pheretima nunezae* were found in disturbed forest in Brgys Sibucal and Small Potongan at elevations of 902–1067 m asl; overall, it was one of the least common species, comprising 2.1% of all specimens collected (Table 1).

*Pheretima boniao* n. sp. (Fig. 4C, Table 2)

**Material examined.** Adult (NMA 4518), Brgy Small Potongan, municipality of Concepcion, Misamis Occidental Province, Mt. Malindang Range, 8°24'04"N, 123°36'47"E, 848 m asl, Mindanao Island, Philippines , coll. Nonillon Aspe, M. Lluch and J. Adeva, Feb. 18–25, 2004. Paratype: one adult (NMA 4531), same data as for holotype.

**Etymology.** The species is named in honor of Dr. Renato Boniao, a collaborator at Malindang Biodiversity Research Program and a professor at Mindanao State University-Naawan, Naawan, Misamis Oriental, Philippines.

**Diagnosis.** Body with purplish brown stripes; closely spaced spermathecal pores in 7/8; closely spaced male pores appearing as one in xviii; spermathecae round; elongate prostate glands from xvi to xxi.

**Description.** In living animals, purplish brown dorsal stripes at intersegmental furrows; equators nonpigmented; ventral side non-pigmented; clitellum gray. Length 101–133 mm; diameter 5–5.5 mm at x; 5.5–6 mm at xx; body cylindrical in cross-section, tail tapered; 98–108 segments. Paired spermathecal pores at 7/8, 0.14 circumference apart ventrally; female pore single in xiv; openings of copulatory bursae very closely spaced in floor of pit 0.6 mm wide in xviii, 0.03 circumference apart ventrally, no setae between openings. Clitellum annular, extending from xiv to xvi. Setae more numerous on ventral side, 59–78 setae on vii, 62–68 setae on xx, dorsal gap present, ventral gap absent.

Septa 5/6/7/8 thin, 10/11–13/14 slightly muscular, 8/9 very thin, 9/10 lacking. Dense tufts of nephridia on anterior faces of 5/6 and 6/7, nephridia of intestinal segments mainly on body wall on anterior and posterior faces of septa, located at septum/body wall junction. Large gizzard in viii–xi; esophagus with circumferential lamellae from xi to xiii; intestine originates in xiv; caeca originate in xxvii, extend forward to xxiv, with serrate ventral margin; typhlosole a simple fold of about 1/6 lumen diameter, originating in xxvii; intestinal wall with 33–45 longitudinal blood vessels.

Hearts in xi–xiii, esophageal; commissural vessels vi, vii, and ix lateral, absent in viii; supra-esophageal vessel extends from x to xiii; extra-esophageal vessels join ventral esophageal wall in x, receive efferent parieto-esophageal vessels in xiv.

Ovaries and funnels free in xiii; paired spermathecae post-septal in viii, with nephridia on ducts; each spermatheca consists of small rounded rectangular ampulla, very large bulbous muscular duct, expanding ectally, and single stalked diverticulum attached to posterior face of muscular bulb of duct, terminating in round receptacle attached by its end; stalks become abruptly stout midway towards ectal end. Spermathecal duct walls thick, complexly corrugated. Spermatophores lacking. Male sexual system holandric; testes and funnels enclosed in ventrally joined sacs in x and xi; seminal vesicles in xi and xii, each with long dorsal lobe; vasa deferentia slender, free from body wall, passing around anterior lateral face of copulatory bursae en route to ental end of prostatic ducts; prostates in xvi to xxi, each racemose, 4 lobed, wrapped around lateral margin of copulatory bursa; muscular duct attaches to dorsal face of copulatory bursa at center, runs along surface, and enters anterior face. Ductlets from anterior prostatic lobes join vas deferents and posterior ductlets at common junction with muscular prostatic duct. Copulatory bursae ovate, extending from xvii to xx; coelomic surface of copulatory bursa muscular; the outlet of the two bursae exit towards a common male pore; secretory diverticula lacking. Floor of bursae lacks pads; roof with small anterior pad; penis absent.

**Remarks.** *Pheretima boniaoi* **n. sp.** belongs to the *P. sangirensis* group of Sims & Easton (1972). It differs from all subspecies of *P. sangirensis* in having striped pigmentation, in having a closer space between the spermathecal pores, especially the male pores, which appear as one, and in having more elongate prostates. The new species is similar to *P. tigris* **n. sp.**, *P. immanis* **n. sp.**, and *P. virgata* from Kitanglad (James, 2004) in having dorsal striped pigmentation, but the latter three are much larger worms. *Pheretima boniao* **n. sp.** is similar to *P. vicinipora* from Mt. Kitanglad (James, 2004) and to *P. wati* **n. sp.** in having closely spaced spermathecal pores (although these are much closer together in *P. vicinipora*; 0.04 circumference apart) and male pores, but the latter two are smaller and are pigmented all over. Another distinctive character of *P. boniaoi* **n. sp.** is the stalks of the spermathecal diverticula, which become abruptly stout midway towards the ectal end.

**Occurrence.** Only two individuals of *Pheretima boniaoi* n. sp. were found in disturbed forest in Brgys Small Potongan and Brgy Lake Duminagat, at elevations of 915–1024 and 1479–1662 m, respectively (Table 1).

# Pheretima malindangensis n. sp.

(Figs 2E, 5A. Table 2)

**Material examined.** Holotype: adult (NMA 4513) Brgy Sibucal, Oroquieta City, Misamis Occidental Province, Mt. Malindang Range (8°19'31"N, 123°38'02"E), 991 m asl., Mindanao Island, Philippines , coll. Nonillon Aspe, M. Lluch, and J. Adeva, Feb. 18–25, 2004. Paratypes: 2 adults (NMA 4536); one adult (ZRC.ANN.0020), same collection data as for holotype.

Etymology. The species is named after Mt. Malindang National Park.

**Diagnosis.** Small worm with adult length reaching 60–81 mm, purplish brown; distance between spermathecal pores and male pores relatively short; spermathecal ampulla small, rounded, rectangular, with large, bulbous, muscular duct; gizzard large, extending from viii to xi; intestinal origin in xvi; hearts in xi to xiii, absent in x; elongate prostate glands extending from xvi to xxi; copulatory bursae large and ovate extending from xvii to xx; caeca extending from xvii to xxiii. Penial setae present on penial body of copulatory bursae.

**Description.** Living animals with dorsum dark purplish-brown anteriorly, fading to medium brown posteriorly; equators non-pigmented; ventral side non-pigmented; clitellum gray. Length 60–81 mm (n=3 adults);

diameter 4.0–4.5 mm at x, 4.0–5.0 mm at xx; body cylindrical in cross-section, tail blunt; 69–96 segments. First dorsal pore 12/13; paired spermathecal pores at 7/8, 0.16 circumference apart ventrally, with prominent internal ridges leading into each pore. Female pore single in xiv; openings of copulatory bursae paired in xviii, 0.11 circumference apart ventrally, no setae between openings. Clitellum annular, extending from xiv to xvi. Setae evenly distributed, 43–47 setae on vii, 50–57 on xx, no dorsal gap, ventral gap present.



**FIGURE 5.** Schematic drawings of the internal morphology of Philippine *Pheretima* species, in dorsal view: (A) *P. malindangensis n. sp.*; (B) *P. misamisensis n. sp.*; (C) *P. wati n. sp.*; Abbreviations: s, spermatheca; h, heart; p, prostate gland; cb, copulatory bursa; c, caecum. Scale bars: 5 mm.

Septa 5/6/7/8 and 10/11-13/14 slightly muscular, 8/9/10 absent. Dense tufts of nephridia on anterior faces of 5/6 and 6/7; nephridia of intestinal segments mainly on body wall at anterior and posterior faces of septa, located at septum/body wall junction.

Large gizzard extending from viii to xi; esophagus with circumferential lamellae within xi and xii, with digitiform internal texture from xiii to xiv; intestine originates in xvi; caeca originate in xxvii, extending forward to xxiii, with serrate ventral margins; typhlosole a simple fold about 1/6 lumen diameter, originating in xxvii; intestinal wall with 30 longitudinal blood vessels.

Hearts in xi to xiii, esophageal, absent in x; commissural vessels vi, vii, and ix lateral; viii extending to gizzard; supra-esophageal vessel extends from x to xiii; extra-esophageal vessels join ventral esophageal wall in x, receive efferent parieto-esophageal vessels in xiv.

Ovaries and funnels free in xiii; paired spermathecae post-septal in viii, with nephridia on ducts; ampulla small, rounded, rectangular; spermathecal duct large, bulbous, muscular, its wall thick and corrugated; single stalked diverticulum attached to posterior face of muscular bulb of duct, terminating in bean-shaped receptacle attached by its end, stalks longer than receptacle, increasing in diameter ectally. Two spermatophores present in each ampulla. Male sexual system holandric; testes and funnels enclosed in unpaired ventral sacs in x and xi; seminal vesicles in xi and xii, each with short dorsal lobe; vasa deferentia slender, free from body wall, passing around anterior lateral face of copulatory bursae en route to ental end of prostatic ducts; each prostate racemose, 4 or 5 lobed, from xvi to xxi, wrapped around lateral margin of copulatory bursa; muscular duct enters dorsal face of copulatory bursa just posterior of center. Ductlet from anterior prostatic lobes joins vas deferens, posterior ductlet at common junction with muscular prostatic duct. Large, ovate copulatory bursae extending from xvii to xx, broader in anterior portion; coelomic surface of copulatory bursa muscular, secretory diverticula lacking. Floors of bursae with anterior and posterior pads flanking opening, gutter leading from opening up to base of penis; roofs

with single angular posterior pad and large anterior glandular mass. Large blocky centrally placed penis bearing 5 penial setae; copulatory bursae lack penial sheaths.

**Remarks.** *Pheretima malindangensis* **n. sp.** belongs to the *P. sangirensis* group of Sims & Easton (1972). It is unique in having setae on the penial body. It differs from all subspecies of *P. sangirensis* in having closer spacing between the spermathecal pores and between the male pores, in lacking a dorsal setal gap (also lacking in *P.s. crassicystis*), and in having a ventral setal gap; in the origin of intestine; and in lacking hearts in x (Table 2). It is similar in size and coloration to *P. wati* **n. sp.**, *P. longiprostata* **n. sp.**, and *P. nolani* n. sp (see descriptions below), but differs (apart from the setae on the penis) in the male pore spacing, in lacking a dorsal setal gap, and having a ventral setal gap; in the origin of intestine, and shape of spermathecae; and in the size, shape, and position of the prostates and copulatory bursae (Table 2). *Pheretima malindangensis* does not closely resemble any species in the *sangirensis* group at Mt. Kitanglad (James 2004).

**Occurrence.** *Pheretima malindangensis* was found in Brgys Sibucal and Lake Duminagat, at elevations of 902–2027 m asl, with more individuals found in Brgy Sibucal. It occurred in the soil and above ground in substrates such as rotting logs (Table 1).

#### Pheretima misamisensis n. sp.

(Fig. 5B, Table 2)

**Material examined.** Holotype: adult (NMA 4516) Brgy Sibucal, Oroquieta City, Misamis Occidental Province, Mt. Malindang Range (8°19'31"N, 123°38'02"E), 991 m asl., Mindanao Island, Philippines , coll. Nonillon Aspe, Nolan Aspe, M. Lluch, and J. Adeva, Feb. 18–25, 2004. Paratypes: two adults (NMA 4537); two adults (ZRC.ANN.0021), Brgy Lake Duminagat, municipality of Don Victoriano, Misamis Occidental Province, Mt. Malindang Range (8°17'55"N, 123°37'01"E), 1500 m asl., coll. Nonillon Aspe and J. Adeva, Oct. 9–15, 2003.

Etymology. The species is named after Misamis Occidental Province, where this species was collected.

**Diagnosis.** Small, brown worm, reaching 55–65 mm in adult length; one pair of spermathecal pores widely spaced at 7/8; intestinal origin in xv; elongate prostate glands extending from xvi to xxii; low, circular copulatory bursae in xvii to xix; short caeca extending from xxvii to xxv.

**Description.** In living animals, dorsum very dark red-brown to black anteriorly, medium red-brown posteriorly; equators non-pigmented; ventral side non-pigmented; clitellum dark. Length 55–65 mm, diameter 3.5 mm at x (n=5 adults), 3–4 mm at xx; 90–103 segments; body cylindrical in cross-section, tail blunt. First dorsal pore 12/13; paired spermathecal pores sublateral on 7/8; 0.3 circumference apart ventrally; female pore single in xiv, openings of copulatory bursae paired in xviii, 0.23 circumference apart ventrally, 6 or 7 setae between openings. Clitellum annular, extending from xiv to xvi. Setae on ventrum more closely spaced compared with that of the dorsum, 42-51 setae on vii, 43-48 setae on xx, dorsal gap present, ventral gap absent.

Septa 5/6/7/8 and 10/11–13/14 slightly muscular, 8/9 very thin, 9/10 partial. Dense tufts of nephridia on anterior faces of 5/6 and 6/7; nephridia of intestinal segments located mainly on body wall at anterior and posterior faces of septa, at septum/body wall junction. Large gizzard in viii to x; esophagus with circumferential lamellae from xi to xii, digitiform internal texture from xiii to xiv; intestinal origin in xv; caeca originating in xxvii, extending forward to xxv; typhlosole rudimentary; intestinal wall with 32 longitudinal blood vessels.

Hearts in x to xiii, esophageal; commissural vessels in vi, vii, and ix lateral; those in viii extend to gizzard; supra-esophageal vessel extends to between x and xiii; extra-esophageal vessels join ventral esophageal wall in x, receive efferent parieto-esophageal vessels in xiv.

Ovaries and funnels free in xiii; paired spermathecae preseptal in vii, with nephridia on ducts. Each spermatheca consists of blunt reniform ampulla; equally long, stout duct; and single stalked diverticulum attached to duct near body wall, terminating in blunt ovate receptacle; stalks longer than spermathecal duct. Male sexual system holandric; testes and funnels enclosed in paired ventral sacs in x and xi, but funnels of x extend into xi; seminal vesicles in xi and xii, each with short, acinous dorsal lobe; vasa deferentia slender, free from body wall, passing over anterior lateral face of copulatory bursae en route to ental end of prostatic ducts; prostates in xvi to xxii, each racemose, 5- or 6-lobed, wrapped around lateral margin of copulatory bursa; muscular duct enters posterior dorsal face of copulatory bursa. Ductlets from anterior prostatic lobes join vas deferens; posterior ductlets join anterior ductlets at junction with muscular prostatic duct. Copulatory bursae low circular domes extending

from xvii to xix. Coelomic surface of copulatory bursa muscular, secretory diverticula lacking; walls consist of outer muscular layer, inner glandular layer; floors of bursae with one large anterior pad, inner posterior dorsal face with very short, conical penis; penial sheaths in copulatory bursae absent.

**Remarks.** *Pheretima misamisensis* **n. sp.** belongs to the *P. sangirensis* group of Sims & Easton (1972). It is similar to *P.s. chica* (Michaelsen, 1896) in size (54–120 mm) but differs in color (purple in *P.s. chica*); the spacing of the spermathecal pores and male pores (0.25 and 0.2 circumference apart, respectively, in *P.s. chica*); and in the number of setae in the post-clitellar region (>60 in *P.s. chica*). *Pheretima misamisensis* is most similar to *P. wati* **n. sp.** in size, the origins of the gizzard and intestine, and the number of hearts (Table 2). However, in *P. misamisensis* the spermathecal and male pores are widely spaced, whereas they are more closely spaced in *P. wati*; in *P. misamisensis*, septa 9/10 is absent, whereas in *P. wati* septa 8/9 is absent. These two species also differ in the number of setae on vii; shape of the spermathecae; size and position of the prostates and copulatory bursae; and length of the caeca. *Pheretima misamisensis* is similar in length to *P. quincunxia*, *P. asurgo*, and *P. rubida* at Mt. Kitanglad (James, 2004), but differs from the latter three in the spacing between spermathecal pores (0.13 circumference apart in *P. quincunxia*, 0.15 circumference apart in *P. asurgo*, and 0.12 circumference apart in *P. rubida*), the origin of the intestine (xvi in *P. quincunxia* and *P. rubida*; xvi in *P. asurgo*), the absence of septa in 9/10, and the length of the prostate (xvii–xix in *P. quincunxia*; xvi–xx in *P. asurgo* and *P. rubida*). *Pheretima misamisensis* also differs from *P. rubida* and *P. surgo* in the location of the first dorsal pore, which is in 11/12, and from *P. quincunxia* in pigmentation (the latter is unpigmented).

**Occurrence.** *Pheretima misamisensis* was not found on any of the sampling plots, but was detected in haphazard samples at four of the five sites listed in Table 1; it occurred at elevations above ~900 m in Brgys Sibucal, Small Potongan, and Lake Duminag, but was not found at 238–271 m in Brgy Toliyok. We found it in soil and rotting logs (Table 1).

#### Pheretima wati n. sp.

(Fig. 5C, Table 2)

**Material examined.** Holotype: adult (NMA 4517) Brgy Sibucal, Oroquieta City, Misamis Oriental Province, Mt. Malindang Range (8°19'31"N, 123°38'02"E), 991 m asl., Mindanao Island, Philippines , coll. Nonillon Aspe, Nolan Aspe, M. Lluch, and J. Adeva, Feb. 18–25, 2004. Paratypes: five adults (NMA 4538), same collection data as for holotype. Other material: three adults (ZRC.ANN.0022), Brgy Lake Duminagat, municipality of Don Victoriano, Misamis Occidental Province, Mt. Malindang Range (8°17'55"N, 123°37'01"E), 1500 m asl., coll. Nonillon Aspe and J. Adeva, Oct. 9–15, 2003.

Etymology. The species name 'wati' is the word for small earthworm in Cebuano dialect.

**Diagnosis.** Small, purplish-brown worm reaching 67–75 mm in adult length; one pair of spermathecal pores at 7/8; male pores very closely spaced; relatively large, elongate spermathecae; intestinal origin in xv; caeca extending from xxvii to xxii; long prostate extending from xv to xxii, copulatory bursae elongate extending from xvii to xxi.

**Description.** Living animals purplish-brown dorsally, fading to yellow brown ventrally; equators pigmented. Length 67–75 mm (n=9 adults); diameter 3.5–4.0 mm at x; 4.0 mm at xx; body cylindrical in cross-section, tail narrowing gradually to sharp point; 90–104 segments. First dorsal pore at 12/13; spermathecal pores paired at 7/8, 0.17 circumference apart ventrally; female pore single in xiv; depressed region where the copulatory bursae open in in xviii; copulatory bursae paired, 0.08 circumference apart ventrally, no setae between openings. Clitellum annular, extending from xiv to xvi. Setae more closely spaced on ventrum than on dorsum, 59–71 setae on vii, 52–60 setae on xx, dorsal gap present, ventral gap absent.

Septa 5/6-7/8 and 9/10-13/14 thin, 8/9 absent. Dense tufts of nephridia on anterior faces of 5/6 and 6/7; nephridia of intestinal segments located mainly on body wall at anterior and posterior faces of septa, at septum/ body wall junction. Gizzard large in viii to x; esophagus with low, vertical lamellae from x to xiii; intestinal origin in xv; caeca originate in xxvii, extend forward to xxii; typhlosole a simple fold about 1/3 lumen diameter, originating at 27/28; intestinal wall with 34-38 longitudinal blood vessels.

Hearts in x to xiii, esophageal; commissural vessels lateral in vi, vii, and ix, lacking in viii; supra-esophageal vessel from x to xiii; extra-esophageal vessels join ventral esophageal wall in x, receive efferent parieto-esophageal vessels in xiii.

Ovaries and funnels free in xiii, spermathecae post-septal in viii, with nephridia on ducts; large glandular mass on interior ventral surface of viii, partially obscuring spermathecal ducts and diverticula; spermatheca with ovate to pyriform ampulla, slender muscular duct, stalked diverticulum attached ectally to duct, terminating in ovate receptacle; stalk shorter than spermathecal duct. One spermatophore present in each ampulla. Male sexual system holandric; testes and funnels enclosed in paired sacs in x and xi; seminal vesicles in xi and xii, each with short, round, knobby dorsal lobe; vasa deferentia slender, free from body wall en route to ental end of prostatic ducts; prostates in xv to xxii, each racemose with 5 or 6 separate lobes, distributed around dorsal-lateral margin of copulatory bursa; muscular duct enters posterior dorsal surface of copulatory bursa. Ductlets from anterior prostatic lobes join vas deferens and posterior ductlets at common junction with muscular prostatic duct. Copulatory bursae elongately bean-shaped extending from xvii to xxi. Coelomic surface of copulatory bursa muscular, secretory diverticula lacking; floors of bursae with medial longitudinal ridge, roofs with posterior glandular pad and penial platform with small, central peak; anterior half of bursa occupied by glandular mass.

**Remarks.** A member of the *P. sangirensis* group of Sims & Easton (1972), *P. wati* **n. sp.** is similar to all subspecies of *P. sangirensis*; to *P. nunezae* **n. sp.**, *P. misamisensis* **n. sp.**, and *P. longiprostata* **n. sp.** From Mt. Malindang; and to *P. baungonensis* from Mt. Kitanglad (James 2004) in having the intestinal origin in xv. However, it has more setae on vii than the other species, and its male pores are much more closely spaced. Moreover, it differs from the others in the shape and length of the spermathecae, the septal arrangement (absent in 9/10 in *P. baungonensis*), and the extent and shape of prostates and copulatory bursae (xvii–xix and xviii, respectively in *P. baungonensis*), and the caeca are much shorter in *P. baungonensis*. The new species is similar to *P. vicinipora* from Mt. Kitanglad (James, 2004) in having very closely spaced male pores, but the new species has its first dorsal pore in 12/13 (13/14 in *P. vicinipora*), its spermathecal pores are more distant than in *P. vicinipora* (0.08), and its caeca and prostates are more extensive (xxvii–xxv and xvi–xix, respectively, in *P. vicinipora*). Among the Malindang species, *P. wati* has the second most extensive prostate glands relative to body length after *P. longiprostata*; the prostates extend across 8 segments from xv to xxii. Like *P. tigris* **n. sp.** and *P. immanis* **n. sp.**, *P. wati* lacks penes, but unlike them, the male pores are very close together, though not joined as one. The glandular mass in viii is also unique.

**Occurrence**. *Pheretima wati* was found at all sites, at 238–2027 m asl, and was most common at 915–1024 m in Brgy Small Potongan. It occurred both in soil and above ground in substrates such as rotting logs. It was one of the more common species, comprising 11.8% of all worms collected (Table 1).

# Pheretima longiprostata n. sp.

(Fig. 6A, Table 2)

**Material examined.** Holotype: adult (NMA 4519) Brgy Small Potongan, municipality of Concepcion, Misamis Occidental Province, Mt. Malindang Range (8°24'04"N, 123°36'47"E), 900 m asl., Mindanao Island, Philippines, coll. Nonillon Aspe, Nolan Aspe, M. Lluch, and J. Adeva, Feb. 18–25, 2004. Paratype: one adult (NMA 4539), same collection data as for holotype.

**Etymology.** The species name derives from the Latin 'longus' (long) and 'prostata' (prostate gland), referring to the long prostate glands.

**Diagnosis.** Very small, yellowish-brown worm reaching 37–41 mm in adult length; first dorsal pore at 11/12; one pair of spermathecal pores at 7/8; spermathecae small with oval ampulla and stout duct; intestinal origin in xv; elongate prostate glands extending from xv to xxiii; short caeca extending from xxvii to xxv; 20 intestinal vessels.

**Description.** In living animals, dorsum light yellowish-brown anteriorly, fading posteriorly; equators nonpigmented; ventral side non-pigmented; clitellum gray. Length 37–41 mm (n=2 individuals); diameter 3.5 mm at x, 3 mm at xx; body cylindrical in cross-section, tail tapering; 82-90 segments. First dorsal pore at 11/12; paired spermathecal pores at 7/8, 0.16 circumference apart ventrally; female pore single on xiv; openings of copulatory bursae paired on xviii, 0.16 circumference apart ventrally, 0–5 setae between openings. Clitellum annular, extending from xiv to xvi. Setae evenly distributed, 35–40 setae on vii, 37–47 setae on xx, dorsal gap present, ventral gap absent.



**FIGURE 6.** Schematic drawings of the internal morphology of Philippine *Pheretima* species, in dorsal view: (A) *P. longiprostata* **n. sp.**; (B) *P. nolani* **n. sp.**; (C) *P. longigula* **n. sp.**; Abbreviations: s, spermatheca; h, heart; p, prostate gland; cb, copulatory bursa; c, caecum. Scale bars: 5 mm.

Septa 5/6/7/8 thin, 8/9/10 absent, 10/11–13/14 thin. Dense tufts of nephridia on anterior faces of 5/6 and 6/7; nephridia of intestinal segments located mainly on body wall at anterior and posterior faces of septa, at septum/ body wall junction. Gizzard large, extending from viii to x; esophagus with lamellae from xi to xiii; intestinal origin in xv; caeca originate in xxvii, extending forward to xxv; typhlosole a simple fold of about 1/4 lumen diameter, originating at 26/27. Intestinal wall with 20 longitudinal blood vessels.

Hearts in x to xiii, esophageal; commissural vessels in vi, vii, and ix, lateral; supra-esophageal vessel extends from x to xiii; extra-esophageal vessels join ventral esophageal wall in x, receive efferent parieto-esophageal vessels in xiv.

Ovaries and funnels free in xiii; paired spermathecae pre-septal in vii, with nephridia on ducts; each spermatheca with transversely placed oval ampulla, short thick muscular duct with slight bulge for diverticulum attachment, single stalked diverticulum attached to posterior face of duct, terminating in ovate receptacle; stalk longer than receptacle. Spermathecal duct walls thick, complexly corrugated. Male sexual system holandric; testes and funnels enclosed in paired sacs in x and xi; seminal vesicles in xi and xii, each with short dorsal lobe; vasa deferentia slender, free from body wall, passing around lateral face of copulatory bursae en route to ental end of prostatic ducts; relatively large and extensive prostates in xv to xxiii, each racemose, bilobed, wrapped around lateral margins of copulatory bursa; muscular duct attached over half of its length to medial face of copulatory bursa, running along surface and entering at apex. Single ductlets from anterior prostatic duct. Copulatory bursae ovate, extending from xvii to xx, attached to body wall; coelomic surface of copulatory bursa muscular, secretory diverticula lacking. Interiors of bursae lacking pads; large penis from dorsal apex fills most of bursal interior; copulatory bursae lack penial sheaths.

**Remarks.** *Pheretima longiprostata* **n. sp.** belongs to the *P. sangirensis* group of Sims & Easton (1972). Individuals of this species were by far the smallest among the *P. sangirensis* group at Malindang, and are among the smallest *Pheretima* reported from the Philippines. In size and color, *P. longiprostata* is most similar among the Malindang species to *P. vergrandis* **n. sp.** (see description below). However, the two species differ in the location of the first dorsal pore, the number and position of spermathecae and male pores, the length of the caeca, and the size

and shape of the prostate glands. *Pheretima longiprostata* has the most elongate prostate glands relative to body size among the known Philippine *Pheretima* species, extending 9 segments from xv to xxiii (see Table 2). *Pheretima wati* **n**. **sp**. has prostate glands similar in size to those of *P. longiprostata*, extending 8 segments from xv to xxii, but the two species differ in size, coloration, location of the first dorsal pore, septal arrangement, length of the caeca, the shape of the spermathecae, and the number of intestinal vessels. Prostate glands function to produce fluids in which sperm cells can be transferred between worms during copulation (Edwards & Bohlen 1996), and these glands may also help to provide the cocoon with nutrients. However, the physiological significance of long or large prostate glands is not clear. Some species in *Pheretima* and in *Amynthas* (Kinberg, 1867) lack prostate glands; in these cases, the clitellum may be larger so as to supply the necessary nutrients to the cocoon. This remains to be investigated.

**Occurrence.** *Pheretima longiprostata* was uncommon, with only a few individuals found in disturbed forest in Brgys Small Potongan and Sibucal. We did not observe it above 1067 m asl. Individuals occurred in the soil and on rotten logs (Table 1).

# Pheretima nolani n. sp.

(Fig. 6B, Table 2)

**Material examined.** Holotype: adult (NMA 4520) Brgy Sibucal, Oroquieta City, Misamis Occidental Province, Mt. Malindang Range (8°19'31"N, 123°38'02"E), 900 m asl., Mindanao Island, Philippines , coll. Nonillon Aspe, M. Lluch, and J. Adeva, Feb. 18–25, 2004. Paratypes: two adults (ZRC.ANN.0028), Brgy Lake Duminagat, municipality of Don Victoriano, Misamis Occidental Province, Mt. Malindang Range (8°17'55"N, 123°37'01"E), 1500 m asl., coll. Nonillon Aspe, Nolan Aspe and J. Adeva, Oct. 9–15, 2003.

**Etymology.** The species is named after Nolan Aspe, who assisted in the fieldwork.

**Diagnosis.** Worm reaching 89–97 mm in adult length; body purplish brown; one pair of spermathecal pores at 7/8; spermathecae small, irregular, knobby, with short, thick duct; single-stalked diverticula terminating in sausage-shaped receptacle; intestinal origin in xv; prostate glands from xv to xx; caeca extending from xxvii to xxii; 42–44 intestinal vessels.

**Description.** In living animals, dorsum purplish black anteriorly, fading to medium brown posteriorly; narrow equators non-pigmented; ventral side non-pigmented. Length 89–97 mm (n=2 adults); diameter 5 mm at x; 4.5 mm at xx; body cylindrical in cross-section, tail narrowing gradually to sharp point; 111 segments. First dorsal pore at 12/13; paired spermathecal pores at 7/8, 0.14 circumference apart ventrally; female pore single on xiv; openings of copulatory bursae paired on xviii, 0.12 circumference apart ventrally, 2 setae between openings. Clitellum annular, extending from xiv to xvi. Setae on ventrum more closely spaced compared with that of the dorsum, 33–48 setae on vii, 42 setae on xx, dorsal gap present, ventral gap absent.

Septa 5/6/7/8 thinly muscled, 8/9 membranous, 9/10 absent, 10/11-13/14 slightly muscular. Dense tufts of nephridia on anterior faces of 5/6 and 6/7; nephridia of intestinal segments located mainly on body wall at anterior and posterior faces of septa, at septum/body wall junction. Large gizzard extending from viii to x; esophagus with lamellae extending from xi to xiii; intestine originates in xv; caeca originates in xxvii, extends forward to xxii, with serrate ventral margins; typhlosole a simple fold of about 1/6 lumen diameter, originating at 26/27; intestinal wall with 42-44 longitudinal blood vessels.

Hearts in x to xiii, esophageal; commissural vessels in vi, vii, and ix, lateral; supra-esophageal vessel extends from x to xiii; extra-esophageal vessels join ventral esophageal wall in x, receive efferent parieto-esophageal vessels in xiv.

Ovaries and funnels free in xiii; paired spermathecae pre-septal in vii, with nephridia on ducts. Spermatophores spherical, with small appendage. Male sexual system holandric; testes and funnels enclosed in paired sacs in x and xi; seminal vesicles in xi and xii, each with short dorsal lobe; vasa deferentia slender, free from body wall, passing around anterior face of copulatory bursae en route to ental end of prostatic ducts; prostates in xv to xx, each racemose, 4 lobes, wrapped around lateral margin of copulatory bursa, muscular duct attached over most of its length to lateral face of copulatory bursa, running along surface and entering dorsal face. Two or 3 ductlets from anterior prostatic lobe join vas deferens; 2 or 3 posterior ductlets join at common junction with muscular prostatic duct. Copulatory bursae hemispherical extending from xvii to xix; coelomic surface of each

bursa muscular, secretory diverticula lacking. Floors of bursae with some folds adjacent to opening but lacking pads; roofs with small posterior pad, large penis attached to anterior internal wall of bursa, only the tip free; copulatory bursae lack penial sheaths.

**Remarks.** This species belongs to the *P. sangirensis* group of Sims & Easton (1972). It differs from all subspecies of *P. sangirensis* in having the spermathecal pores and male pores more closely spaced, in having fewer setae in the post-clitellar region, in having a septum in 8/9, and in having more extensive prostate glands. Among the Malindang *sangirensis* species, *Pheretima nolani* **n. sp.** is similar to *P. wati* **n. sp.** in having setal gaps and in the relative spacing between the spermathecal pores and between the male pores, in the origins of the gizzard and intestine, and in the number of hearts. However, *P. wati* is smaller, has more setae around the equatorial segments, has fewer intestinal vessels, lacks penes, and lacks a septum at 8/9, whereas *P. nolani* lacks a septum at 9/10. The prostate of *P. nolani* extends for 6 segments from xv to xx, whereas that in *P. wati* extends 8 segments from xv to xxii. The shape of the spermathecae also differs, and the copulatory bursae in *P. nolani* is most similar to *P. baungonensis* James, 2004 in terms of the size, number, and location of spermathecae, but the latter is dark brown in color; lacks dorsal setal gaps; has the spermathecal pores and male pores spacings 0.32 circumference apart and 0.19 circumference apart, respectively; has the first dorsal pore is in 13/14; has smaller prostate glands and copulatory bursae; has fewer longitudinal intestinal vessels; and has penes.

**Occurrence.** *Pheretima nolani* was common than other species, especially in primary forest in Brgy Lake Duminagat; it was most abundant in the highest elevation range (1845–2027 m), but was not observed in Brgys Small Potongan and Toliyok, at lower elevations (Table 1).

# Pheretima longigula n. sp.

(Figs 2D, 6C, Table 2)

**Material examined.** Holotype: adult (NMA 4511) Brgy Lake Duminagat, municipality of Don Victoriano, Misamis Occidental Province, Mt. Malindang Range (8°17'55"N, 123°37'01"E), 1500 m asl., Mindanao Island, Philippines, coll. Nonillon Aspe, Nolan Aspe and J. Adeva, Oct. 9–15, 2003. Paratypes: three adults (NMA 4535); two adults (ZRC.ANN.0019), same collection data as for holotype.

**Etymology.** The species name is derived from the Latin 'longus' (long) and 'gula' (throat), referring to the long esophagus.

**Diagnosis.** Slender worm reaching 139–186 mm in adult length; red-brown dorsally; one pair of spermathecal pores at 7/8; two pairs of seminal vesicles extending from xi to xiv; slender esophagus; intestine begins in xxi; penes with sheath; bilobed copulatory bursae in xvii to xviii; prostates posterior to copulatory bursae in xix, xx.

**Description.** Animals in life with red-brown dorsum; equators pigmented. Length 139–186 mm (n=6 adults); diameter 3.5–4.0 mm at x, 3.8–4.5 mm at xx; body cylindrical in cross-section; 99–110 segments. First dorsal pore at 12/13; pair of crescent shaped spermathecal pores, concave edge of pores anterior to 7/8, 0.24–0.27 circumference apart ventrally; female pore single in xiv; openings of copulatory bursae paired in xviii, 0.17–0.21 circumference apart ventrally, 0–4 setae between openings. Clitellum annular, extending from xiv to xvi. Setae unevenly distributed, 28–47 setae on vii, 27–51 setae on xx, no dorsal or ventral gaps.

Septa 5/6–7/8 and 10/11–13/14 muscular, 8/9/10 absent. Dense tufts of nephridia on anterior faces of 5/6 and 6/ 7; nephridia of intestinal segments located mainly on septa, rather few and very small. Anterior internal organs all elongate; large gizzard extending from viii to x, esophagus has chevron-patterned lamellae from x to xi, low vertical lamellae from xii to xiii; esophagus long, slender, extending from 15/16 to xix; intestine originates in xxi; caeca originate in xxvii, extend forward to xxii, simple with smooth ventral margin; typhlosole originates gradually from xxxiii, simple fold, 1/3 lumen diameter; intestinal wall with 32–36 longitudinal blood vessels.

Hearts in x to xiii, esophageal; commissural vessels vi, vii, and ix lateral; those in viii extend to gizzard; supraesophageal vessel from x to xv; extra-esophageal vessels join ventral esophageal wall in x, receive efferent parietoesophageal vessels in xiii and xiv.

Ovaries and funnels free in xiii; spermathecae paired, preseptal in vii, with nephridia on ducts; ampulla ovate, spermathecal ducts bulbous, muscular, expanding ectally, with three large ridges on internal posterior side, parallel to one another and duct axis; stalked diverticulum attached to duct near ampulla, terminating in short ovate to

lanceolate receptacle; stalk short, curved. Spermatophores lenticular to spherical, with short, thin tail curved back onto body of spermatophore. One individual has a misplaced small spermatheca at intersegment 8/9 on the right side of the body wall. Male sexual system holandric; testes and funnels enclosed in paired ventral sacs in x and xi; seminal vesicles in xi–xii and xii –xiv; vasa deferentia slender, free from body wall en route to ental end of prostatic ducts, traveling along medial surface of copulatory bursae; each prostate racemose in xix to xx, muscular duct entering medial posterior face of copulatory bursa; copulatory bursae bilobed, elongate in xvii and xviii, anterior to the prostates. Coelomic surface of copulatory bursa muscular, secretory diverticula lacking; bursae have glandular mass with long, arched pad directed towards opening; posterior portion containing long, nearly cylindrical penis with circular sheath entirely within both lobes of the bursa.

**Remarks.** *Pheretima longigula* **n. sp.** belongs to the *P. montana* group of Sims & Easton (1972), characterized by having penis sheaths, which the *P. sangirensis* group lacks. The *Pheretima montana* group once comprised seven species, but Blakemore's (2007) review of the group concluded that all but two of these species, *P. hahli* Ude, 1905 and *P. vitiensis* Beddard, 1892, are synonymous to *P. montana*. The only Philippine species detected so far in the *montana* group, *P. longigula* is longer than *P. montana* (length= 70–135 mm) although *P. montana* is thicker (5 mm diameter). The spermathecal pores are more widely spaced in *P. montana* (0.5 circumference apart) and the spermathecal duct is longer and more slender compared to that of *P. longigula*. *Pheretima longigula* differs from *P. hahli* and *P. vitiensis* in the origin of the intestine (xv in *P. hahli* and *P. vitiensis*), the size of the gizzard (viii–ix in *P. hahli*), the length of the prostate (xvii–xix in *P. hahli* and *P. vitiensis*), the origin of the caeca (xxvi in *P. hahli* and *P. vitiensis*), and color (yellow brown in *P. hahli* and *P. vitiensis*). *Pheretima vitiensis* is metandric according to Beddard (1892), but Michaelsen (1900) apparently found differently in placing this species in synonymy with *P. montana*. Most *Pheretima* species in the Philippines have the intestine originating in xv or xvi, and *P. longigula* is unique in having the intestinal origin in xxi, with a correspondingly long esophagus. This species is also unique in the shape of the copulatory bursae and their position relative to the prostate glands, and in having the typhlosole originating in xxxiii, whereas in most other species, it originates in xxvii.

**Occurrence.** *Pheretima longigula* was uncommon (2.1% of total specimens), occurring at high elevations (1479–2027 m) in primary and disturbed forest in Brgy Lake Duminagat (Table 1).

Pheretima adevai n. sp.

(Fig. 7A,B, Table 3)

**Material examined.** Holotype: (NMA 4524) Brgy Small Potongan, municipality of Concepcion, Misamis Occidental Province, Mt. Malindang Range, 8°24'04" N, 123°36'47" E, 900 m asl, Mindanao Island, Philippines , coll. Nonillon Aspe, Nolan Aspe, M. Lluch and J. Adeva, Feb. 18–25, 2004. Paratypes: three adults (NMA 4543), same collection data as for holotype. Other material: two adults (ZRC.ANN.0025), Brgy Lake Duminagat, municipality of Don Victoriano, Misamis Occidental Province, Mt. Malindang Range (8°17'55"N, 123°37'01"E), 1500 m asl., coll. Nonillon Aspe and J. Adeva, Oct. 9–15, 2003.

Etymology. The species is named after Julius Adeva, who assisted in the fieldwork.

**Diagnosis.** Slender brown worm reaching 110–131 mm in adult length; four pairs of spermathecal pores in 5/ 6–8/9; space between spermathecal pores wider than space between male pores; first dorsal pore at 12/13; intestinal origin in mid-xv; prostates in xviii to xix; caeca extending from xxvii to xxiii.

**Description.** In living animals, dorsum brown, darker anteriorly; equators pigmented. Length 110–131 mm (n=6 adults); diameter 5 mm at x, 4 mm at xx; body cylindrical in cross-section; 83–99 segments. First dorsal pore at 12/13; spermathecal pores at 5/6/7/8/9, 0.25 circumference apart ventrally; female pore single in xiv; openings of copulatory bursae paired in xviii, 0.16 circumference apart ventrally, 3–7 setae between openings. Clitellum annular, extending from xiv to xvi. Setae unevenly distributed, 32–37 setae on vii, 36–39 setae on xx, no dorsal or ventral gaps.

Septa 5/6/7/8 and 10/11-13/14 muscular, 8/9 present ventrally, 9/10 absent. Dense tufts of nephridia on anterior faces of 5/6 and 6/7; nephridia of intestinal segments located mainly on body wall at anterior and posterior faces of septa, at septum/body wall junction. Large gizzard in ix to x; esophagus with low vertical lamellae extending from x to xiii; intestine originates in mid-xv; caeca originate in xxvii, extend forward to xxiii, with smooth, simple ventral margin; typhlosole rudimentary; intestinal wall with 34-38 longitudinal blood vessels.

Hearts in x to xiii, esophageal; commissural vessels in vi, vii, and ix lateral; those in viii extend to gizzard; supra-esophageal vessel extends from x to xv; extra-esophageal vessels join ventral esophageal wall in x, receive efferent parieto-esophageal vessels in xiii.

Ovaries and funnels free in xiii; spermathecae paired in vi to ix, with many nephridia on ducts; each spermatheca with ovate, spherical, or pyriform ampulla, short thick non-muscular duct, stalked diverticulum attached to anterior face of duct near ampulla, terminating in short, oblong receptacle containing 2 or 3 rounded masses of sperm; stalk short. No spermatophores were observed in spermathecal ampullae. Male sexual system holandric; testes and funnels enclosed in paired sacs in x and xi; seminal vesicles in xi and xii, each with long, narrow dorsal lobe; vasa deferentia slender, free from body wall en route to ental end of prostatic ducts; prostates in xviii to xix, each racemose and bilobed in shape of butterfly wings; short muscular duct enters apex of copulatory bursa in xviii. Coelomic surface of copulatory bursa muscular, secretory diverticula lacking, walls thin; each bursa ovate-hemispheric, with elongate, conical penis on bursa roof; one spherical pad anterior and one posterior to opening.

**Remarks.** *Pheretima adevai* **n. sp.** belongs to the *P. darnleiensis* species group of Sims & Easton (1972). Sims & Easton (1972) synonymized 15 species under the name *P. darnleiensis* Fletcher, 1887, all characterized by having either 4 or 5 pairs of spermathecal pores, located in 5/6–8/9, with an optional fifth pair in 4/5. Incongruently, Darmawan *et al.* (2012), described nominal *P. darnleiensis* from Darmaga, Indonesia, to have 4 pairs of spermathecal pores, from 4/5–7/8. Blakemore *et al.* (2007) further expanded the synonymy to include very large worms (about 700 mm long) from Mt. Kinabalu and Borneo, and possibly some of the *Pheretima dubia* group (three pairs of spermathecae vii–ix). After examining several of the species included in the synonymy of *P. darnleiensis*, Hong & James (2011a) suggested that species-level differences had been ignored, or had been discounted against the large number of spermathecae. They argued that the synonymy was excessive and buried significant morphological and geographical diversity in an increasingly meaningless concept of *P. darnleiensis*, and concluded that it is not probably useful to place into synonymy morphologically distinguishable taxa of greatly differing sizes. In any case, synonymy decisions in the *P. darnleiensis* group need to be reviewed, and the issue needs to be addressed with both morphological and molecular data.

*Pheretima adevai* **n. sp.**, *P. lluchi* **n. sp.**, and *P. potonganensis* **n. sp.** (see below) at Mt. Malindang are the only species in the *P. darnleiensis* group presently known from Mindanao Island. *Pheretima adevai* differs from *P. darnleiensis* in the location of the first dorsal pore, the spacing between the spermathecal pores and between the male pores, and the number of setae between the male pores (Table 3). *Pheretima adevai* is similar to *P. lluchi* **n. sp.** in size and in the origin of the gizzard, but the two differ in the location of the first dorsal pore, the spermathecal and male pore spacings, the origin of the intestine, the number of intestinal vessels, and the extent of the prostates and copulatory bursae (Table 3).

Seven species in the *darnleiensis* group were recently described from Luzon (*P. cabigati* Hong & James, 2008a from Banaue; *P. pugnatoris* and *P. tabukensis* Hong & James, 2010 from Kalinga; *P. margaritata, P. kalbaryonensis*, and *P. thaii* Hong & James, 2011a from Kalbaryo; and *P. barligensis* Hong & James, 2011b from Mountain. Province), aside from three other species placed synonymy (Sims & Easton 1972) with *P. darnleiensis*: *Perichaeta belli* Rosa, 1898 from Mindoro Island; *Perichaeta vaillanti* Beddard, 1912; and *Pheretima benguetensis* Beddard, 1912. *Perichaeta belli* is 75 mm long, has zebra-like brown bands dorsally, has 48 setae in vii, has 8 setae between the male pores, and has very short caeca in xxvi–xxv. *Perichaeta benguetensis* is 190 mm in length, has purplish blue pigmentation, has the first dorsal pore in 7/8, and lacks seta in 8/9/10. These features differ markedly from those in *P. adevai*. Length and other pertinent characters in *Pe. vaillanti* are unavailable for comparison with the other species. Among recently described species, *P. margaritata* and *P. pugnatoris* are most similar to *P. adevai* in size and in the origin of the intestine (xv), but differ from *P. adevai* in the location of the first dorsal pore (9/10 in *P. margaritata*; 11/12 in *P. pugnatoris*), in the number of setae on vii (24 in *P. margaritata*; 16–19 in *P. pugnatoris*), in lacking a septum in 8/9, in the origin of the gizzard in viii, and in the length of the caeca (xvii–xxv and xxvii–xxiv in *P. margaritata* and *P. pugnatoris*, respectively). In addition, *P. adevai* has the male pores closer together than in *P. margaritata*, and a shorter prostate than in *P. pugnatoris*.

**Occurrence.** *Pheretima adevai* was the most abundant species at Malindang, comprising 19.4% of all individuals collected (Table 1). Although we detected it in disturbed habitat in Brgy Small Potongan at 915–1024 m elevation, it was most common in Brgy Lake Duminagat at elevations of 1479–2027 m. It mostly inhabited soil, but some individuals were collected on rotten logs and other substrates above ground (Table 1).



**FIGURE 7.** (A) Diagrammatic ventral view of polythecal *Pheretima adevai*, showing the spermathecal pores (sp), clitellum (cl), and male pores (m). (B–D) Schematic drawings of the internal morphology of Philippine *Pheretima* species, in dorsal view: (B) *P. adevai* **n. sp.**; (C) *P. lluchi* **n. sp.**; (D) *P. potonganensis* **n. sp.** Abbreviations: s, spermatheca; h, heart; p, prostate gland; cb, copulatory bursa; c, caecum. Scale bars: B–D: 5 mm.

# Pheretima lluchi n. sp.

(Fig. 7C, Table 3)

**Material examined.** Holotype: (NMA 4525) Brgy Sibucal, Oroquieta City, Misamis Occidental Province, Mt. Malindang Range (8°19'31"N, 123°38'02"E), 991 m asl., Mindanao Island, Philippines , coll. Nonillon Aspe, Nolan Aspe, M. Lluch, and J. Adeva, Feb. 18–25, 2004. Paratypes: three adults (NMA 4544), same collection data as for holotype. Other paratypes: two adults (ZRC.ANN.0026), Brgy Lake Duminagat, municipality of Don Victoriano, Misamis Occidental Province, Mt. Malindang Range (8°17'55"N, 123°37'01"E), 1357 m asl., coll. Nonillon Aspe and J. Adeva, Oct. 9–15, 2003.

Etymology. The species is named after Myko Lluch, who assisted in the fieldwork.

**Diagnosis.** Brown, slender worm reaching 104–135 mm in adult length; four pairs of spermathecal pores in 5/ 6 to 8/9; distance between spermathecal pores same as that between male pores; first dorsal pore in 13/14; intestinal origin in xvi; prostates in xviii to xx; caeca from xxvii to xxiv.

**Description.** In living animals, dorsum brown, darker anteriorly; equators pigmented. Length 104–135 mm (n=6 adults); diameter 4 mm at x, 4.5 mm at xx; body cylindrical in cross-section, tail blunt; 71–104 segments. First dorsal pore at 13/14; spermathecal pores at 5/6/7/8/9, 0.2 circumference apart ventrally; female pore single in xiv; openings of copulatory bursae paired in xviii, 0.2 circumference apart ventrally, 5–6 setae between openings. Clitellum annular, extending from xiv to xvi. Setae evenly distributed, 29–30 setae on vii, 39–45 setae on xx, no dorsal or ventral gaps.

Septa 5/6/7/8 and 10/11–13/14 muscular, 8/9/10 absent. Dense tufts of nephridia on anterior faces of 5/6 and 6/ 7; nephridia of intestinal segments located mainly on body wall at anterior and posterior faces of septa, at septum/ body wall junction. Large gizzard in ix to x; esophagus with circumferential lamellae from xi to xiii, pebbly texture in xiv; intestine originates in xvi; caeca originate in xxvii, extend forward to xxiv, simple, with smooth ventral margin; typhlosole rudimentary; intestinal wall with 28–30 longitudinal blood vessels.

Hearts in x to xiii, esophageal; commissural vessels in vi, vii, and ix, lateral, viii extending to gizzard; supraesophageal vessel extends from x to xv; extra-esophageal vessels join ventral esophageal wall in x, receive efferent parieto-esophageal vessels in xiii.

Ovaries and funnels free in xiii; ovisacs lacking; spermathecae 4 pairs in vi to ix, with many nephridia on

ducts; each spermatheca with ovate to spherical ampulla and short, thick, non-muscular duct; stalked diverticulum attached to lateral face of duct at middle, terminating in short, banana-shaped receptacle; stalk about as long as receptacle. Spermatophores lacking. Male sexual system holandric; testes and funnels enclosed in paired sacs in x and xi; seminal vesicles in xi and xii, lacking dorsal lobes; vasa deferentia slender, free from body wall en route to ental end of prostatic ducts; each bilobed prostate racemose in xviii to xix; short, muscular duct enters apex of copulatory bursa in xviii, ectal half of duct attached to copulatory bursa surface. Coelomic surface of copulatory bursa muscular, secretory diverticula lacking; bursa a low, ovate dome; conical penis with thick base projects from bursa roof.

Character	Pheretima darnleiensis*	Pheretima adevai	Pheretima lluchi	Pheretima
	Fletcher, 1887	n. sp.	n. sp.	potonganensis n. sp.
Body pigmentation	?	Dorsally pigmented all over	Dorsally pigmented all over	Dorsally pigmented all over
Length	75–170	110–131	104–135	63–89
Location of spermathecal pores	5/6/7/8/9	5/6/7/8/9	5/6/7/8/9	5/6/7/8/9
First dorsal pore	11/12	12/13	13/14	12/13
Setae vii; xx	12–35; 38–45	32–37; 36–39	29–30; 39–45	32–34; 28–44
Setae bet. male pores	12	3–7	5–6	4
Sper. pores spacing	0.2	0.25	0.2	?
Male pores spacing	0.2	0.16	0.2	0.17
Setal gaps D; V	?; -	-; -	-; -	-; +
Septa in 5/6-13/14	+ or - in 8/9; - in 9/10	- in 9/10	- in 8/9/10	+
Origin of gizzard	ix/viii	ix	ix	ix
Origin of intestine	XV	XV	xvi	xiv
Caeca	xxvii–xxiv	xxvii–xxiii	xxvii–xxiv	xxvii–xx
Origin of typhlosole	?	xxvii	xxvii/xviii	xxvii
Intestinal vessels	?	34–38	28–30	26
Location of hearts	x–xiii	x–xiii	x–xiii	x–xiii
Prostate glands	xviii–xix	xviii–xix	xviii–xx	xvii–xix
Copulatory bursae	?	xviii	xviii–xix	xviii–xix
Penes	+	+	+	+

TABLE 3. Comparison of species in the Pheretima darnleiensis group at Mt. Malindang.

\*Description from Fletcher (1887) and Hong & James (2011b); excluding the description by Blakemore *et al.* (2007).

**Remarks.** *Pheretima lluchi* **n. sp.** belongs to the *P. darnleiensis* group of Sims & Easton (1972). It differs from *P. darnleiensis* in the location of the first dorsal pore, in the number of setae between male pores, in the origin of intestine, and in the length of the prostates (Table 3). *Pheretima lluchi* furthermore differs from *Perichaeta belli* (Rosa, 1898) and *P. benguetensis* (Beddard, 1912), which Sims & Easton (1972) synonymized with *P. darnleiensis*, in color and pigmentation pattern (brown bands in *Pe. belli*; purplish blue pigmentation in *P. benguetensis*), in the number of setae (more in *Pe. belli*; 40), in the location of the first dorsal pore (7/8 in *P. benguetensis*), and in the extent of the caeca (xxvi–xxv in *Pe. belli*; xxv–xx in *P. benguetensis*), among other characters. *Pheretima lluchi* is similar to *P. adevai* **n. sp.** in the size and origin of the gizzard, but the two species differ in the location of the first dorsal pore, the origin of the intestine, the lengths of the caeca and prostates, and markedly in the spacings of the spermathecal and male pores (Table 3). *Pheretima lluchi* is similar to *P. margaritata* and *P. pugnatoris* in size, septal arrangement, and the origin of the gizzard, but differs from them in the number of setae on vii (24 in *P. margaritata*; 16–19 in *P. pugnatoris*), the location of the first dorsal pore (9/10 in *P. margaritata*; 11/12 in *P. pugnatoris*), the origin of the intestine (xv in the two latter species), the length of the caeca and prostates (xxvii–xxv and xvii–xviii, respectively in *P. margaritata*, and xxvii–xxiv and xvii–xix, respectively in *P. margaritata*, and pores (0.25–0.28 and 0.26 circumference

apart, respectively, in *P. margaritata*; 0.26–0.29 and 0.17–0.18 in *P. pugnatoris*). Other Philippine *Pheretima* species with more than one pair of spermathecae are *P. castilloi* James *et al.*, 2004; *P. callosa* James, 2004; and *P. philippina* Rosa, 1891. These species differ from *P. lluchi* in size and in having 3 pairs of spermathecae (5/6–7/8 in *P. castilloi*; 6/7–8/9 in *P. callosa* and *P. philippina*).

**Occurrence.** *Pheretima lluchi* was uncommon, comprising 1.3% of the total individuals found on plots; we detected it in Brgys Sibucal and Lake Duminagat, at elevations of 902–2027 m. It inhabited both the soil and substrates above ground, such as rotten logs. The species was not observed at lower elevations (Table 1).

# Pheretima potonganensis n. sp.

(Fig. 7D, Table 3)

**Material examined.** Holotype: (NMA 4526) Brgy Small Potongan, municipality of Concepcion, Misamis Occidental Province, Mt. Malindang Range (8°24'04"N, 123°36'47"E), 900 m asl., Mindanao Island, Philippines, coll. Nonillon Aspe, Nolan Aspe, M. Lluch, and J. Adeva, Feb. 18–25, 2004. Paratypes: three adults (NMA 4545), same collection data as for holotype. Other material: 12 adults (ZRC.ANN.0027), Brgy Sibucal, Oroquieta City, Misamis Occidental Province, Mt. Malindang Range (8°19'31"N, 123°38'02"E), 991 m asl., Mindanao Island, Philippines, coll. Nonillon Aspe, Nolan Aspe, M. Lluch, and J. Adeva, Feb. 18–25, 2004.

Etymology. The species is named after Brgy Small Potongan, the type locality.

**Diagnosis.** Brown worms reaching 63–89 mm in adult length; 4 pairs of spermathecal pores from 5/6 to 8/9; first dorsal pore at 12/13; no dorsal setal gap, ventral setal gap present; septa all present from 5/6 to 13/14; intestinal origin in xiv; prostates from xvii to xix; caeca from xxvii to xx.

**Description.** In living animals, dorsum purple-brown, darker anteriorly; ventral side slightly pigmented anteriorly; equators pigmented; clitellum gray. Length 63–89 mm (n= 16 adults); diameter 4 mm at x, 4 mm at xx; body cylindrical in cross-section; 69–96 segments. First dorsal pore at 12/13; inconspicuous spermathecal pores paired at 5/6/7/8/9; female pore single in xiv; openings of copulatory bursae paired in xviii, white transverse slits, 0.17 circumference apart ventrally, 4 setae between openings. Five annuli per segment in ix–xiii. Clitellum brown, annular, extending from xiv to xvi. Setae on ventrum more closely spaced than those on dorsum, 32-34 setae on vii, 28-44 setae on xx, dorsal gap absent, ventral gap present.

Septa 5/6–13/14 thin, but 13/14 slightly muscular. Dense tufts of nephridia on anterior faces of 5/6 and 6/7; nephridia of intestinal segments located mainly on body wall at anterior and posterior faces of septa, at septum/ body wall junction. Large gizzard in ix to x; esophagus with chevron-patterned lamellae extends from xi to xiii; intestine originates in xiv; caeca originate in xxvii, extend forward to xx, simple, with smooth ventral margin; typhlosole rudimentary; intestinal wall with 26 longitudinal blood vessels.

Hearts in x to xiii, esophageal; commissural vessels in vi, vii, and ix lateral, those in viii extend to gizzard; supra-esophageal vessels in x to xiii; extra-esophageal vessels join ventral esophageal wall in x, receive efferent parieto-esophageal vessels in xiii.

Ovaries and funnels free in xiii, ovisacs lacking; spermathecae paired from vi to ix, with many nephridia on ducts; each spermatheca with ovate to quadrangular ampulla, short non-muscular duct, stalked diverticulum attached to duct near body wall, terminating in short ovate receptacle; stalk almost as long as ampulla. Male sexual system holandric; testes and funnels enclosed in midventral sac in x, paired sacs in xi; seminal vesicles in xi and xii, each with short dorsal lobe; vasa deferentia slender, free from body wall en route to ental end of prostatic ducts; prostates from xvii to xix; each racemose, bilobed, wrapped around copulatory bursa in xviii–xix; short, muscular duct enters apex of copulatory bursa in xviii. Copulatory bursae in xviii to xix. Coelomic surface of copulatory bursae muscular, secretory diverticula lacking; bursae low, circular domes; penis an irregular lump with terminal crease, extending from bursa roof; one horizontally directed pad anterior and the other posterior to opening in each bursa; an angular lateral projection between them may be a third pad.

**Remarks.** *Pheretima potonganensis* **n. sp.** belongs to the *P. darnleiensis* group of Sims & Easton (1972). It differs from *P. darnleiensis* in the location of the first dorsal pore, male pore spacing, the number of setae between the male pores, the presence of ventral gaps, the presence of a septum in 8/9, and the origin of the intestine (Table 3). It also differs markedly from *Perichaeta belli* and *P. benguetensis*, which Sims & Eastion (1972) synonymized with *P. darnleiensis*, in coloration and pigmentation pattern and in the extent of caeca, among other characters.

Individuals of *P. potonganensis* are smaller than those of *P. adevai* **n. sp.** and *P. lluchi* **n. sp.**, and unlike the latter two species, septa are present from 5/6 to 13/14 (Table 3). *Pheretima potonganensis* also differs in having ventral setal gaps and in the size of the prostate glands, and the caeca are markedly longer than in *P. adevai* **n. sp.** and *P. lluchi*, extending 8 segment lengths from xxvii to xx. *Pheretima potonganensis* differs from *P. lluchi* also in the location of the first dorsal pore. *Pheretima potonganensis* is similar to *P. tabukensis* from Kalinga, Luzon in the distance between male pores relative to body size, and both have septa from 5/6 to 13/14, but these species differ in the number of setae in vii (19–20 in *P. tabukensis*), the location of the first dorsal pore (11/12 in *P. tabukensis*), the origin of the intestine (xv in *P. tabukensis*), and the lengths of the prostates and caeca (xvii–xviii and xxvii–xxv, respectively, in *P. tabukensis*) (Hong & James 2010).

We observed numerous small, round outgrowths attached on the body wall inside some specimens of *P. potonganensis*. These occurred in different body regions, but were concentrated mostly in the spermathecal region. We speculate that these are some type of parasitic cysts inside the earthworms, but this remains to be investigated.

**Occurrence.** *Pheretima potonganensis* was the second-most abundant species after *P. adevai*, comprising 11.2% of all individuals found on plots. It was also relatively widespread across Mt. Malindang, occurring in disturbed forest at elevations of 238–1662 m, though we did not find it in primary forest at higher elevations. It occurred both in the soil and above ground on substrates such as rotten logs (Table 1).

#### Pheretima vergrandis n. sp.

(Fig. 8A,B, Table 4)

**Material examined.** Holotype: adult (NMA 4521) Brgy Sibucal, Oroquieta City, Misamis Occidental Province, Mt. Malindang Range (8°19'31"N, 123°38'02"E), 900 m asl., Mindanao Island, Philippines, coll. Nonillon Aspe, Nolan Aspe, M. Lluch, and J. Adeva, Feb. 18–25, 2004. Paratypes: four adults (NMA 4541), same collection data as for holotype. Other material: four adults (ZRC.ANN.0023), Brgy Lake Duminagat, municipality of Don Victoriano, Misamis Occidental Province, Mt. Malindang Range (8°17'55"N, 123°37'01"E), 1500 m asl., coll. Nonillon Aspe and J. Adeva, Oct. 9–15, 2003.

**Etymology.** The species name is from the Latin 'vergrandis' (small, tiny), referring to the small size of individuals of this species.

**Diagnosis.** Very small, light-brown worm reaching 35–75 mm in adult length; single mid-ventral spermathecal pore on 7/8; single male pore mid-ventral on xviii; first dorsal pore at 13/14; spermatheca with irregularly rounded ampulla, bulbous muscular duct expanding ectally with single stalked diverticulum attached to middle of duct; hearts from x to xiii; elongate racemose prostates in xvi to xxi; columnar copulatory bursae in xviii to xx; caeca extending from xxvii to xxiv.

**Description.** Living animals with very light-brown dorsum; no stripes; clitellum pale; body cylindrical in cross-section, tail narrowing gradually to sharp point. Length 35-75 mm (n=10 adults); diameter 2.3–3.0 mm at x; 2.3–2.7 mm. at xx; 85–99 segments. First dorsal pore 13/14; single mid-ventral spermathecal pore with wide white lips at 7/8; female pore single in xiv; openings of copulatory bursae united mid-ventrally in xviii. Clitellum annular, extending from xiv to xvi. Setae unevenly distributed, 37–42 setae on vii, 50–54 setae on xx, dorsal and ventral gaps present.

Anterior septa all delicate, 8/9/10 absent. Dense tufts of nephridia on anterior faces of 5/6 and 6/7; nephridia of intestinal segments located on body wall at septum/body wall junction and on anterior and posterior faces of septa. Large gizzard extends from viii to x; esophagus with villous-pebbly lining extends from x to xiii; intestinal origin in xv; caeca originate in xxvii, extend forward to xxiv; typhlosole a simple fold of about 1/5 lumen diameter, originating at 27/28; intestinal wall with 24–28 longitudinal blood vessels.

Hearts in x to xiii, esophageal, absent in x; commissural vessels in vi, vii, and ix lateral; those in viii extend to gizzard; supra-esophageal vessel extends from x to xv; extra-esophageal vessels join ventral esophageal wall in x, receive efferent parieto-esophageal vessels in xiii.

Ovaries and funnels free in xiii; single spermatheca preseptal in vii, with nephridia on ducts; spermatheca with irregularly rounded ampulla, bulbous muscular duct expanding ectally; duct internally corrugated, with two large internal ridges on anterior side; single stalked diverticulum attached to middle of duct, terminating in spherical receptacle; stalk short. Spermatophores spherical, with short, narrow tail. Male sexual system holandric; testes and

funnels enclosed in paired sacs in x and xi; seminal vesicles in xi and xii, each with long dorsal lobe; vasa deferentia slender, free from body wall en route to ental end of prostatic ducts; prostates in xvi to xxi; each racemose, wrapped around dorsolateral margin of copulatory bursa; muscular duct partially attached to and entering posterior face of copulatory bursa. Copulatory bursae in xviii to xx; columnar with rounded apex, attached to body wall at end; oriented towards common opening through body wall. Coelomic surface of copulatory bursae muscular; secretory diverticula lacking; roof with slender, tapering penis.

**Remarks.** Among the few monothecal species placed in *Pheretima* is *P. ambonensis* Cognetti, 1913 (Sims & Easton 1972). Originally described from Ambon, Indonesia, *P. ambonensis* has a single spermathecal pore located midventrally in 7/8, with 2 spermathecal diverticula. It is 125 mm long with 98 segments, and has 32–40 setae in the pre-clitellar and 50–60 setae in the post-clitellar areas. Its male pores are 0.2 circumference apart ventrally (James 2004), the intestine originates in xv, and penes are present. *Pheretima vergrandis* **n. sp.** differs from *P. ambonensis* in size, and in having a single diverticulum and a single male pore. Other monothecal species in the Philippines are *P. monotheca* James, 2004 and *P. monoporata* James, 2004, both from Mt. Kitanglad; *P. arayatensis* James *et al.*, 2004 from Mt. Arayat in Luzon; and *P. concepcionensis* **n. sp.** described herein. In contrast to *P. vergrandis*, these species all have 2 spermathecal diverticula and 2 male pores, like *P. ambonensis*. In addition, the spermathecal pore is in 5/6 in *P. monotheca*, and in 8/9 in *P. arayatensis* (Table 4). Individuals of *P. vergrandis* are among the smallest in *Pheretima* species recorded in the Philippines. The condition of having a single diverticulum seems to be derived from two spermathecae present ancestrally. A single diverticulum could have resulted from the loss of one spermatheca (in this case, the left, as the one present is consistently offset toward the right side), or it could have resulted from fusion. Likewise, two male openings is the ancestral condition, but the two pores have fused externally in species like *P. vergrandis*.

**Occurrence.** *Pheretima vergrandis* was moderately common (6.9% of all individuals collected on plots) in Brgys Sibucal and Lake Duminagat, at elevations of 902–1662 m. It was not observed in Brgys Small Potongan or Toliyok. The species inhabited soil and rotten logs (Table 1).



**FIGURE 8.** (A) Diagrammatic ventral view of monothecal *Pheretima vergrandis* **n. sp.** showing the single spermathecal pore (sp), clitellum (cl), and single male pore (m). (B–D) Schematic drawings of the internal morphology of Philippine *Pheretima* species: (B) *P. vergrandis* **n. sp.**; (C) *P. concepcionensis* **n. sp.**; (D) athecate *Pheretima subanesis* **n. sp.** (E) Diagrammatic ventral view showing the clitellum (cl) and a pair of male pores (m), as in *P. concepcionensis* and *P. subanensis*. Abbreviations: s, spermatheca; h, heart; p, prostate gland; cb, copulatory bursa; c, caecum. Scale bars: B–D: 5 mm.

I		I	1			
	Pheretima	Pheretima monotheca	Pheretima	Pheretima	Pheretima	Pheretima
	monoporata	James, 2004	arayatensis	vergrandis	concepcionensis n.	subanensis
Character	James, 2004		James <i>et al.</i> , 2004	n. sp.	sp.	n. sp.
Body pigmentation	Dorsally	Dorsally pigmented	Dorsally pigmented	Dorsally	Dorsally pigmented	Dorsally pigmented
	pigmented	all over	all over	pigmented	all over	all over
	all over			all over		
Length [mm]	60 - 70	62	88 - 141	35-75	>89	67
Spermathecal pore	7/8	5/6	8/9	7/8	7/8	0
First dorsal pore	12/13 (4); 13/14	12/13	12/13	13/14	12/13	12/13
	(1)					
Setae vii; xx	26–34; 32–36	36; 32	54; 87	37-42; 50-54	40-50; 56-68	36; 45
Setae bet. male pores	0	ω	5-6	0	2	5
Male pores spacing	0.05	0.11	3	0	0.14	0.21
Setal gaps D; V	÷.	, , +	3	÷	+;+	÷.
Spermathecal	two	two	two	one	two	0
diverticulum						
Septa in 5/6-13/14	+ in 4/5, - in 13/14	+ in 4/5; - in 8/9/10 and 13/14	- in 8/9	- in 8/9/10	- in 8/9/10	- in 8/9/10
Origin of gizzard	viii	viii	viii	viii	viii	ix
Origin of intestine	xvii	xviii	XV	XV	xvi	XV
Caeca	xxvii–xxiii	xxvii–xxiii	xxvii–xxii	xxvii–xxiv	XXVII–XXV	XXVII–XXIII
Origin of typhlosole	xxvii	xxvii	xxvii	xxvii/xviii	xxvii	xxvii
Intestinal vessels	18-20	26	ί	24–28	30 - 35	ί
Location of hearts	x-xiii	x—xiii	x-xiii	x—xiii	x—xiii	xi–xiii
Prostate glands	xvi, xvi–xx	xviii (?)	xviii	xvi–xxi	xvii–xix	xvii–xx
Copulatory bursae	xviii	xviii	xviii (?)	xviii–xx	XVIII	xviii–xix
Penes		+	+	+	+	

**TABLE 4.** Comparison of monothecate Philippine *Pheretima* species, including athecate *Pheretima subanensis* **n. sp**.

#### Pheretima concepcionensis n. sp.

(Fig. 8C, Table 4)

**Material examined.** Holotype: adult, amputee (NMA 4522), Brgy Small Potongan, municipality of Concepcion, Misamis Occidental Province, Mt. Malindang Range (8°24'04"N, 123°36'47"E), 900 m asl., Mindanao Island, Philippines , coll. Nonillon Aspe, M. Lluch, and J. Adeva, Feb. 18–25, 2004. Paratype: one adult, posterior end missing (NMA 4542), same collection data as for holotype.

Etymology. The species name refers to the municipality of Concepcion, the type locality.

**Diagnosis.** Brown worm; single spermathecal pore located midventrally at 7/8; first dorsal pore 12/13; single spermatheca post-septal in viii, with nephridia on ducts; spermatheca with blocky, ovate ampulla, bulbous muscular duct expanding ectally with two stalked diverticula attached to middle of duct; prostate glands in xvii to xix; copulatory bursae confined to xviii; penis present; caeca extending from xxvii to xxv.

**Description.** In living animals, dorsum very dark brown anteriorly, fading to medium brown posteriorly; equators pigmented; clitellum lighter, ventral side non-pigmented. Length of holotype >89 mm; diameter 5.2 mm at x; 4.2 mm at xx; body cylindrical in cross-section, tail narrowing gradually to sharp point; >104 segments. First dorsal pore at 12/13; single midventral spermathecal pore with elevated white lips at 7/8; female pore single in xiv; openings of copulatory bursae paired on xviii, 0.14 circumference apart ventrally, 2 setae between openings. Clitellum annular, extending from xiv to xvi. Setae evenly distributed, 40–50 setae on vii, 56–68 setae on xx, dorsal and ventral gaps present.

Septa 5/6/7/8 and 10/11-13/14 slightly muscular, 8/9/10 absent. Dense tufts of nephridia on anterior faces of 5/6 and 6/7; nephridia of intestinal segments located mainly on body wall at anterior and posterior faces of septa, at septum/body wall junction. Large gizzard extends from viii to x; esophagus with low vertical lamellae extends from x to xiii; intestine originates in xvi; caeca originate in xxvii, extend forward to xxv; typhlosole a simple fold of about 1/4 lumen diameter, originating at 26/27; intestinal wall with 30-35 longitudinal blood vessels.

Hearts in x to xiii, esophageal; commissural vessels in vi, vii, and ix, lateral; those in viii extend to gizzard; supra-esophageal vessel extends from x to xv; extra-esophageal vessels join ventral esophageal wall in x, receive efferent parieto-esophageal vessels in xiii.

Ovaries and funnels free in xiii; single spermatheca post-septal in viii, with nephridia on ducts; spermatheca with blocky, ovate ampulla; three spermatophores present; bulbous muscular duct expanding ectally, two stalked diverticula attached to middle of duct, terminating in ovate receptacles; stalks about same length as spermathecal duct and receptacles. Male sexual system holandric; testes and funnels enclosed in paired sacs in x and xi; seminal vesicles in xi and xii, each with long, slender dorsal lobe; vasa deferentia slender, free from body wall, passing over anterior lateral face of copulatory bursae en route to ental end of prostatic ducts; prostates in xvii to xix, each racemose, 3- to 4-lobed, wrapped around dorsal-lateral margin of copulatory bursa; muscular duct enters posterior face of copulatory bursae in xviii hemispherical. Coelomic surface of bursae muscular, secretory diverticula lacking; floor of bursae thick, cleft by 5 furrows converging on opening; roof with blunt ovate penis.

**Remarks.** Pheretima concepcionensis **n. sp.** is similar to P. ambonensis Cognetti, 1913 and P. monoporata James, 2004 in having the spermathecal pore located in intersegment 7/8 and the spermatheca with two identical diverticula. It differs from P. ambonensis in the location of the first dorsal pore (11/12 in P. ambonensis), in the presence of dorsal and ventral setal gaps (both lacking in *P. ambonensis*), in the male pore spacing (0.14) circumference apart ventrally, compared to 0.2 circumference in P. ambonensis) (James, 2004), in having the intestinal origin in xvi rather than xv; in having the spermatheca post-septal in viii (in vii in *P. ambonensis*), and in the two diverticula terminating in ovate receptacles with long stalks about the same length as the spermathecal duct and receptacle (the two diverticula have much shorter chambers and stalks in P. ambonensis Cognetti, 1913). Pheretima concepcionensis differs from P. monoporata in size (P. monoporata is smaller), in the number of setae (fewer in *P. monoporata*), in the ventral setal gap (lacking in *P. monoporata*), in septal arrangement (setae in 8/9/10 present in *P. monoporata*), in the origin of the intestine (vii in *P. monoporata*), in the size of the prostate (slightly larger in P. monoporata), and in the length of caeca (longer in P. monoporata) (Table 4). Pheretima concepcionensis is similar to P. monotheca in having two diverticula on the spermathecal duct, but the latter species is smaller, has fewer setae, lacks ventral gaps, has the spermathecal pore in 5/6, has closer male pore spacing, has the origin of the intestine in xviii, and has longer caeca (Table 4). Pheretima concepcionensis is similar to P. vergrandis n. sp. in the arrangement of septa, origin of the gizzard in viii, origin of the intestine, and

the presence of penes, but the former species is larger, has the first dorsal pore at 12/13, has two male pores on xviii, and has shorter caeca and prostate glands (Table 4).

**Occurrence.** *Pheretima concepcionensis* was uncommon, comprising 3.4% of individuals on plots; we found it in disturbed forest in Brgys Sibucal, Small Potongan, and Lake Duminagat, at elevations of 915–1662 m. It occurred both in the soil and above ground, on substrates such as on rotten logs (Table 1).

#### Pheretima subanensis n. sp.

(Fig. 8D, Table 4)

Material examined. Holotype: adult, NMA 4523 Brgy Sibucal, Oroqieta City, Misamis Occidental Province, Mt. Malindang Range (8°19'31"N, 123°38'02"E), 991 m asl., Mindanao Island, Philippines, coll. Nonillon Aspe, M. Lluch, and J. Adeva, Feb. 18–25, 2004. Paratype: adult, amputee (ZRC.ANN.0024), same collection data as above. Etymology. The species is named after the indigenous tribe of Mt. Malindang, the "Subanen".

**Diagnosis.** Small, purplish brown worm reaching around 67 mm in adult length; ventral gap absent; first dorsal pore at 12/13; hearts paired in xi to xiii, absent in x; spermathecae absent; racemose prostate glands in xvii to xx, with columnar copulatory bursae in xviii to xix; penes lacking; caeca in xxvii to xxiii.

**Description.** In living animals, dorsum dark purplish brown anteriorly, fading to medium brown posteriorly; equators pigmented; clitellum off-white; ventral side non-pigmented. Length 67 mm (holotype); diameter 3.5 mm at x; 3.5 mm at xx; body cylindrical in cross-section, tail blunt; 119 segments. First dorsal pore at 12/13; spermathecal pores absent; female pore single in xiv; openings of copulatory bursae paired on xviii, 0.21 circumference apart ventrally, 5 setae between openings. Clitellum brown, annular, extending from xiv to xvi. Setae unevenly distributed, 36 setae on vii, 45 setae on xx, dorsal gap present, ventral gap absent.

Septa 5/6/7/8, 10/11–13/14 thinly muscular, 8/9/10 absent. Dense tufts of nephridia on anterior faces of 5/6 and 6/7; nephridia of intestinal segments located mainly on body wall at anterior and posterior faces of septa, at septum/body wall junction. Large gizzard in ix to x; esophagus with circumferential lamellae extending from xi to xii, with digitiform internal texture from xiii to xiv; intestine originates in xv; caeca originate in xxvii, extend forward to xxiii; typhlosole a simple fold of about 1/4 lumen diameter, originating at 26/27.

Hearts in xi to xiii, esophageal; commissural vessels in vi, vii, ix lateral; those in viii extend to gizzard; supraesophageal vessel extends from x to xiii; extra-esophageal vessels join ventral esophageal wall in x, receive efferent parieto-esophageal vessels in xiv.

Ovaries and funnels free in xiii; spermathecae absent. Male sexual system holandric; testes and funnels appear reduced compared to other species, enclosed in paired ventral sacs in x and xi; seminal vesicles in xi and xii, each with short dorsal lobe; vasa deferentia slender, free from body wall, passing around base of copulatory bursae en route to ental end of prostatic ducts; prostates in xvii to xx, each racemose, 3-lobed. Ductlet from anterior prostatic lobes joins vas deferents and posterior ductlet at common junction with muscular prostatic duct. Copulatory bursae in xviii to xix columnar, with rounded apex, attached to body wall at end; oriented towards common opening through body wall. Coelomic surface of bursae muscular, secretory diverticula lacking; penes absent.

**Remarks.** Sims & Easton (1972) stated that it was not possible for them to distinguish between athecate forms of *Pheretima* and *Metaphire* Sims & Easton, 1972 provided that the only character that distinguishes the two genera is the presence of nephridia on the spermathecal ducts in *Pheretima* and the absence of nephridia in that position in *Metaphire*. The two genera are identical in other characters such as the origin of the intestinal caeca in xxvii and the presence of copulatory bursae. Sims & Easton (1972) noted that several species assigned to *Metaphire* might belong in *Pheretima sensu stricto*, and *vice versa*, since the presence or absence of nephridia on the spermathecal in descriptions. By the same token, generic assignment to *Pheretima* or *Metaphire* is problematic for athecal worms, because spermathecal ducts are lacking, making the presence or absence of nephridia on the ducts a moot point.

Here, we propose that the relative size of the copulatory bursae may be a distinguishing character between *Pheretima* and *Metaphire*, with species in *Pheretima* (e.g., this study) tending to have more prominent domeshaped, intra-coelomic copulatory bursae than those in *Metaphire* (e.g., Ohfuchi 1938, 1957; Tsai *et al.* 2004; Bantaowong *et al.* 2011), and if this is the case, it would be useful in assigning athecal worms to one or the other of these genera (Chang *et al.* 2009). Homology among copulatory bursae has not been clear; some authors consider only invaginations of the body wall into the coelom to comprise copulatory bursae, whereas others also consider intramural chambers and even shallow indentations to be copulatory bursae. In the case of *Pheretima* vs. *Metaphire* as defined by Sims & Easton (1972), the type of invagination is the same in the two genera: a large or small bursa visible from within the body, and this is the source of the difficulty in assigning athecal worms in the *Pheretima* complex with caeca and copulatory bursae to one or the other of these genera. The criterion of having a large or small, invaginated copulatory bursa would seem to exclude from either genus any species whose male pore invaginations are entirely within the body wall (intramural), or whose male pores lie in shallow indentations.

Examples of species originally identified as *Pheretima* but reassigned to *Metaphire* by Sims & Easton (1972) because nephridia on the spermathecal ducts were not mentioned in descriptions are members of the octothecal, holandric *M. ignobilis* Gates, 1935 species group, which are most similar to *P. darnleiensis*. Members of this group apparently have only intramural male pores but not intra-coelomic copulatory bursae as in true *Pheretima*. One member of this group, *M. riukiuensis* Ohfuchi, 1957, has only thick epidermal lips pressed together covering the male pores, rather than an invagination. None of these species would be considered synonyms of *P. darnleiensis*, and it is clear that a major taxonomic revision of *Metaphire* is necessary.

Island	Locality	N [species]
Luzon		30
	Kalbaryo	4
	Kalinga	6
	Mt. Province & Banaue <sup>1</sup>	9
	Mt. Arayat	2
	Mt. Makiling	2
	Mt. Isarog	7
Catanduanes		2
Mindanao		34
	Mt. Kitanglad	15
	Mt. Malindang	18
	Mt. Apo <sup>2</sup>	1
Cebu		1
Total		67

**TABLE 5**. Diversity of *Pheretima* species reported from various localities and islands in the Philippines. None of the species has been reported at more than one locality in the Philippines, and only two species (see the footnotes) also occur outside the Philippines.

<sup>1</sup> Includes nominal *P. darnleiensis*, also reported from Papua New Guinea, Fiji, Malaysia, Indonesia, and Singapore. <sup>2</sup> Includes *P. urceolata*, also reported from Indonesia.

Joshi *et al.* (1999) reported an athecal earthworm 200–300 mm long from Ifugao, Luzon, but it is likewise not clear whether this species belongs in *Pheretima* or in *Metaphire*. James (unpublished) however thought that this species is most likely a *Pheretima* basing on the size and shape of the copulatory bursae. Aspe (unpublished data) also described another athecal species > 300 mm long at Bukidnon, central Mindanao, with prominent dome-shaped copulatory bursae, and result on molecular analysis shows that this species belongs to the *Pheretima* clade rather than that of *Metaphire*. *Pheretima subanensis* **n. sp.** is similar to *P. malindangensis* **n. sp.**, *P. vergrandis* **n. sp.**, and *P. potonganensis* **n. sp.** in relative size and coloration, but it is athecal, whereas the latter three are bithecal, monothecal and octothecal, respectively. The athecal species also differs from the others in male pore spacing, setal gaps, the size and position of the prostate glands and copulatory bursae, and the intestinal origin in xv rather than in xvi.

Gates (1972) listed the following as indicators that lumbricid or megascolecid earthworms are parthenogenetic: (1) testes and/or seminal vesicles retained in the juvenile state in adult specimens; (2) absence of spermatozoal iridescence in male funnels and/or spermathecae; (3) spermatophores lacking or, if present, lack spermatozoa inside. In *Pheretima subanesis* **n. sp.**, the testes appear to be reduced, and we observed no spermatozooidal iridescence in the sperm funnels. These observations suggest that this species is parthenogenetic.

**Occurrence.** *Pheretima subanensis* **n. sp.** was found in disturbed forest in Brgy Small Potongan, at 915–1024 m elevation (Table 1).

### Discussion

Edwards & Bohlen (1996) noted that earthworm communities typically contain from one to 15 species. Most earthworm communities contain around three to six species, with a remarkable degree of consistency among different habitats and different geographic regions, both temperate and tropical. Earthworm diversity is higher than the norm at Mt. Malindang, with at least 22 species (the 18 *Pheretima* species described herein, and three *Pithemera* and one *Polypheretima* species that will be described elsewhere) and also at Mt. Kitanglad (18 species; James 2004) (Table 5). Aspe *et al.* (2009) reported that species diversity of earthworms at high elevations was high compared to lower elevations and that in disturbed areas at the lower elevations, especially in the grasslands and agricultural areas, the exotic *Pontoscolex corethrurus* Müller, 1857 was abundant, with an average of 45 individuals/m<sup>2</sup>. The results agree with the study conducted by Tsai *et al.* (2004) in Taiwan wherein the number of native species decreased while the number of exotic species increased with the decrease in elevation. Species richness was high in the forested sites situated in the higher elevations, but abundance was observed to be extremely low (mostly < 1 individual/m<sup>2</sup>). This may be due to the network of thick moss and roots that mats the soil, which also makes digging more difficult. However, based on experiencees in the other sites in the Philippines, this low abundance is the usual case in pristine habitats.

Blakemore (2007) listed a total of 40 valid *Pheretima* species in the Pacific region, described from 1886 to 2004. Prior to 2004, only three valid *Pheretima* species were known from the Philippines: a highly questionable report of *P. darnleiensis* from Benguet (near Banaue), Luzon Island and from Mindoro Island; *P. philippina* from Cebu Island; and a questionable record of *P. urceolata* Horst, 1893 from Mt. Apo, Mindanao Island (Blakemore, 2007). From 2004 to present (including this study), 64 new *Pheretima* species have been added, bringing the total number of *Pheretima* earthworms for the Philippines to 67 species. Table 5 shows the diversity of the *Pheretima* species reported by site and by island in the Philippines. Among these species, only two, *P. darnleiensis* and *P. urceolata*, are known to occur outside the country (nominal *P. darnleiensis* has been reported from Darnley Island (Torres Strait), Papua New Guinea, Fiji, Malaysia, Indonesia, and Singapore; *P. urceolata*, from Indonesia). The known ranges of the rest of the species are all restricted to areas around the type localities. This pattern indicates a remarkable degree of endemicity, both among local areas, among islands in the Philippines, and in the Philippines as a whole, and suggests that many species remain to be detected in the Philippines. Furthermore, we have no knowledge at all of the breadth of ranges of earthworm species in the Philippines, although the lack of species in common between Mt. Malindang and Mt. Kitanglad, about 125 km apart, indicates that the ranges are quite limited in size.

James (2004) suggested that *Pheretima* species on islands such as Indonesia and Borneo that neighbor the Philippines are unlikely to have colonized the Philippines in the past two million years, nor has there likely been genetic exchange among islands, because water depths between islands now range from 200 to 1000 m, too deep to have permitted land connections during the Pleistocene (Heaney 1985). In addition, the Zamboanga Peninsula, where Mt. Malindang is located, was separate from the rest of Mindanao until the end of the Miocene, as it is part of the Greater Sunda Shelf in the west, whereas the rest of Mindanao originated from the east (Hall 1996). This may explain why the *Pheretima* species assemblage at Mt. Malindang is so different from that at Mt. Kitanglad (James 2004). On the other hand, there is increasing evidence that dispersal across water by rafting, including dispersal by soil-dwelling invertebrates and vertebrates (de Queiroz 2005; Vidal *et al.* 2008), may be more common than previously thought, and so lack of close evolutionary connections among earthworms among the Philippine Islands, and between the Philippines and neighboring archipelagos, cannot be assumed a priori. Future molecular studies can elucidate the evolutionary relationships among species and populations at several levels: between the Zamboanga Peninsula and the rest of Mindanao; among the Philippine Islands; and between the Philippine archipelagos and continental areas in southeastern Asia.

This paper adds new members to the *Pheretima* (*Pheretima*) sangirensis, montana, and darnleiensis groups of Sims & Easton (1972), new monothecal species related to *P. ambonensis*, and an athecate *Pheretima* species. We expect that additional *Pheretima* species will be detected in the Philippines. Molecular data can shed light on

whether the species groups are natural groups, and on the utility of various taxonomic characters in delineating species.

To facilitate the further study of Philippine earthworms, we provide the following key to the *Pheretima* species described herein from the Mt. Malindang Range. 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 species of *Pheretima* reported from the Mt. Malindang Range

1	One pair of spermathecae
-	Four pairs of spermathecae
-	Single spermatheca
-	No spermatheca, length around 67 mm Pheretima subanensis n. sp.
2	Large worms, adult width $\geq 8 \text{ mm}$
-	Small or slender worms, adult width $\leq 8 \text{ mm}$
3	Dorsum with oval pigmented dots on intersegmental furrows, adult length 226–235 mm
	Dorsum with strings on intercommental furrows
-	Dorsum vium surpes on intersegmental furrows
-	Dorsum with dark red to purple stripes on intersegmental furrows, adult length 230–283 mm Pharatima tigris <b>n</b> sn
-	Dorsum with thick dark number to black strings on intersegmental furrows, adult length up to 365 mm
	Pheretima immanis n. sp.
5	Dorsum dark, gradually fading towards ventral side, intestine originating in xiv, adult length 223–315 mm.
	Pheretima lago <b>n. sp.</b>
-	Dorsum dark gray-brown anteriorly, fading posteriorly, intestine originating in xv Pheretima nunezae n. sp.
6	Dorsum with stripes on intersegmental furrows, male pores appearing as one, adult length 101–133 mm
	Pheretima boniaoi n. sp.
-	Dorsum pigmented all over
7	Intestine originating in xv, dorsal setal gap present, ventral setal gap absent
-	Intestine originating in xvi, dorsal setal gap absent, ventral setal gap present, dorsum purplish brown, adult length 69–96 mm.
	Pheretima malindangensis <b>n. sp.</b>
-	Intestine originating in xxii, no dorsal or ventral setal gaps, dorsum red-brown, adult length 139–186 mm
0	Pheretima longigula n. sp.
8	Prostates in xv–xx, caeca in xvii–xxii, adult length 89–97 mm
-	Prostates in xv–xxii, caeca in xxvii–xxii, adult length 6/–/5 mm
-	Prostates in xv1-xx1, caeca in xxv1-xxv, adult length 55-65 mm
-	First area between male nores less than distance between snermathecal nores, first dorsal nore in 12/13, adult length 110, 131
9	Phavetima adovai n sn
-	Spermathecal pores and male pores have the same distance between pores first dorsal pore in 13/14 adult lenoth 104–135 mm
	Pheretima Iluchi n. sn.
-	Spermathecal pores inconspicuous, first dorsal pore at 12/13, adult length 63–89 mm. Pheretima potonganensis n, sp.
10	One spermathecal diverticulum, single male pore, first dorsal pore at 13/14, adult length 35–50 mm
	Pheretima vergrandis <b>n</b> . sp.
-	Two spermathecal diverticula, male pores paired, first dorsal pore at 12/13, average adult length ca. 90 mm
	Pheretima concepcionensis <b>n. sp.</b>

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