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# **STRUGGLE FOR EXISTENCE: EARTHWORMS THROUGH DEFORESTATION IN BUNGKU (JAMBI) AND MOUNT GEDE (WEST JAVA)**

**ANDY DARMAWAN**

**G362110081**



**GRADUATE SCHOOL  
BOGOR AGRICULTURAL UNIVERSITY  
BOGOR  
2016**



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## STATEMENT LETTER

I hereby declare that dissertation entitled “Struggle for Existence of Earthworms in Bungku (Jambi) and Mount Gede (West Java)” is original result of my own research supervised by supervisory committee and has never been submitted in any form at any institution before. All information from other authors cited here are mentioned in the text and listed in the reference at the end part of the dissertation.

Bogor, January 2016

*Andy Darmawan*

Student ID G362110081

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## SUMMARY

ANDY DARMAWAN. Struggle for Existence: Earthworms through Deforestation in Bungku (Jambi) and Mount Gede (West Java). Supervised by BAMBANG SURYOBROTO, TRI ATMOWIDI, and WASMEN MANALU.

The Gause's principle, whereby species without niche differentiation expel each other leads to reduced diversity. This principle has been proven in laboratory and we show this principle in the nature. It is preceded by humans that alter the environment by changing the forests into plantations. In the same time, humans also introduce agricultural plantations and deliberately or not, introduce earthworms along with the plantations. The native and exotic earthworms can live together as long as they do not share the overlapping niche and equilibrium competition is not attained. However, the deforestation has made the earthworms exist in competitive equilibrium and consequently reduces the earthworm diversity.

We began the research on July 2012. The first sampling was conducted in Bungku Village, Jambi, Indonesia on November 2012. The sampled areas included secondary forests, oil palm plantations, rubber plantations, and rubber jungles. We discovered only one species of earthworm, which was *Pontoscolex corethrurus*. The second sampling was conducted in Mount Gede, West Java, Indonesia between early July and the end of October 2012 and between early September and the end of December 2013. We observed two regions in Mount Gede, viz. Bodogol and Situ Gunung. The sampled areas included forests, mixed plantations, and homogenous plantations.

We recovered 23 species of earthworms and 5 among them (*Drawida nepalensis* Michaelsen, 1907, *Notoscolex javanica* (Michaelsen, 1910), *Pheretima pura* species-group of Sims & Easton, 1972, *Polypheretima moelleri* (Michaelsen, 1921), and *Polypheretima sempolensis* Easton, 1979) were native of the Oriental region. Seven species (*Amyntas asiaticus* Michaelsen, 1900, *Amyntas hupeiensis* (Michaelsen, 1895), *Amyntas illotus* species-group sensu Sims & Easton, 1972, *Amyntas morrisi* species-group sensu Sims & Easton, 1972, *Amyntas robustus* (Perrier, 1872), *Metaphire planata* (Gates 1926), and *Ocnerodrilus occidentalis* Eisen, 1878) were reported for the first time in Indonesia. The others (*Amyntas aeruginosus* (Kinberg, 1867), *Amyntas gracilis* (Kinberg, 1867), *Amyntas minimus* (Horst, 1893), *Dichogaster affinis* (Michaelsen, 1890), *Drawida barwelli* (Beddard, 1886), *Metaphire californica* (Kinberg, 1867), *Metaphire javanica* (Kinberg, 1867), *Perionyx excavatus* Perrier, 1872, *Pheretima darnleiensis* (Fletcher, 1886), *Polypheretima bifaria* species-group of Easton, 1979, and *Pontoscolex corethrurus* (Muller, 1857)) were believed to be introduced through agricultural plantations. The most dominant species were *Ocnerodrilus occidentalis* and *Pontoscolex corethrurus*.



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Here we show that anthropogenic disturbance has altered the environmental condition. The agricultural plantations in our study act as transplant experiment for Gause's principle. The constant alteration is reflected by increasing of soil temperature, pH, and water content, while C-organic content is decreasing. This environmental alteration does not support stenotopic earthworms and it drives them to die. Two leftover species, *Ocnerodrilus occidentalis* and *Pontoscolex corethrurus*, thrived to be eudominant competing species. It is indicated by the increasing density of one of the two causes lower density of the other. However, *Ocnerodrilus occidentalis* is able to sustain viable population and ousting *Pontoscolex corethrurus* in area with high soil temperature.

Key words: competition, exotic, Gause's principle, plantation, soil.

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## RINGKASAN

ANDY DARMAWAN. Perjuangan untuk Hidup: Cacing Tanah Melalui Deforestasi di Bungku (Jambi) dan Gunung Gede (Jawa Barat). Dibimbing oleh BAMBANG SURYOBROTO, TRI ATMOWIDI, dan WASMEN MANALU.

Prinsip Gause, di mana spesies dengan niche yang tidak berbeda saling menyingkirkan, mengakibatkan penurunan keanekaragaman. Prinsip ini telah dibuktikan di laboratorium dan kami menunjukkan prinsip ini berlaku dalam kehidupan nyata. Hal ini diawali oleh manusia yang mengubah lingkungan dengan melalui perubahan hutan menjadi perkebunan. Pada saat yang sama, manusia juga mengintroduksi tanaman agrikultur dan dengan sengaja atau tidak, ikut mengintroduksi cacing tanah bersama tanaman tersebut. Cacing asli dan eksotik dapat hidup bersamaan selama mereka memiliki relung yang berbeda dan kesetimbangan kompetisi tidak tercapai. Namun, deforestasi telah membuat cacing tanah hidup dalam kesetimbangan kompetisi dan mengakibatkan penurunan keanekaragamannya.

Kami memulai penelitian pada bulan Juli 2012. Sampling pertama dilakukan di Desa Bungku, Jambi, Indonesia pada bulan November 2012. Daerah sampling meliputi hutan sekunder, kebun kelapa sawit, kebun karet, dan hutan karet. Kami hanya menemukan satu spesies cacing tanah, yaitu *Pontoscolex corethrurus*. Sampling kedua dilakukan di Gunung Gede, Jawa Barat, Indonesia antara awal Juli hingga akhir Oktober 2012 dan awal September hingga akhir Desember 2013. Kami mengamati dua daerah, yaitu Bodogol dan Situ Gunung. Daerah sampling meliputi hutan, kebun campuran, dan kebun monokultur.

Kami memperoleh 23 spesies cacing tanah dan 5 spesies (*Drawida nepalensis* Michaelsen, 1907, *Notoscolex javanica* (Michaelsen, 1910), *Pheretima pura* species-group of Sims & Easton, 1972, *Polypheretima moelleri* (Michaelsen, 1921), dan *Polypheretima sempolensis* Easton, 1979) merupakan cacing Oriental. Tujuh spesies (*Amyntas asiaticus* Michaelsen, 1900, *Amyntas hupeiensis* (Michaelsen, 1895), *Amyntas illotus* species-group sensu Sims & Easton, 1972, *Amyntas morrissi* species-group sensu Sims & Easton, 1972, *Amyntas robustus* (Perrier, 1872), *Metaphire planata* (Gates 1926), dan *Ocnerodrilus occidentalis* Eisen, 1878) merupakan cacing yang baru dilaporkan di Indonesia. Cacing lainnya (*Amyntas aeruginosus* (Kinberg, 1867), *Amyntas gracilis* (Kinberg, 1867), *Amyntas minimus* (Horst, 1893), *Dichogaster affinis* (Michaelsen, 1890), *Drawida barwelli* (Beddard, 1886), *Metaphire californica* (Kinberg, 1867), *Metaphire javanica* (Kinberg, 1867), *Perionyx excavatus* Perrier, 1872, *Pheretima darnleiensis* (Fletcher, 1886), *Polypheretima bifaria* species-group of Easton, 1979, dan *Pontoscolex corethrurus* (Muller, 1857)) diduga diintroduksi melalui tanaman agrikultur. Cacing yang dominan adalah *Ocnerodrilus occidentalis* dan *Pontoscolex corethrurus*.



Pada tulisan ini kami menunjukkan gangguan oleh manusia telah mengubah kondisi lingkungan. Tanaman agrikultur pada studi ini analog dengan percobaan prinsip Gause. Perubahan yang konstan ditunjukkan oleh peningkatan bahang, pH, dan kandungan air tanah, sementara karbon organik menurun. Perubahan lingkungan ini tidak mendukung cacing tanah dengan toleransi rendah sehingga mengakibatkan kematian. Dua spesies yang bertahan, *Ocnerodrilus occidentalis* dan *Pontoscolex corethrurus* muncul sebagai cacing tanah yang mendominasi dan saling berkompetisi. Hal tersebut ditunjukkan dengan peningkatan kepadatan salah satu spesies diikuti oleh penurunan kepadatan spesies lainnya. *Ocnerodrilus occidentalis* mampu mencapai populasi yang tinggi dan mengalahkan *Pontoscolex corethrurus* pada daerah dengan bahang tanah yang tinggi.

Kata kunci: eksotik, kompetisi, perkebunan, prinsip Gause, tanah.

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# **STRUGGLE FOR EXISTENCE: EARTHWORMS THROUGH DEFORESTATION IN BUNGKU (JAMBI) AND MOUNT GEDE (WEST JAVA)**

**ANDY DARMAWAN**

Dissertation  
submitted in partial fulfillment of the requirements for  
Doctoral Degree  
in  
Major of Animal Bioscience

**GRADUATE SCHOOL  
BOGOR AGRICULTURAL UNIVERSITY  
BOGOR  
2016**



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## FOREWORD

*“Deo, parentibus et magistris non potest satis gratiae rependi”*

(Martin Luther 1483-1546)

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Bogor, January 2016

*Andy Darmawan*



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## TABLE OF CONTENT

TABLE OF CONTENT	xv
LIST OF TABLES	xvi
LIST OF FIGURES	xvi
LIST OF APPENDICES	xvii
1 GENERAL INTRODUCTION	1
2 EARTHWORMS (OLIGOCHAETA) FROM BUNGKU VILLAGE (JAMBI) AND MOUNT GEDE (WEST JAVA)	5
Abstract	5
Introduction	5
Material and Method	8
Result	9
Taxonomy	10
References	28
Appendix	34
3 <i>Pontoscolex corethrurus</i> (Müller, 1857) (Oligochaeta: Glossoscolecidae) IN FOREST TRANSFORMATION SYSTEM IN BUNGKU VILLAGE, JAMBI, INDONESIA	37
Abstract	37
Introduction	37
Material and Methods	38
Result	41
Discussion	43
References	44
4 COMPETITION OF TWO SURVIVED EXOTIC EARTHWORMS ( <i>Ocnerodrilus occidentalis</i> Eisen, 1878 AND <i>Pontoscolex corethrurus</i> (Muller, 1857)) FROM DEFORESTATION IN MOUNT GEDE, INDONESIA	47
Abstract	47
Introduction	47
Material and Methods	49
Result	53
Discussion	56
References	57
Appendices	61
5 GENERAL DISCUSSION	65
6 CONCLUSION	67
CURRICULUM VITAE	68

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## LIST OF TABLES

2.1	Earthworms collected from Bungku Village and Mount Gede. Species with asterisk (*) were reported for the first time in Indonesia. See material and method for area explanation	7
3.1	Kruskal-Wallis test of <i>Pn. corethrurus</i> density in each system. The values are mean of <i>Pn. corethrurus</i> abundance/m <sup>2</sup> ± SD	41
3.2	Kruskal-Wallis test of soil parameters in each system. Mean ± SD, values with the same letter in a row are not significantly different (p-value < 0.05)	42
3.3	Soil parameters affecting <i>Pn. corethrurus</i> abundance	42
4.1	Soil parameters, presented in minimum-maximum value, in forest and plantation areas in Mount Gede were tested by multiple comparison Kruskal-Wallis" rank sum test ( $\alpha = 0.05$ ). Values with the same superscripts in a row are not significantly different. n indicates the amount of the plot	53
4.2	Sampling areas in Mount Gede. Bodogol region (B) was sampled in three forest (B1–B3), two mixed plantations (B4, B5), and four homogenous plantation areas (B6–B9). Situ Gunung region (S) was sampled in three forests (S1–S3) and six homogenous plantation areas (S4–S9)	54
4.3	Relative dominance (RD) and prevalence (P) of earthworm species in forests and plantations in Mount Gede. All values are ranging from 0 (worst) to 100 (best). Species with asterisks are natives of the Orient	55

## LIST OF FIGURES

1.1	Model of diversity in function of rate of displacement (equivalent to population growth rate), and frequency of population reduction (equivalent to disturbance) (from Huston 1979).	2
3.1	Study site in Jambi Province, Indonesia.	39
4.1	Forest (B1–B3, S1–S3) and mixed plantation (B4–B5) areas supported more earthworm species than homogenous plantations (B6–B9, S5–S9). B and S represent areas in Bodogol and Situ Gunung regions. The bigger circle denotes a higher species density. The dots (●) denote Shannon's diversity index and their medians (—) in forest, mixed, and homogenous plantations. Crosses (x) denote total earthworm densities (excluding unknown species) and their medians (- - -). For genera	



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abbreviation: *A* = *Amyntas*, *Di* = *Dichogaster*, *Dr* = *Drawida*, *M* = *Metaphire*, *N* = *Notoscolex*, *O* = *Ocnerodrilus*, *Pe* = *Perionyx*, *Ph* = *Pheretima*, *Pn* = *Pontoscolex*, *Po* = *Polypheretima*. Species with asterisks were natives of the Orient.

49

## LIST OF APPENDICES

2.1	Compilation of earthworm species in Indonesia.	34
4.1	Earthworms recovered (ind/m <sup>2</sup> ) from each area in Bodogol. Species with asterisks are natives of the Orient. See Table 4.2 for explanation of the areas. n indicates the amount of the plot. Unknown species was excluded from diversity and dominance indices analysis.	61
4.2	Earthworms recovered (ind/m <sup>2</sup> ) from each area in Situ Gunung. Species with asterisks are natives of the Orient. See Table 4.2 for explanation of the areas. n indicates the amount of the plot. Unknown species was excluded from diversity and dominance indices analysis.	62
4.3	Rarefaction curve in Bodogol (B) and Situ Gunung (S) region.	62
4.4	Soil parameter from each area in Bodogol (B1–B9) and Situ Gunung (S1–S9). For soil physical factors: data ± SD.	63
4.5	Relative dominance (%) of earthworm species in each area from Bodogol. Species with asterisks are natives of the Orient. See Table 4.2 for explanation of the areas.	63
4.6	Relative dominance (%) of earthworm species in each area from Situ Gunung. Species with asterisks are natives of the Orient. See Table 4.2 for explanation of the areas.	64
4.7	It was more probable to found higher <i>O. occidentalis</i> density than <i>Pn. corethrurus</i> along increasing of soil temperature (inside rectangle). Arrows pointing left indicates higher <i>O. occidentalis</i> density over <i>Pn. corethrurus</i> in certain area (see Appendix 4.4 for detailed soil parameters in each area), and vice versa. The areas without <i>O. occidentalis</i> and <i>Pn. corethrurus</i> (B1, B3, and S1) were omitted.	64



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## 1 GENERAL INTRODUCTION

The term of struggle for existence employed by Darwin (1859) includes dependence of one being on another and success in leaving progeny. In mixed population where a species affects the others by altering environment, growth rate of each species depends on population size already accumulated, inherent growth rate, and unutilized potentialities of growth. The unutilized potentialities of growth are complex variable. Vacant spaces might also be affected by waste product (Gause 1932). These ideas lead to general theory that competing species cannot long coexist in nature. The theory has been refined by several scientists (Hardin 1960, Darlington 1972, Huston 1979) and now it is known as Gause's principle. The original concept refers to the simple single-resource competition where a resource becomes direct and limiting factor for two populations (Darlington 1972). It is often extended into „competitive exclusion principle“ which stated that “1) if two noninterbreeding populations do “the same thing”, 2) if they are sympatric, 3) if population A multiplies faster than population B, then ultimately A will completely displace B, which will become extinct” (Hardin 1960).

Competitive exclusion exists in competitive equilibrium with several assumptions, such as: stable uniform environment, same limiting resource at the same time, and equilibrium is achieved. Practically, this condition rarely occurs in nature, but the immediate outcome can be observed by increasing the density of one competitor with concomitant decrease of the other (Huston 1979). Naturally, most of communities exist in non-competitive equilibrium. Environmental alteration, which affects the factors those prevent the competitive equilibrium such as population growth rate and reduction, causes attainment of competitive equilibrium (Fig. 1.1).

Competitive equilibrium can lead to reduced diversity. A model proposed by Huston (1979) shows the relationship between diversity and attainment of competitive equilibrium. Diversity is described by 3D contour lines where the highest density lies within the center of each contour line. Hence, low growth rate (transect A) with low disturbance results in high diversity as the competitive equilibrium will take a long time to be approached. Increasing frequency of reduction in this condition will reduce the diversity as population growth is not fast enough to recover from the high disturbance. Meanwhile, high growth rate (transect B) is susceptible to approaching competitive equilibrium quickly. This condition must be compensated by high frequency of reduction to maintain the high diversity. The same case reflects in transect C and D. In low frequency of reduction condition (transect C), increasing growth rate will reduce diversity as the competitive equilibrium will be reached quickly. Then, in high frequency of reduction (transect D), low growth rate cannot catch the rate of reduction and

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diversity will be decreased. This model has been proved in laboratory, and we showed that it is valid in the real world of earthworm.

Earthworms are classed as Oligochaeta. At first, Linnaeus (1758) grouped the worms into only two groups (*Lumbricus terrestris* and *L. marinus*), and currently, Oligochaeta consists about 9.500–10.300 species in 804 genera of 38 families (Blakemore 2010). This class is characterized by having few setae (8 up to a hundred) on each segment, not having parapodia, and absence of appendages on head (or less appendages variation if present). Several body segments are modified into clitellum which functions in reproduction (Edwards 2004).

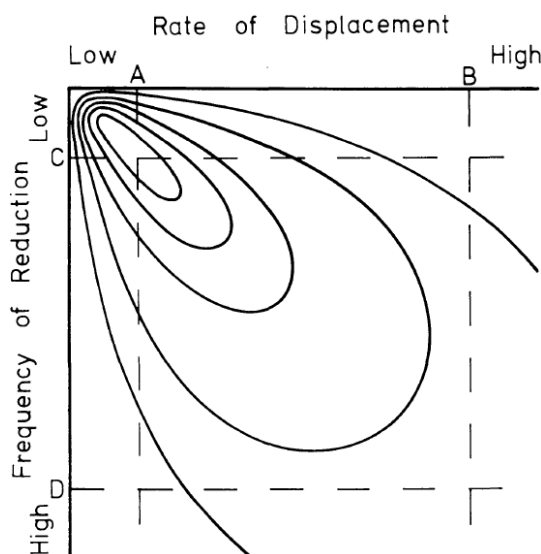


Figure 1.1 Model of diversity in function of rate of displacement (equivalent to population growth rate), and frequency of population reduction (equivalent to disturbance) (from Huston 1979).

Earthworms can be found almost everywhere in this earth. The places where they may be found usually have constant soil temperature fluctuation and moisture such as forest, plantation, or garden. They have different tolerance to the environmental stress, therefore earthworm species may be varied within different areas (Edwards 2004). According to their ecological status, earthworms can be classified into epigeic, anecic, and endogeic. Epigeic earthworms live on the ground surface and feeding on litters. They do not have permanent burrow. Consequently, they are quite mobile. Anecic earthworms build vertical burrow where one end is opened into the surface. They come out from their burrow to feed. Meanwhile, endogeic earthworms build their burrow in the ground. They rarely come out to surface, so they feed mainly on almost decomposed organic matter and soil (Chaudhuri *et al.* 2008, Blakemore 2010).

We elevate an issue concerning anthropogenic disturbance, which is changing nature equilibrium and reducing earthworm diversity. Indonesia

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experienced the third largest annual forest lost in 2000–2010 (FAO 2010). We studied the earthworms in Mount Gede (West Java) and Bungku Village (Jambi) as these areas are undergoing forest transformation into plantations. The difference between acidic soil in Jambi and volcanic soil in Mount Gede probably causes the different earthworm community. Most of the recorded earthworms are introduced along agricultural plantations. The forest disturbance has caused unfavorable environmental condition for most stenotopic earthworms and killing them. The left out eurytopic earthworms which have the overlapping niche compete each other. In severely degraded condition, it is possible to leave a single species of earthworm completely dominated the area.

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## 2 EARTHWORMS (OLIGOCHAETA) FROM BUNGKU VILLAGE (JAMBI) AND MOUNT GEDE (WEST JAVA)

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### Abstract

We conducted the sampling in Bungku Village (Jambi) on November 2012. Meanwhile, we performed the sampling in Mount Gede (West Java) between early July and the end of October 2012 and between early September and the end of December 2013 in the wet season. Our study recovered 23 species of earthworms with 7 species were reported for the first time in Indonesia, i.e: *Amyntas asiaticus* Michaelsen, 1900, *Amyntas hupeiensis* (Michaelsen, 1895), *Amyntas illotus* species-group sensu Sims & Easton, 1972, *Amyntas morrisi* species-group sensu Sims & Easton, 1972, *Amyntas robustus* (Perrier, 1872), *Metaphire planata* (Gates, 1926), and *Ocnerodrilus occidentalis* Eisen, 1878. *Pontoscolex coerthrurus* was the only species found in Jambi. Most of the recorded species were megascolecids in Mount Gede with *Ocnerodrilus occidentalis* Eisen, 1878 was the most dominant species.

Key words: Bodogol, first reported, Situ Gunung.

### Introduction

Earthworm systematic requires assessment of external and internal characters, especially the reproductive organs (Stephenson 1923, James 2000, Blakemore 2010). They are prominent and expensive to maintain, causing these characters become conservative, i.e. less influenced by environment (Blakemore 2010). Therefore, a diagnosis of reproductive organs, which are positioned internally, is needed to confirm the earthworm identity (Stephenson 1923, James 2000, Blakemore 2010).

Present studies of earthworm in Indonesia conducted earthworm identification based on merely external characters (Wibowo 2000, Milasari 2013), resulting dubious conclusion. Oktavia (2013) reported *Pheretima andamanensis* (mistyped as “*andamaensis*”) from Darmaga, but the description probably contain miscounted segment of male pores. Some vermicultures are also misidentified the



cultured earthworms due to lack of knowledge of earthworm characters (pers. obs.). Hence, studies of earthworm taxonomy in Indonesia are scarce.

Reliable records of recent Indonesian earthworm were presented by Blakemore & Nugroho (2008), and Nugroho (2010). The compilation of their works revealed 217 species of earthworms in Indonesia (Appendix 2.1). Our study recovered 23 species of earthworms with 7 species are reported for the first time in Indonesia (Table 2.1). Earthworms with broken anterior part could not be identified, and then they were grouped into “unknown”.

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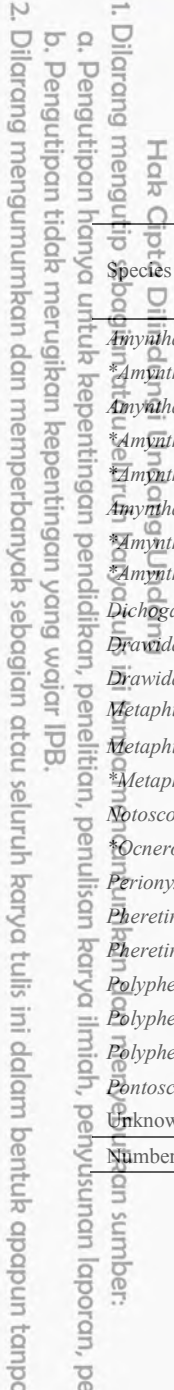


Table 2.1 Earthworms collected from Bungku Village and Mount Gede. Species with asterisk (\*) were reported for the first time in Indonesia. See material and method for area explanation

Species	Sampling area																				Total	Prevalence
	B1	B2	B3	B4	B5	B6	B7	B8	B9	S1	S2	S3	S4	S5	S6	S7	S8	S9	J			
<i>Amyntas aeruginosus</i> (Kinberg, 1867)										3		5									8	2
* <i>Amyntas asiaticus</i> Michaelsen, 1900	2																				2	1
<i>Amyntas gracilis</i> (Kinberg, 1867)											6	4	1								11	3
* <i>Amyntas hupeiensis</i> (Michaelsen, 1895)	4	1																			5	2
* <i>Amyntas illotus</i> species-group sensu Sims & Easton, 1972	6	1		33	27	17	4		1	17	10	16	2		1						135	12
<i>Amyntas minimus</i> (Horst, 1893)										39	6	7									52	3
* <i>Amyntas morrissi</i> species-group sensu Sims & Easton, 1972											1										1	1
* <i>Amyntas robustus</i> (Perrier, 1872)	4	3	1	1	1					6	2	18			1						37	9
<i>Dichogaster affinis</i> (Michaelsen, 1890)		7			2				4			1		1			1	2			18	7
<i>Drawida barwelli</i> (Beddard, 1886)	17	68									47	3									135	4
<i>Drawida nepalensis</i> Michaelsen, 1907			2							4											6	7
<i>Metaphire californica</i> (Kinberg, 1867)	12	3		11	3		1				3	13	4								50	8
<i>Metaphire javanica</i> (Kinberg, 1867)	1		1							1											3	3
* <i>Metaphire planata</i> (Gates 1926)			20	1																	21	2
<i>Notoscolex javanica</i> (Michaelsen, 1910)		1			23				50					5	1	2		4			86	7
* <i>Ocnerodrilus occidentalis</i> Eisen, 1878		15		87	72	6	15	37	684		3		69	317	157	27	32	247			1768	14
<i>Perionyx excavatus</i> Perrier, 1872				6	18			4													28	3
<i>Pheretima darnleiensis</i> (Fletcher, 1886)							3														3	1
<i>Pheretima pura</i> species-group of Sims & Easton, 1972						1															1	1
<i>Polypheretima bifaria</i> species-group of Easton, 1979											1	1									2	2
<i>Polypheretima moelleri</i> (Michaelsen, 1921)										4											4	1
<i>Polypheretima sempoensis</i> Easton, 1979										8	3	3									14	3
<i>Pontoscolex corethrurus</i> (Muller, 1857)		121		169	452	146	104	26	2		5	18	13	19	6	1		28	940	2050	15	
Unknown	16	30	7	21	26	10	1	0	7	54	62	32	0	13	3	0	0	5			287	
Number of known species	7	9	4	7	8	4	5	3	5	8	11	11	5	4	5	3	2	4			4727	

## Material and Method

We conducted the sampling in Bungku Village (Jambi) on November 2012. Meanwhile, we performed the sampling in Mount Gede (West Java) between early July and the end of October 2012 and between early September and the end of December 2013 in the wet season. The sampling location included 19 areas:

J – Jambi: Oil palm plantations, rubber plantations, rubber jungle, and secondary forest. These areas were dominated by oil palm (*Elais guineensis*), grass (Gramineae), rubber (*Hevea brasiliensis*), Asian melastome (*Melastoma candidum*), billion (*Eusideroxylon zwageri*), tempinis (*Sloetia elongate*), medang (*Litsea firma*), and bamboo (Bambusoideae).

B1 – Bodogol forest: dominated by rasamala (*Altingia excelsa*), grasses, and bushes.

B2 – Bodogol forest: dominated by calliandra (*Calliandra* sp.), grasses, and bushes.

B3 – Bodogol forest: dominated by coffee (*Coffea* sp.), tepus (*Elateriospermum tapos*), grasses, and bushes.

B4 – Bodogol mixed plantation: dominated by coffee (*Coffea* sp.), talas (*Colocasia esculenta*), jackfruit (*Artocarpus heterophyllus*), and papaya (*Carica papaya*).

B5 – Bodogol mixed plantation: dominated by coffee (*Coffea* sp.), talas (*Co. esculenta*), manglid (*Magnolia blumei*), and java tea (*Orthosiphon aristatus*).

B6 – Bodogol avocado plantation (*Persea americana*). There were some cassava plantations (*Manihot esculenta*) and bushes surrounding the avocado plantation.

B7 – Bodogol avocado plantation (*P. americana*).

B8 – Bodogol cucumber plantation (*Cucumis sativus*).

B9 – Bodogol cassava plantation (*M. esculenta*).

S1 – Situ Gunung forest: dominated by rasamala (*Al. excelsa*), tepus (*Et. tapos*), grasses, and bushes.

S2 – Situ Gunung forest: dominated by dammar (*Agathis dammara*), grasses, and bushes.

S3 – Situ Gunung forest: dominated by rasamala (*Al. excelsa*), sago palm (*Cycas* sp.), grasses, and bushes.

S4 – Situ Gunung cabbage plantation (*Brassica oleracea capitata*).

S5 – Situ Gunung cassava plantation (*M. esculenta*).

S6 – Situ Gunung chili plantation (*Capsicum* sp.).

S7 – Situ Gunung onion plantation (*Allium cepa*).

S8 – Situ Gunung groundnut plantation (*Arachis hypogaea*).

S9 – Situ Gunung Chinese chard plantation (*Brassica rapa chinensis*).

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Within forests and mixed plantations, earthworms were collected from soil under cleared grasses, bushes, and litters. Meanwhile, in homogenous plantations, earthworms were collected from soil between rows of the plantations.

Earthworm extraction was conducted using a digging and hand-sorting method. A single plot 900 cm<sup>2</sup> wide and 30 cm deep was set up, as earthworms are generally concentrated in the upper 30 cm (Fragoso & Lavelle 1992, Smith *et al.* 2008). Due to the different topographical conditions, the amount of plots made in each area varied from 10 to 75. Those plots in each area were placed randomly and were separated 100 cm apart from each other.

Extracted earthworms were preserved in 70% ethanol prior to identification. Earthworm identification was based on criteria established by Stephenson (1923), Sims & Easton (1972), Easton (1979), and Blakemore (2010).

## Result

We recovered 23 species in 10 genera and 5 families. *Pontoscolex corethrurus* was the only species found in Jambi. Most of the recorded species were megascolecids in Mount Gede with *Ocnerodrilus occidentalis* Eisen, 1878 was the most dominant species.

Phylum Annelida, Class Oligochaeta, Superorder Haplotaxida, Order Megadrili, Suborder Lumbricina

Family Glossoscolecidae

Genus *Pontoscolex*

1. *Pontoscolex corethrurus* (Muller, 1857)

Family Megascolecidae

Genus *Amyntas*

2. *Amyntas aeruginosus* (Kinberg, 1867)

3. *Amyntas asiaticus* Michaelsen, 1900

4. *Amyntas gracilis* (Kinberg, 1867)

5. *Amyntas hupeiensis* (Michaelsen, 1895)

6. *Amyntas illotus* species-group sensu Sims & Easton, 1972

7. *Amyntas minimus* (Horst, 1893)

8. *Amyntas morrisi* species-group sensu Sims & Easton, 1972

9. *Amyntas robustus* (Perrier, 1872)

Genus *Metaphire*

10. *Metaphire californica* (Kinberg, 1867)

11. *Metaphire javanica* (Kinberg, 1867)

12. *Metaphire planata* (Gates, 1926)

Genus *Notoscolex*

13. *Notoscolex javanica* (Michaelsen, 1910)

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Genus *Perionyx*

14. *Perionyx excavatus* Perrier, 1872

Genus *Pheretima*

15. *Pheretima darnleiensis* (Fletcher, 1886)
16. *Pheretima pura* species-group of Sims & Easton, 1972

Genus *Polypheretima*

17. *Polypheretima bifaria* species-group of Easton, 1979
18. *Polypheretima moelleri* (Michaelsen, 1921)
19. *Polypheretima sempoensis* Easton, 1979

Family Ocnerodrilidae

Genus *Ocnerodrilus*

20. *Ocnerodrilus occidentalis* Eisen, 1878

Family Octochaetidae

Genus *Dichogaster*

21. *Dichogaster affinis* (Michaelsen, 1890)

Suborder Moniligastrida

Family Moniligastridae

Genus *Drawida*

22. *Drawida barwelli* (Beddard, 1886)
23. *Drawida nepalensis* Michaelsen, 1907

## Taxonomy

### *Amyntas aeruginosus* Kinberg, 1867

*Amyntas aeruginosus* Kinberg, 1867: 101. [Type locality Guam, Marianas Islands. Types in Stockholm Museum: 154].

*Perichaeta aeruginosa* Beddard, 1891:278.

*Pheretima aeruginosus*: Michaelsen, 1900: 253); Michaelsen, 1903: 94.

*Amyntas aeruginosus* (part): Sims & Easton, 1972: 211; Lee, 1981: 542, figs. 2-6.

**Material examined.**-3 acitellate specimens (dissected), Situ Gunung forest, coll. A. Darmawan, 8 and 18 Oct 2012.

**Description.** Length 76-81 mm. Width (segment xx) 3.00-4.32 mm. Segments 98-101. Colour (preserved) white with white stripe ventrally. Prostomium open epilobus. First dorsal pore 12/13. Setae (segment xx) perichaetine, 44-68. Nephropores absent. Clitellum not seen. Male pores 18, paired, ca. about 0.25. Female pore not seen. Spermathecal pores 7/8,8/9, paired. Genital markings not seen. Septa 4/5-7/8, 10/11-13/14 thick. Dorsal blood vessel single, continuous onto pharynx. Hearts 11-13. Gizzard 8-10. Calciferous glands not seen. Intestine origin 14. Caeca 27-23, simple, paired. Nephridia meroic. Testes holandric. Seminal vesicles 11,12, paired. Ovaries 13, paired. Prostates racemose, paired,

occupying 16-18, ducts open to 18, copulatory pouches absent. Spermathecae 7/8,8/9, paired, no nephridia.

**Distribution:** Cosmopolitan. Oceania domain (Michaelsen 1900, Lee 1981, Easton 1984), Indonesia (Java) (Michaelsen 1903), West New Guinea (Cognetti 1914).

**Remarks:** The name given by Kinberg (1867) was probably incorrect spelling of *Amynthas*. Blakemore (2015, pers. comm.) commented this issue “the name *Amyntas* was incorrect subsequent spelling of correct name *Amynthas* in the same Kinberg paper. This caused problems of homonymy because there is already a genus *Amyntas* (no "h"). Hence somebody put *Pheretima* as the prior genus. But that was a mistake and the correct original and prior genus should be *Amynthas*. *Pheretima* is retained but is a separate (and subordinate)”.

### *Amynthas asiaticus* Michaelsen, 1900

*Amyntas asiaticus* Michaelsen, 1900:13. [Type locality Tien-Tsin, China on Tibet borders. Types in Moscow Museum].

*Pheretima asiatica*: Michaelsen, 1900: 527.

*Amynthas asiaticus*: Sims & Easton, 1972: 236 (*sieboldi* group).

**Material examined.**-2 mature (clitellate) specimens (dissected), Bodogol Forest, coll. A. Darmawan, 30 Jul 2012.

**Description.** Length 42-47 mm. Width (segment xx) 1.64-1.76 mm. Segments 100-104. Colour (preserved) pale white. Prostomium prolobus. First dorsal pore 12/13. Setae (segment xx) perichaetine, about 38. Nephropores absent. Clitellum 14-16, annular. Male pores 18, paired, ca. 0.4-0.5. Female pore 14, midventral. Spermathecal pores 6/7,7/8,8/9, paired, ca. 0.2-0.3. Genital markings not seen. Septa 6/7, 7/8, 10/11-12/13 thick. Dorsal blood vessel single, continuous onto pharynx. Hearts not seen. Gizzard 8-10. Calciferous glands not seen. Intestine origin 15-16. Caeca 27-25,24, simple, paired. Nephridia meroic. Testes holandric. Seminal vesicles 11,12, paired. Ovaries 13, paired. Prostates racemose, paired, occupying 17-19, ducts open to 18, copulatory pouches absent. Spermathecae (6),7,8,(9), paired, diverticula longer than ampulla.

**Distribution:** China, Tibet, SE Asia (Blakemore 2010).

**Remarks:** The name given by Michaelsen (1900) was probably referred to *Amynthas*. See remarks on *A. aeruginosus*.

### *Amyntas gracilis* (Kinberg, 1867)

*Nitocris gracilis* Kinberg, 1867: 102. [Type locality Rio de Janeiro. Types in Stockholm Museum].  
*Perichaeta hawayana* Rosa, 1891: 396. [Type locality Hawaii. Type in Vienna].  
*Perichaeta bermudensis* Beddard, 1892: 160.  
*Perichaeta mandhorensis* Michaelsen, 1892: 241, figs. 18-19. [Types Humboldt Museum, Berlin: 484].  
*Amyntas ijimae*: Beddard, 1900: 635.  
*Pheretima hawayana*: Michaelsen, 1900: 271, 316.  
*Amyntas hawayanus*: Beddard, 1900: 420.  
*Amyntas gracilis*: Sims & Easton, 1972: 235; Easton, 1982: 728; Sims & Gerard, 1985: 130.

**Material examined.** -2 mature (clitellate, 1 half-broken, dissected), and 4 not fully mature (aclitellate, dissected), Situ Gunung forest, coll. A. Darmawan, 10 Oct 2012; 1 not fully mature (aclitellate, dissected), cabbage plantation in Situ Gunung, coll. A. Darmawan, 2 Dec 2013.

**Description.** Length 70-89 mm. Width (segment xx) 2.00-3.78 mm. Segments 70-109. Colour (preserved) pale white. Prostomium open epilobus. First dorsal pore mostly 10/11, sometimes 9/10. Setae (segment xx) perichaetine, about 48-60. Nephropores absent. Clitellum 14-16, annular. Male pores 18, paired, ca. 0.3. Female pore 14, midventral. Spermathecal pores 5/6, 6/7, 7/8, paired. Genital markings 18, discs median to male pores. Septa 4/5-7/8 thick, 10/11-14/15 weak. Dorsal blood vessel single, continuous onto pharynx. Hearts 11-13. Gizzard 8-10. Calciferous glands absent. Intestine origin 15-16. Caeca 27-24, simple or hemipinate, paired. Nephridia meroic. Testes holandric. Seminal vesicles 11, 12, paired. Ovaries 13, paired. Prostates racemose, paired, occupying 16, 17-20, 21 ducts open to 18, copulatory pouches absent. Spermathecae 5/6, 6/7, 7/8, paired, ampulla pear shaped.

**Distribution:** Tropical and warm temperate localities on most continents: Neotropical domain (Gates 1972, Feijoo *et al.* 2004, Brown & Fragoso 2007), Australia (Easton 1982), Hawaii and New Guinea (Nakamura 1992). Rarely reported from northern Europe.

### *Amyntas hupeiensis* (Michaelsen, 1895)

*Perichaeta hupeiensis* Michaelsen, 1895: 35, fig. 11-12. [Type locality Shi-hui-yao by Wuchang in the province of Hupei, China].  
*Amyntas hupeiensis*: Michaelsen, 1899: 6. [From Central Japan (Nakahama)].  
*Pheretima hupeiensis*: Michaelsen, 1900: 273; Chen, 1933: 251, fig. 19; Kobayashi, 1938: 152; Grant, 1955: 49; Gates, 1937: 356; 1958; 1972: 213; 1982: 52.  
*Amyntas hupeiensis*: Sims & Easton, 1972: 237; Easton, 1981: 36, 53; Blakemore, 2003; Chang *et al.*, 2009: 50, fig. 21.

**Material examined.**-2 mature (clitellate, 1 half-broken, dissected), and 2 not fully mature (aclitellate, dissected), Bodogol forest, coll. A. Darmawan, 30Jul 2012

**Description.** Length 42-64 mm. Width (segment xx) 1.36-1.76 mm. Segments 100-114. Colour (preserved) pale white. Prostomium epilobus or proepilobus. First dorsal pore 12/13. Setae (segment xx) perichaetine, 42-48. Nephropores absent. Clitellum 14-16, annular. Male pores 18, paired, ca. 0.2. Female pore 14, midventral. Spermathecal pores 6/7,7/8,8/9, paired. Genital markings 18, paired discs on segments 17 and 19. Septa 5/6,7/8 thick, 10/11-13/14 weak. Dorsal blood vessel single, continuous onto pharynx. Hearts seen in 13. Gizzard 8-10. Calciferous glands absent. Intestine origin 15-16. Caeca 27-25, simple, paired. Nephridia meroic. Testes holandric. Seminal vesicles 11, 12, paired. Ovaries 13, paired. Prostates racemose, paired, occupying 17-19 ducts open to 18, copulatory pouches absent. Spermathecae 6,7,8, paired, diverticula longer than ampulla.

**Distribution:** East Asia, Vietnam (Michaelsen 1899, Michaelsen 1900, Easton 1981, Blakemore 2010) and introduced into North America, New Zealand (Easton 1981), Australia.

### ***Amyntas illotus* species-group sensu Sims & Easton, 1972**

*Amyntas illotus* species-group Sims & Easton, 1972: 236.

*Amyntas illotus* group; Easton, 1981: 53.

*Amyntas illotus* group; Tsai *et al.*, 2002.

**Material examined.**-2 aclitellate (dissected), Bodogol mixed plantation, coll A. Darmawan, 10 and 14 Oct 2013; 1 aclitellate (dissected), Bodogol avocado plantation, coll A. Darmawan, 30 Sep 2013; 1 aclitellate (dissected), Situ Gunung forest, coll A. Darmawan, 12 Oct 1012; 1 clitellate (dissected), Situ Gunung forest, coll A. Darmawan, 18 Oct 2012; 1 acclitellate (dissected), Situ Gunung chilli plantation, coll A. Darmawan, 9 Dec 2013.

**Description.** Length 60-100 mm. Width (segment xx) 1.00-4.00 mm. Segments 85-120. Colour (preserved) pale brown. Prostomium epilobus. First dorsal pore 12/13. Setae (segment xx) perichaetine, 40-56. Nephropores absent. Clitellum 14-16, annular, or absent. Male pores 18, paired, or absent. Female pore 14, midventral, or absent. Spermathecal pores absent. Genital markings absent. Septa 4/5-7/8,11/12-16/17 thick. Dorsal blood vessel single, continuous onto pharynx. Hearts 11-13. Gizzard 8-10,11. Calciferous glands absent. Intestine origin 14-18. Caeca 27-25, simple, paired. Nephridia meroic. Testes holandric or absent. Seminal vesicles 10,11, paired, or absent. Ovaries 13, paired. Prostates racemose, paired, very small on 17 without copulatory pouches, or absent. Athecate.

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Parthenogenetic morph of this species may be lacking of male reproductive organs.

**Distribution:** Most of these parthenogenetic events have no particular biogeographic nor phylogenetic merit. Reported from China, Taiwan, Korea, Japan, Myanmar (Blakemore 2010).

### *Amyntas minimus* (Horst, 1893)

*Perichaeta minima* Horst, 1893: 66, fig. 27. [Type locality Tjibodas, Java. Primary type in Leiden Museum: 1836].

*Pheretima enchytraeoides* Michaelsen, 1916: 33. [Type locality in Queensland].

*Pheretima zoysiae* Chen, 1933: 288, fig. 27. [Type locality Chekiang. Types in Nanking (Ann. 570) or in Smithsonian Institution].

*Pheretima humilis* Gates, 1942: 120.

*Pheretima subtilis* Gates, 1943: 104.

*Pheretima minima*: Gates, 1961: 298, 306, 308; Gates, 1972: 201; 1982: 57.

*Amyntas minimus*: Easton, 1979: 119; Easton, 1981: 55; Easton, 1982: 728; Easton, 1984: 118.

**Material examined.** -1 mature (clitellate), dissected, Situ Gunung forest, coll A. Darmawan, 8 Oct 2012.

**Description.** Length about 50 mm. Width (segment xx) about 1 mm. Segments not counted. Colour (preserved) pigmentless. Prostomium and first dorsal pores not observed. Setae perichaetine. Nephropores absent. Clitellum 14-16, annular. Male pores 18, paired. Female pore 14, midventral, or absent. Spermathecal pores 5/6, paired, or absent. Genital markings 20 on median. Septa, dorsal blood vessel, and hearts not observed. Gizzard 9-11. Calciferous glands absent. Intestine origin 16. Caeca 27-25, simple, paired. Nephridia meroic. Testes, seminal vesicles, and ovaries not observed. Prostates racemose, paired, very small on 18, copulatory pouches absent. Spermathecae 5/6, paired, ampulla and diverticula long without nephridia, or absent.

**Distribution:** USA, West and South Africa, Oriental domain, Papua New Guinea, Australia, Oceania domain (Blakemore 2010).

### *Amyntas morrisi* species-group sensu Sims & Easton, 1972

*Perichaeta morrisi* Beddard, 1892: 166, Pl. IX, fig. 1. [Types in British Museum 1904:10.5.199-201].

*Pheretima morrisi*: Michaelsen, 1900: 287; Chen, 1933: 267; Gates, 1937: 361; 1968: 253; Gates, 1972: 202; 1982: 59.

*Amyntas barbadensis*: Michaelsen, 1900: 254.

*Pheretima hawayana lineata* Gates, 1926: 154; 1931: 384-386, fig. 24 of spermathecae.

*Amyntas morrisi*: Sims & Easton, 1972: 236, figs. 1A, 1H; Easton, 1981: 55; Easton, 1982: 729, fig. 4c; Sims & Gerard, 1985: 132, fig. 47a; Chang *et al.*, 2009: 60, fig. 26.

**Material examined.**-1 mature (clitellate), dissected, Situ Gunung forest, coll A. Darmawan, 10 Oct 2012.

**Description.** Length about 65 mm. Width about 2.5 mm. Segments 108. Colour (preserved) pale white. Prostomium epilobus. First dorsal pore not observed. Setae perichaetine. Nephropores absent. Clitellum 14-16, annular. Male pores 18, paired. Female pore 14, midventral. Spermathecal pores 5/6,6/7, paired. Genital markings and septa not observed. Dorsal blood vessel single, continuous onto pharynx. Hearts not observed. Gizzard 8-10. Calciferous glands and intestine origin not observed. Caeca from 27, simple, paired. Nephridia meroic. Testes, seminal vesicles, and ovaries not observed. Prostates racemose on 18, copulatory pouches absent. Spermathecae 6,7, paired, no nephridia.

**Distribution:** Originally from China or Japan. Reported in Middle and South America (Gates 1982, Brown & Fragoso 2007), Europe (England, Spain, Italy), Oriental domain (Gates 1972), New Guinea (Sillitoe 2003), Australia (Brisbane) (Easton 1982), Hawaii.

### *Amyntas robustus* (Perrier, 1872)

*Perichaeta robusta* Perrier, 1872: 112, figs. 67-68. [Type locality Ile de France (= Mauritius). Types in Paris Museum].

*Perichaeta masatacae* Beddard, 1892: 761. [Types in British Museum, listed as BMNH: 1904.10.5.91-2]; Ohfuchi, 1938: 62, figs. 6-7; Sims & Easton (1972: 181).

*Pheretima robusta*: Michaelsen, 1900: 299; Gates, 1935: 15; Ljungström, 1971: 27.

*Pheretima lauta*: Chen, 1933: 282, fig. 26.

*Pheretima corrugata* Chen, 1931: 131; 1933: 278 (non *corrugata kulingiana*). [Szechuan. Types in Smithsonian Institution].

*Amyntas robustus*: Sims & Easton, 1972: 234; Easton, 1981: 56.

**Material examined.**-3 mature (clitellate, 1 half broken), dissected, Bodogol forest, coll. A. Darmawan, 31 Jul 2012 and 2 Aug 2012; 3 not fully mature (aclitellate, 1 half broken), dissected, Bodogol forest, coll. A. Darmawan, 1, 2, and 7 Aug 2012; 1 mature (clitellate), dissected, Bodogol mixed plantation, coll. A. Darmawan, 14 Oct 2013; 1 immature (aclitellate), dissected, Bodogol mixed plantation, coll. A. Darmawan, 10 Oct 2013; 5 mature (clitellate, 1 half broken), dissected, Situ Gunung forest, coll. A. Darmawan, 10, 16, and 18 Oct 2012; 13 not fully mature (aclitellate, 3 half broken), dissected, Situ Gunung forest, coll. A. Darmawan, 8, 10, 16, and 18 Oct 2012.

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**Description.** Length 69-160 mm. Width (segment xx) 1.76-5.4 mm. Segments 87-128. Colour (preserved) pale brown or pale white. Prostomium open epilobus. First dorsal pore 11/12 or 12/13. Setae (segment xx) perichaetine, 32-48. Nephropores absent. Clitellum 14-16, annular. Male pores 18, paired, ca. 0.3-0.5. Female pore 14, single, midventral. Spermathecal pores 7/8,8/9, paired. Genital markings not seen. Septa 5/6-7/8 strong, 10/11 backward weak. Dorsal blood vessel single, continuous onto pharynx. Hearts 11-13. Gizzard 8-10. Calciferous glands absent. Intestine origin 14,15, or 16. Caeca 27-22, simple, paired. Nephridia meroic. Testes holandric. Seminal vesicles 11,12, paired. Ovaries 13, paired. Prostates racemose occupying 16-22, paired, ducts open to 18, copulatory pouches absent. Spermathecae 7,8, paired, no nephridia.

**Distribution:** A probable homeland is in China (Gates 1972). Reported from Oriental domain (Thai & Samphon 1991), China, Taiwan, Korea, Japan (Easton 1981).

### *Dichogaster affinis* (Michaelsen, 1890)

*Benhamia affinis* Michaelsen, 1890: 9, fig. 20. [Type locality Quilimane, Zanzibar. Type in Hamburg Museum].

*Benhamia mexicana* Rosa, 1891: 394.

*Benhamia crassa* Beddard, 1893: 681, figs. 6,7. [Types at Kew obtained from Lagos. Type BMNH 1904:10:5:829].

*Dichogaster affinis*: Michaelsen, 1900: 345; 1903: 20; Gates, 1942: 128; Gates, 1972: 278.

*Dichogaster sinuosus* Stephenson, 1931: 74. [From Lalaw, Burma. Syntypes BMNH 1930:5:9:22-24].

*Dichogaster* (*Diplotheodrilus*) *affinis*: Csuzdi, 1996: 357; 2000: 58.

**Material examined.**-1 mature (clitellate), dissected, Bodogol mixed plantation, coll. A. Darmawan, 4 Nov 2013; 1 mature (clitellate), dissected, Situ Gunung forest, coll. A. Darmawan, 16 Oct 2012.

**Description.** Length 40-60 mm. Width (segment xx) 1-2 mm. Segments >95. Colour (preserved) pigmentless. Prostomium epilobus. First dorsal pore 5/6. Setae (segment xx) lumbricine, closely paired ventrally. Nephropores minute. Clitellum probably 13-20, saddle. Male pores grooves on 17-19. Female pores 14, paired on raised pad. Spermathecal pores 7/8,8/9, paired. Genital markings not seen. Septa 8/9-12/13 strong. Dorsal blood vessel single, continuous onto pharynx. Hearts 11-12. Two gizzards, co-joined, seen in 7-8. Calciferous glands 15-17, 3 pairs. Intestine origin 17. Acaecate. Nephridia meroic. Testes holandric. Seminal vesicles 11,12, paired. Ovaries 13, paired. Prostates confined in 17-19, paired. Spermathecae 7,8, paired.

**Distribution:** Oriental domain (Julka 1988, Thai 2000, Blakemore 2010), American continent (Michaelsen 1900, Michaelsen 1903, Csuzdi 1997, Csuzdi 2000, Brown & Fragoso 2007), African continent (Talavera 1992), Pacific Islands (Easton 1984), Australia (Blakemore 2010).

### *Drawida barwelli* (Beddard, 1886)

*Moniligaster barwelli* Beddard, 1886: 94, figs. 4-6; Beddard, 1887: 678; Beddard, 1893: 692; Beddard, 1895: 200. [Type locality Manila, Luzon, P.I.].

*Moniligaster bahamensis* Beddard, 1893: 690, figs 1-5; Beddard, 1895: 202. [Type locality Bahamas].

*Drawida barwelli* (part?): Michaelsen, 1900: 116.

*Drawida bahamensis*: Michaelsen, 1900: 118; Gates, 1965: 85.

*Drawida japonicus bahamensis*: Michaelsen, 1910: 50.

*Drawida barwelli*: Blakemore, 2010.

*Drawida barwelli*: laps.Global Names Index, 2010 (<http://www.organismnames.com/details.htm?lsid=628477>).

**Material examined.**-2 mature (clitellate), dissected, Bodogol forest, coll. A. Darmawan, 30 Jul and 1 Aug 2012; 1 mature (clitellate), dissected, Situ Gunung forest, coll A. Darmawan, 12 Oct 2012.

**Description.** Length 26-70 mm. Width (segment xx) 0.84-1.24 mm. Segments 94-153. Colour (preserved) pigmentless. Prostomium prolobus. Dorsal pores absent. Setae (segment xx) lumbricine, closely paired ventrally. Nephropores present. Clitellum indistinct in 10-13, saddle. Male pores 10/11, paired. Female pores 12, paired. Spermathecal pores 7/8, paired. Genital markings not seen. Septa 5/6-14/15 strong. Dorsal blood vessel single. Hearts 8-9. Three moniliform gizzards in 13, 14, 15. Calciferous glands absent. Intestine origin 20. Acaecate. Nephridia holoic. Testes 9, paired. Seminal vesicles not observed. Ovaries 11, paired. Prostates 10, paired, small. Spermathecae 7/8, paired.

**Distribution:** The original home is thought to be in the Indo-China region (Gates 1972). Reported in Neotropical domain (Gates 1982), England, Vietnam, Philippines, Sumatra, Australasia domain (Standen 1988, Blakemore 2010), Oceania domain (Gates 1982, Easton 1984).

### *Drawida nepalensis* Michaelsen, 1907

*Drawida burchardi* Michaelsen, 1903: 7. [From Sumatra (Lomgei Lalah, Indragiri)].

*Drawida nepalensis* Michaelsen, 1907: 146. [From Gowchar near Katmandu, Nepal. Types in Hamburg, 7140]; Stephenson, 1923: 146; Gates, 1934: 242; 1962: 331; 1972: 256; 1972: 257; 1982: 18.

*Drawida troglodytes* Stephenson, 1924: 129. [From 2,000 ft. at entrance, Siju Cave, Garo Hills, Assam. Type in Indian Museum W 1150/1].

*Drawida abscisa* Gates 1962: 336-339. [From Sandoway, Bay of Bengal, Myanmar. Types Indian Museum 3068].

**Material examined.**-2 not fully mature (aclitellate, 1 half broken), dissected, Bodogol forest, coll. A. Darmawan, 7 Aug 2012; 1 mature (clitellate), dissected, Situ Gunung forest, coll. A. Darmawan, 10 Oct 2012; 1 not fully mature (aclitellate), dissected, Situ Gunung forest, coll. A. Darmawan, 8 Oct 2012.

**Description.** Length 71-95 mm. Width (segment xx) 3.20-3.93 mm. Segments 146-171. Colour (preserved) pale white. Prostomium prolobus. Dorsal pores absent. Setae (segment xx) lumbricine, closely paired. Nephropores present. Clitellum 10-13, annular. Male pores 10/11 or 11, paired. Female pores 11/12, paired. Spermathecal pores probably 7/8, paired. Genital markings not seen. Septa 5/6-11/12 thick. Dorsal blood vessel single, continuous onto pharynx. Hearts 10. Four moniliform gizzards, 14-25, 26. Calciferous glands not seen. Intestine origin 26 or 27. Acaecate. Nephridia holoic. Testes 9, 10, paired. Seminal vesicles not seen. Ovaries 11, paired. Prostates probably in 10, paired. Spermathecae not seen.

**Distribution:** Oriental domain, China.

### *Metaphire californica* (Kinberg, 1867)

*Pheretima californica* (part) Kinberg, 1867:102. [Type locality Sausalita Bay, California. Types from San Francisco in the Stockholm Museum: 160].

*Perichaeta hesperidum* Beddard, 1892:169. [Type locality Barbados. Types BM 1904:10:5:13].

*Amyntas hesperidum*: Beddard, 1900: 417.

*Pheretima californica*: Michaelsen, 1900: 258, 275; 1903: 95; Gates, 1937: 312, 348; 1972: 174; 1982: 42.

*Pheretima kiangensis* Michaelsen, 1931: 21. [Soochow. Types in Hamburg].

*Pheretima sakaguchii* Ohfuchi, 1938: 53, figs. 1-2. [From Wakayama-ken and Kochi-ken, i.e., widespread].

*Metaphire californica* Sims & Easton, 1972: 238; Easton, 1981: 57; Easton, 1982:731; Sims & Gerard, 1985: 132, fig. 47c.

**Material examined.**-5 mature (clitellate, 2 half broken), dissected, Bodogol forest, coll. A. Darmawan, 31 Jul and 2 Aug 2012; 1 not fully mature (aclitellate), dissected, Bodogol forest, coll. A. Darmawan, 30 Jul 2012; 6 mature (clitellate), dissected, Bodogol mixed plantation, coll. A. Darmawan, 10 and 14 Oct 2013; 1 mature (clitellate), dissected, Bodogol avocado plantation, coll. A. Darmawan, 3 Oct 2013; 5 mature (clitellate, 1 half broken), dissected, Situ Gunung forest, coll. A. Darmawan, 10, 12, 16, and 18 Oct 2012; 2 mature (clitellate), dissected, Situ Gunung cabbage plantation, coll. A. Darmawan, 2 Dec 2013; 2 not fully mature (aclitellate), dissected, Situ Gunung cabbage plantation, coll. A. Darmawan, 2 Dec 2013.

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**Description.** Length 50-200 mm. Width (segment xx) 1.00-4.56 mm. Segments 80-118. Colour (preserved) pale brown. Prostomium open epilobus. First dorsal pore varied from 7/8 (rare) to 12/13 (common). Setae (segment xx) perichaetine, 36-52. Nephropores absent. Clitellum 14-16, annular. Male pores 18, paired, ca. 0.3-0.4. Female pore 14, midventral. Spermathecal pores 7/8,8/9, paired. Genital markings not seen. Septa 4/5-7/8, 10/11-13/14 thick. Dorsal blood vessel single, continuous onto pharynx. Hearts 11-13. Gizzard 8-10. Calciferous glands absent. Intestine origin 15 or 16. Caeca 27-22, simple, paired. Nephridia meroic. Testes holandric. Seminal vesicles 11,12, paired. Ovaries 13, paired. Prostates racemose, paired, occupying 15-23, ducts open to 18, copulatory pouches present. Spermathecae 7,8, paired, ampulla large, diverticula long and coiled, no nephridia.

**Distribution:** Probably indigenous to China or Japan. Recorded many times from the around the world: American continent, South Africa, Portugal (Madeira, Azores), Egypt, Greece, French, Lebanon, Myanmar, Vietnam, China, Taiwan, Japan, Australia, Hawaii, Easter Island.

### ***Metaphire javanica sensu stricto Blakemore, 2010***

*Rhodopis javanica* Kinberg, 1867: 102. [Type locality Tjibodas, Java. Types in Stockholm Museum: 1946].

*Perichaeta javanica* Beddard, 1891: 76.

*Perichaeta operculata* Rosa 1891: 98.

*Pheretima capensis*: Michaelsen, 1900: 259-260.

*Pheretima inflata*: Michaelsen, 1916: 13.

*Metaphire javanica*: Sims & Easton, 1972:215-216.

**Material examined.**-2 mature (clitellate, half broken), dissected, Bodogol forest, 30 Jul and 7 Aug 2012; 1 mature (clitellate), dissected, Situ Gunung forest, coll. A. Darmawan, 8 Oct 2012.

**Description.** Length up to 211 mm. Width (segment xx) 3.89-6.14 mm. Segments about 89. Colour (preserved) brown-purple. Prostomium open epilobus. First dorsal pore varied from 8/9 to 12/13. Setae (segment xx) perichaetine, about 42. Nephropores absent. Clitellum 14-16, annular. Male pores 18, paired, ca. 0.2-0.3. Female pore 14, midventral. Spermathecal pores 7/8,8/9, paired. Genital markings absent. Septa 6/7,7/8, 10/11-13/14 thick. Dorsal blood vessel single, continuous onto pharynx. Hearts 11-13. Gizzard 8-10. Calciferous glands absent. Intestine origin 15 or 16. Caeca 27-24, simple, paired. Nephridia meroic. Testes holandric. Seminal vesicles 11,12, paired. Ovaries 13, paired. Prostates racemose, paired, occupying 16-22, ducts open to 18, copulatory pouches present. Spermathecae 7/8,8/9, paired, diverticula long and coiled, no nephridia.

**Distribution:** South Africa, Indonesia (Java), Timor, China (Hongkong).

### ***Metaphire planata* (Gates, 1926)**

*Pheretima planata* Gates, 1926: 411; Gates, 1972: 211. [Type locality Rangoon. Topotypes in US National Museum].

*Metaphire planata*: Sims & Easton, 1972: 217, 239.

**Material examined.**-3 mature (clitellate), dissected, Bodogol forest, coll. A. Darmawan, 7 Aug 2012; 1 mature (clitellate), dissected, Bodogol mixed plantation, coll. A. Darmawan, 10 Oct 2013.

**Description.** Length 38-100 mm. Width (segment xx) 0.92-3.00 mm. Segments 72-86. Colour (preserved) pale brown-purple. Prostomium epilobus. First dorsal pore varied from 6/7 to 12/13. Setae (segment xx) perichaetine, 34. Nephropores absent. Clitellum 14-16, annular. Male pores 18, paired. Female pore 14, midventral. Spermathecal pores near 6/7,7/8, paired. Genital markings not seen. Septa 4/5,7/8 thick. Dorsal blood vessel single, continuous onto pharynx. Hearts 11-13. Gizzard 8-10. Calciferous glands absent. Intestine origin 15 or 16. Caeca 27-23, simple, paired. Nephridia meroic. Testes probably holandric. Seminal vesicles 11,12, paired. Ovaries 13, paired. Prostates racemose, paired, occupying 17-20, ducts open to 18, copulatory pouches present. Spermathecae 7,8, paired, diverticula long, no nephridia.

**Distribution:** India, Bangladesh (Dacca), Myanmar, Thailand (Chiengmai, Ko Chang), Malaysia.

### ***Notoscolex javanica* (Michaelsen, 1910)**

*Woodwardia javanica* Michaelsen, 1910: 93. [Buitenzorg, Java].

*Woodwardiella javanica*: Gates, 1942: 108.

*Lenoscolex javanica*: Gates, 1960: 243; 1972:136; Blakemore, 2010: 272.

*Notoscolex javanica*: Gates, 1961: 57.

**Material examined.**-2 not fully mature (aclitellate), dissected, Bodogol mixed plantation, coll. A. Darmawan, 17 Oct and 4 Nov 2013.

**Description.** Length 70-80 mm. Width (segment xx) 1 mm. Segments about 121. Colour (preserved) pale white. Prostomium prolobus or epilobus. First dorsal pore varied from 6/7. Setae (segment xx) lumbricine. Nephropores absent. Clitellum not seen in current specimens. Male pores 18, paired. Female pore 14, midventral. Spermathecal pores probably on 7/8,8/9, paired. Genital markings not seen. Septa 5/6,6/7 strong, 13/14-16/17 weak. Dorsal blood vessel single, continuous onto

pharynx. Hearts not observed. Gizzard 5 or 6. Calciferous glands absent. Intestine origin 18. Acaecate. Nephridia meroic. Testes not observed. Seminal vesicles 11,12, paired. Ovaries not observed. Prostates racemose, paired, ducts open to 18, copulatory pouches absent. Spermathecae about 7,8, paired.

**Distribution:** Myanmar (Boyagyi, Thaton district, Mupun, Amherst district) and Java (presumably by introduction).

### *Ocnerodrilus occidentalis* Eisen, 1878

*Ocnerodrilus occidentalis* Eisen, 1878: 10. [Type locality Fresno County]; Michaelsen, 1900: 377; Gates, 1972: 273; 1973; Lee, 1981: 567; Gates 1982: 16.

*Ocnerodrilus calwoodi* Michaelsen, 1898/9.

*Ocnerodrilus tenellulus* Gates, 1945:223. [Type locality Allahabad].

**Material examined.**-3 not fully mature (aclitellate), dissected, Bodogol cucumber plantation, coll. A. Darmawan, 3 and 7 Oct 201; 1 not fully mature (aclitellate), dissected, Situ Gunung forest, coll. A. Darmawan, 10 Oct 2012; 1 mature (clitellate), dissected, Situ Gunung Chinese chard plantation, coll. A. Darmawan, 23 Dec 2013.

**Description.** Length 60-70 mm. Width (segment xx) 1-2 mm. Segments about 106-122. Colour (preserved) pale white. Prostomium prolobus or epilobus. Dorsal pores absent. Setae (segment xx) lumbricine, closely paired. Nephropores present in most specimens. Clitellum seen between 10-17. Male pores probably on 17, paired. Female pores 14, paired, lateral. Spermathecal pores not seen. Genital markings absent. Septa 5/6 onward thick. Dorsal blood vessel single, continuous onto pharynx. Hearts not seen. Gizzard absent. Calciferous glands 9, paired. Intestine origin 12-14. Acaecate. Nephridia holoic. Testes probably holandric. Seminal vesicles 11,12, paired. Ovaries 13, paired. Prostates thin long duct from 17 to 23. Spermathecae present in 7/8 with big ampulla, or absent.

**Distribution:** The original home is thought to be in Central or South America. Pan-tropical, especially if all the reports of various parthenogenetic morphs are included, Australia and Tasmania (Blakemore 2010), less frequently found in temperate regions.

### *Perionyx excavatus* Perrier, 1872

*Perionyx excavatus* Perrier, 1872: 126, figs. 73, 74. [Type locality Saigon. Types in Paris Museum]; Michaelsen, 1900: 208; Stephenson, 1932: 50; Gates, 1972: 141, 1982: 36.

*Perionyx gruenewaldi* Michaelsen, 1891: 33. [Types Leiden and Hamburg, 1914].

*Perionyx intermedius* Beddard, 1892: 689.

*Perionyx parvulus* Stephenson, 1916: 321, fig. 15. [Types in Calcutta].

*Perionyx fulvus* Stephenson, 1916: 322.

**Material examined.**-1 mature (clitellate), dissected, Bodogol mixed plantation, coll. A. Darmawan, 10 Oct 2013.

**Description.** Length about 91 mm. Width (segment xx) about 2 mm. Segments 73. Colour (preserved) dark purple dorsally, pale ventrally. Prostomium open epilobus. First dorsal pore 4/5. Setae (segment xx) perichaetine, 44. Nephropores present. Clitellum 13-17, annular. Male pores 18, very closely paired ventrally. Female pore 14, midventral. Spermathecal pores 7/8,8/9, closely paired ventrally. Genital markings pad under male pores. Septa not observed. Dorsal blood vessel single, continuous onto pharynx. Hearts 11-12. Gizzard absent. Calciferous glands swollen oesophagus in 10-12. Intestine origin 18. Acaecate. Nephridia holoic. Testes holandric. Seminal vesicles 12,13, paired. Ovaries 13, paired. Prostates racemose, paired, copulatory pouches absent. Spermathecae 8,9, paired.

**Distribution:** Original home of this species is believed to be in the Himalayas, deliberate or accidental transportation has greatly extended its range. Reported in USA, Mexico, West Indies (Dominica and Cuba), Africa (Comoro, Samoa, Reunion), Madagascar, UK, Oriental domain, Japan, Korea, Australia, New Zealand, Fiji, Hawaii. Rarely reported from northern Europe.

### *Pheretima darnleiensis* (Fletcher, 1886)

*Perichaeta darnleiensis* Fletcher, 1886:966. [From Darnley Island, Torres Straits, Australia].

*Perichaeta vaillanti* Bedard, 1895: 422; Michaelsen, 1900: 311.

*Perichaeta martensi* Michaelsen, 1892: 242. [From Banka Island east of Sumatra. Types Berlin: 2148]; Michaelsen 1900: 282.

*Perichaeta bosschae* Beddard, 1895: 432; Michaelsen, 1900: 256.

*Perichaeta darnleiensis*: Beddard, 1895: 406.

*Amyntas padasensis lokonensis* Michaelsen, 1899:74. [From Lokon-Gipfel, Tomohon, North Celebes. Type in Basel Museum].

*Amyntas padasensis madelinae*: Michaelsen, 1899:76.

*Amyntas padasensis padasensis*: Michaelsen, 1899: 74.

*Amyntas martensi*: Michaelsen, 1899: 87.

*Amyntas padasensis*: Beddard, 1900a: 624.

*Pheretima belli*: Michaelsen, 1900: 255.

*Pheretima bosschae*: Michaelsen, 1900: 256.

*Pheretima darnleyensis*: Michaelsen, 1900: 263.

*Pheretima floweri*: Michaelsen, 1900: 267.

*Pheretima indica* (part): Michaelsen, 1900: 275; Michaelsen, 1922: 41; Michaelsen, 1928: 40; 1935: 108; Gates, 1935: 82, 83, 94; 1936: 389; 1937: 320; 1949: 26.

*Pheretima martensi*: Michaelsen, 1900: 282.

*Pheretima padasensis typica*: Michaelsen, 1900: 290.

*Pheretima padasensis lokonensis*: Michaelsen, 1900: 290.

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*Pheretima padasensis madelinae*: Michaelsen, 1900: 291.

*Pheretima vaillanti*: Michaelsen, 1900: 311.

*Pheretima decipiens* Beddard, 1912:180. [From Luzon, Philippines].

*Pheretima benguetensis* Beddard, 1912:183, fig. 1. [From 1,524 m in the Province of Benguet, Luzon, Philippines].

*Pheretima kuchingensis* Stephenson, 1916: 337. [Type in Calcutta: 6539].

*Pheretima indica birangi* Michaelsen, 1928: 42.

*Pheretima floweri*: Gates, 1934: 25.

*Pheretima padasensis*: Kobayashi, 1941: 397, fig. 3. [From Caroline Isls.].

*Pheretima (Pheretima) darnleiensis*: Sims & Easton, 1972: 260; Easton, 1982: 732; 1984: 119.

**Material examined.**-3 mature (clitellate), dissected, Bodogol avocado plantation, coll. A. Darmawan, 3 and 7 Oct 2013.

**Description.** Length 70-200 mm. Width (segment xx) 3-4 mm. Segments 86-103. Colour (preserved) dark purple or brown. Prostomium open epilobus. First dorsal pore 12/13. Setae (segment xx) perichaetine, 48-56. Nephropores absent. Clitellum 14-16, annular. Male pores 18, paired. Female pore 14, midventral. Spermathecal pores 5/6,6/7,7/8,8/9 paired. Genital markings not seen. Septa 4/5-7/8 strong, 11/12-12/13 weak. Dorsal blood vessel single, continuous onto pharynx. Hearts 11-13. Gizzard 8-10/11. Calciferous glands absent. Intestine origin 15-16. Caeca 27-24, simple, paired. Nephridia meroic. Testes holandric. Seminal vesicles 11,12, paired. Ovaries 13, paired. Prostates racemose, paired, occupying 16-19, ducts open to 18, copulatory pouches present. Spermathecae 5,6,7,8, paired, nephridia present.

**Distribution:** the tropical Indo-Australasian Archipelago and islands, (Stephensen 1932, Gates 1935, Michaelsen 1935) Fiji and Darnley Island in the Torres Straits.

### *Pheretima pura* species-group of Sims & Easton, 1972

*Pheretima pura* Michaelsen 1900: 296

*Pheretima pura*: Sims & Easton, 1972: 220

**Material examined.**-1 not fully mature (aclitellate), dissected, Bodogol combined avocado and cassava plantation, 30 Sep 2013.

**Description.** Length 80-90 mm. Width (segment xx) 2-3 mm. Segments more than 98. Colour (preserved) dark purple. Prostomium epilobus. First dorsal pore 11/12. Setae (segment xx) lumbricine. Nephropores absent. Clitellum probably 14-16, annular. Male pores 18, paired. Female pore 14, midventral. Spermathecal pores 6/7,7/8, paired. Genital markings not seen. Septa 4/5-7/8, 11/12-12/13 weak. Dorsal blood vessel single, continuous onto pharynx. Hearts seen in 13. Gizzard 8-10. Calciferous glands not seen. Intestine origin 15-16. Caeca 27-25, simple,

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paired. Nephridia meroic. Testes seen in 11. Seminal vesicles 11,12, paired. Ovaries 13, paired. Prostates racemose, paired, ducts open to 18, copulatory pouches present. Spermathecae 6/7,7/8, paired, nephridia present.

**Distribution:** Lesser Sunda Islands (Nugroho 2010), Lombok (Michaelsen 1900).

**Remarks:** This species was identified following Sims & Easton (1972). They did not include the description in their paper.

### ***Polypheretima bifaria* species-group of Easton, 1979**

*Pheretima bifaria* Michaelsen, 1924: 18.

*Pheretima* (*Polypheretima*) *bifaria*: Michaelsen, 1934: 16.

*Pheretima* (*Polypheretima*) *bifaria typical*: Michaelsen, 1938: 171.

*Pheretima* (*Polypheretima*) *bifaria wirzi*: Michaelsen, 1938: 171.

*Metapheretima bifaria bifaria* Sims & Easton, 1972: 233.

*Metapheretima bifaria wirzi* Sims & Easton, 1972: 233.

*Polypheretima bifaria*: Easton, 1979: 41, figs. 14h, 19a.

**Material examined.**-1 not fully mature, dissected, Situ Gunung forest, coll. A. Darmawan, 18 Oct 2012.

**Description.** Length 44-55 mm. Width (segment xx) 1 mm. Segments not counted. Colour pale white. Prostomium and first dorsal pore not observed. Setae (segment xx) perichaetine. Nephropores absent. Clitellum probably 14-16, annular. Male pores and female pores not observed. Spermathecal pores 5/6,6/7,7/8, paired. Genital markings, septa, dorsal blood vessel, and hearts not observed. Gizzard 9-10. Calciferous gland not observed. Intestine origin 15. Acaecate. Nephridia meroic. Testes holandric. Seminal vesicles 11,12, small. Ovaries not observed. Prostates racemose, copulatory pouches absent. Spermathecae 5/6,6/7,7/8, no nephridia.

**Distribution:** Kepulauan Aru (Easton 1979), Papua New Guinea (Blakemore & Nugroho 2008).

### ***Polypheretima moelleri* (Michaelsen, 1921)**

*Pheretima molleri* Michaelsen, 1921: 12

*Metapheretima moelleri*: Sims & Easton, 1972: 233

*Polypheretima moelleri*: Easton, 1979: 38, fig. 14c.

**Material examined.**-1 mature (clitellate), dissected, Situ Gunung forest, coll. A. Darmawan, 8 Oct 2012; 3 not fully mature (aclitellate), dissected, Situ Gunung forest, coll. A. Darmawan, 8 Oct 2012.

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**Description.** Length 71-100 mm. Width (segment xx) 3.16-4.10 mm. Segments more than 117-126. Colour (preserved) white. Prostomium prolobus or epilobus. First dorsal pore 12/13. Setae (segment xx) perichaetine, 56-68. Nephropores absent. Clitellum 14-16, annular. Male pores 18, paired. Female pores not seen. Spermathecal pores 4/5,5/6,6/7,7/8,8/9, paired. Genital markings not seen. Septa 5/6,6/7, 10/11-12/13 strong. Dorsal blood vessel single, continuous onto pharynx. Hearts seen in 10-13. Gizzard 7-10. Calciferous glands not seen. Intestine origin 14-15. Acaecate. Nephridia meroic. Testes holandric. Seminal vesicles 11,12, paired. Ovaries 13, paired. Prostates racemose, paired, ducts open to 18, copulatory pouches absent. Spermathecae 4/5,5/6,6/7,7/8,8/9, paired, diverticula short, no nephridia.

**Distribution:** Indonesia (Sand Bay, South coast of Java) (Easton 1979, Blakemore & Nugroho 2008).

### ***Polypheretima sempoensis* Easton, 1979**

*Polypheretima sempoensis* Easton, 1979: 39, figs. 14d, 18b.

**Material examined.**-2 mature (clitellate), dissected, Situ Gunung forest, coll. A. Darmawan, 8 and 12 Oct 2012; 1 not fully mature (aclitellate), dissected, Situ Gunung forest, coll. A. Darmawan, 12 Oct 2012.

**Description.** Length 50-60 mm. Width (segment xx) about 1.76 mm. Segments more than about 81. Colour (preserved) white. Prostomium not observed. First dorsal pore probably 13/14. Setae (segment xx) perichaetine. Nephropores absent. Clitellum 14-16, annular. Male pores 18, paired. Female pore 14, midventral. Spermathecal pores probably 5/6,6/7, paired. Genital markings not observed. Septa 5/6-7/8, 10/11-12/13 strong. Dorsal blood vessel single, continuous onto pharynx. Hearts seen in 11-14. Gizzard 8-10. Calciferous glands not seen. Intestine origin 14-16. Acaecate. Nephridia meroic. Testes probably holandric. Seminal vesicles 11,12, paired. Ovaries 13, paired. Prostates racemose, paired, ducts open to 18, copulatory pouches absent. Spermathecae 5/6,6/7.

**Distribution:** Indonesia (Mount Raung, Sempol (1400–1500 m), East Java) (Easton 1979, Blakemore & Nugroho 2008).

### ***Pontoscolex corethrurus* (Müller, 1857)**

*Lumbricus corethrurus* Müller, 1857: 113. [Type locality Itajahy (Itajai), SE Brazil].

*Urochaeta hystrix* Perrier, 1872: 142, figs. 85-88. [Types in Paris].

*Urochaeta corethrura*: Perrier, 1874:379.

- Urochaeta australiensis* Beddard, 1891: 278 [Queensland, Australia. Types in BMNH 1904:10:20: 1148-55].
- Pontoscolex corethrurus*: Michaelsen, 1900: 425; Stephenson, 1916; Gates, 1943: 92; 1972: 53-58; 1982: 19; Lee, 1981: 568; Easton, 1984:120.
- Pontoscolex hawaiiensis* Beddard, 1895: 660. [From Hawaii]; 1900: 414.

**Material examined.**-12 mature (clitellate), dissected, Jambi, coll. A. Darmawan, 14-17 Nov 2012; 5 not fully mature (aclitellate), dissected, Jambi, coll. A. Darmawan, 14-17 Nov 2012; 1 half broken, dissected, Jambi, coll. A. Darmawan, 14-17 Nov 2012; 1 mature (clitellate), dissected, Bodogol forest, coll. A. Darmawan, 2 Aug 2012; 3 not fully mature (aclitellate), dissected, Bodogol forest, coll. A. Darmawan, 1 and 2 Aug 2012; 1 mature (clitellate), Situ Gunung forest, coll. A. Darmawan, 16 Oct 2012; 1 not fully mature (aclitellate), Situ Gunung forest, coll. A. Darmawan, 18 Oct 2012.

**Description.** Length 47-71 mm. Width (segment xx) 1.3-2.18 mm. Segments 183-227, secondary annulation. Colour (preserved) pale white. Prostomium retracted. Dorsal pores absent. Setae (segment xx) lumbricine, quincunx in posterior. Nephropores present. Clitellum 15-22, saddle. Male pores not seen. Female pores not seen. Spermathecal pores seen on 6/7,7/8,8/9 paired. Genital markings 19-21. Septa 6/7-9/10 strong. Dorsal blood vessel single, bifurcate at gizzard. Hearts seen in 11-13. Gizzard 6. Calciferous 7,8,9, paired. Intestine origin 14-16. Acaecate. Nephridia holoic. Testes seen in 10, paired. Seminal vesicles 12, long, paired. Ovaries not seen. Prostates absent. Spermathecae 7,8,9, paired.

**Distribution:** Supposedly “*the most widely distributed earthworm*” (Gates 1972). Pan tropical: Nearctic, Neotropical, Afrotropics, Palearctic, Oriental, and Australasia domain. Also reported in American continent, African continent, Oceania domain.

Key to the species of earthworms in Bungku Village and Mount Gede

1. Gizzard absent ..... 2  
Gizzard present ..... 3
2. Male pores on 17, setae lumbricine ..... *Ocnerodrilus occidentalis*  
Male pores on 18 on ventral, setae perichaetine ..... *Perionyx excavatus*
3. Gizzard single ..... 4  
Gizzards multiple ..... 21
4. Caeca absent ..... 5  
Caeca present ..... 9



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5. Setae lumbricine.....	6
Setae perichaetine.....	7
6. Male pores on 18.....	<i>Notoscolex javanica</i>
Male pores not clearly defined, setae quincunx in posterior.....	<i>Pontoscolex corethrurus</i>
7. Spermathecal pores and spermathecae two pairs in 5/6/7.....	<i>Polypheretima sempolensis</i>
Spermathecal pores and spermathecae more than two pairs.....	8
8. Spermathecal pores and spermathecae three pairs in 5/6/7/8.....	<i>Polypheretima bifaria</i> species-group
Spermathecal pores and spermathecae five pairs in 4/5/6/7/8/9.....	<i>Polypheretima moelleri</i>
9. Copulatory pouches present.....	10
Copulatory pouches absent.....	14
10. Spermathecal duct with nephridia.....	11
Spermathecal duct without nephridia.....	12
11. First spermathecal pores on 5/6, four thecal segments ..	<i>Pheretima darnleiensis</i>
First spermathecal pores on 6/7, two thecal segments.....	<i>Pheretima pura</i> species-group
12. First spermathecal pore near 6/7.....	<i>Metaphire planata</i>
First spermathecal pore on 7/8.....	13
13. Male pores on 18, paired, ca. 0.2-0.3.....	<i>Metaphire javanica</i>
Male pores on 18, paired, ca. 0.3-0.4.....	<i>Metaphire californica</i>
14. Spermathecal pores absent, athecate.....	<i>Amyntas illotus</i> species-group
Spermathecal pores present.....	15
15. One thecal segment, first spermathecal pore on 5/6.....	<i>Amyntas minimus</i>
More than one thecal segments.....	16
16. First spermathecal pore on 5/6.....	17
First spermathecal pore posterior to 5/6.....	18

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17. Two thecal segments .....	<i>Amyntas morrisi</i> species-group
Three thecal segments .....	<i>Amyntas gracilis</i>
18. First spermathecal pore on 6/7.....	19
First spermathecal pore on 7/8.....	20
19. Genital markings absent .....	<i>Amyntas asiaticus</i>
Genital markings present .....	<i>Amyntas hupeiensis</i>
20. Male pores on 18, paired, ca. about 0.25 .....	<i>Amyntas aeruginosus</i>
Male pores on 18, paired, ca. 0.3-0.5 .....	<i>Amyntas robustus</i>
21. Two gizzards, co-joined .....	<i>Dichogaster affinis</i>
More than two gizzards, moniliform .....	22
22. Three gizzards in 13-15 .....	<i>Drawida barwelli</i>
Four gizzards in 14-25,26 .....	<i>Drawida nepalensis</i>

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## Appendix

### Appendix 2.1 Compilation of earthworm species in Indonesia.

#### Family Almididae

- Glyphidrilus buettikoferi* Michaelsen, 1922: 9  
*Glyphidrilus papillatus* (Rosa, 1890)  
*Glyphidrilus quadrangulus* (Horst, 1893: 44)  
*Glyphidrilus weberi* Horst, 1889: 76

#### Family Glossoscolecidae

- Pontoscolex corethrurus* (Müller, 1857)

#### Family Lumbricidae

- Bimastos parvus* (Eisen, 1874)  
*Eisenia fetida* (Savigny, 1826)

#### Family Megascolecidae

- Amyntas acrophilus* (Rosa, 1896: 527)  
*Amyntas aelianus* (Rosa, 1892: 545)  
*Amyntas aeruginosus* Kinberg, 1867: 101  
*Amyntas agilis* (Michaelsen, 1923: 2)  
*Amyntas baliensis* (Michaelsen, 1932)  
*Amyntas benhami* (Ude, 1932: 174)  
*Amyntas bonthainensis* (Benham, 1896: 437)  
*Amyntas buitendijki* (Michaelsen, 1922: 45)  
*Amyntas castaneus* Michaelsen, 1899: 56  
*Amyntas colossus* (Cognetti, 1911: 6)  
*Amyntas copulatrix* (Michaelsen, 1922: 49)  
*Amyntas corticis* (Kinberg, 1867)  
*Amyntas culminis* Michaelsen, 1899: 58  
*Amyntas dammermani* (Michaelsen, 1924: 391)  
*Amyntas digitatus* (Benham, 1896: 432)  
*Amyntas doormani* (Michaelsen, 1924: 20)  
*Amyntas dorous* (Michaelsen, 1934: 104)  
*Amyntas enganensis enganensis* (Rosa, 1892: 546)  
*Amyntas enganensis tetrus* (Rosa, 1892: 548)  
*Amyntas festivus* (Michaelsen, 1922: 37)  
*Amyntas fissiger* Michaelsen, 1899: 67  
*Amyntas gastrizusus* (Michaelsen, 1928: 292)  
*Amyntas glandulosus* (Rosa, 1896: 524)  
*Amyntas gracilis* (Kinberg, 1867: 102)  
*Amyntas halmaherae batjanensis* (Michaelsen, 1896: 269)  
*Amyntas halmaherae caecilius* (Michaelsen, 1896)  
*Amyntas halmaherae galelensis* (Michaelsen, 1896)  
*Amyntas halmaherae gamsungi* (Michaelsen, 1896)  
*Amyntas halmaherae halmaherae* (Michaelsen, 1896)

- Amyntas halmaherae imparicystis* (Michaelsen, 1896)  
*Amyntas halmaherae kauensis* (Michaelsen, 1896: 220)  
*Amyntas heurni* (Michaelsen, 1924: 23)  
*Amyntas hexathecus* (Benham, 1897: 440)  
*Amyntas jacobsoni* (Michaelsen, 1922)  
*Amyntas jampeanus fumigatus* Michaelsen, 1899: 64  
*Amyntas jampeanus jampeanus* (Benham, 1896: 430)  
*Amyntas jampeanus tigrinus* Michaelsen, 1899: 66  
*Amyntas juloides* Michaelsen, 1899: 53  
*Amyntas kalaenensis* Michaelsen, 1899: 68  
*Amyntas keianus* (Michaelsen, 1924/5: 394)  
*Amyntas lalangi* (Michaelsen, 1923: 5)  
*Amyntas lompobatangensis* Michaelsen, 1899: 33  
*Amyntas maximus* (Cognetti, 1915: 493)  
*Amyntas minahassae* (Michaelsen, 1896: 235)  
*Amyntas minimus* (Horst, 1893)  
*Amyntas misellus* (Cognetti, 1913: 291)  
*Amyntas miserus* (Cognetti, 1913: 292)  
*Amyntas mjobergi* (Michaelsen, 1923: 10)  
*Amyntas modiglianii* (Rosa, 1889: 134)  
*Amyntas nanus* (Rosa, 1896: 519)  
*Amyntas noebianus* (Michaelsen, 1934: 114)  
*Amyntas ocellatus* Michaelsen, 1899: 89  
*Amyntas omtrekensis* (Cognetti, 1911: 3)  
*Amyntas pataniensis labuhensis* (Michaelsen, 1896: 224)  
*Amyntas pataniensis pataniensis* (Michaelsen, 1896: 212, 222)  
*Amyntas petahanus* (Michaelsen, 1934: 102)  
*Amyntas principalis* (Michaelsen, 1932)  
*Amyntas proporus* (Rosa, 1896)  
*Amyntas purpureus* (Benham, 1897: 445)  
*Amyntas rodericensis* (Grube, 1879)  
*Amyntas sarasinorum* (Michaelsen, 1899)  
*Amyntas semifasciatus* (Michaelsen, 1899)  
*Amyntas silvestris* (Michaelsen, 1923: 16)  
*Amyntas sinabunganus* (Michaelsen, 1923: 12)  
*Amyntas supuensis* (Michaelsen, 1896: 225)  
*Amyntas thienemanni* (Michaelsen, 1932: 602)  
*Amyntas tobaensis* Michaelsen, 1899: 91  
*Amyntas udei* (Rosa, 1896)  
*Amyntas versteegi* (Michaelsen, 1938: 172)  
*Amyntas vialis* (Michaelsen, 1924: 25)  
*Amyntas vordermani* (Horst, 1890)

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- Amyntas wetzeli* (Ude, 1932)  
*Amyntas winkleri* (Michaelsen, 1928: 29)  
*Amyntas zebrus* (Benham, 1896: 442)  
*Amyntas ? forbesi* (Beddard, 1890: 65)  
*Archipheretima picta* (Michaelsen, 1892: 246)  
*Archipheretima zonata* (Michaelsen, 1922: 42)  
*Lampito mauritii* Kinberg, 1866/7  
*Megascolex filiciseta* Stephenson, 1915: 94  
*Metapheretima carolinensis* (Michaelsen, 1910)  
*Metapheretima jocchana* (Cognetti, 1911: 5)  
*Metapheretima myriochaeta* (Cognetti, 1911: 4)  
*Metapheretima sembalunensis* (Ude, 1932: 139)  
*Metaphire baliemensis* (Gates, 1948: 144)  
*Metaphire berhalana* (Stephenson, 1930: 1)  
*Metaphire bindjeyensis* (Michaelsen, 1899: 94)  
*Metaphire bryoni* (Michaelsen in Michaelsen and Boldt, 1932: 618)  
*Metaphire burchardi burchardi* (Michaelsen, 1899: 88)  
*Metaphire caducichaeta* (Benham, 1895: 47)  
*Metaphire cai* (Michaelsen, 1916: 14)  
*Metaphire californica* (Kinberg, 1867: 102)  
*Metaphire densipapillata* (Michaelsen, 1896: 227)  
*Metaphire ditheca* (Michaelsen, 1928)  
*Metaphire falcata* (Horst, 1893: 316)  
*Metaphire fasciata* (Rosa, 1892: 543)  
*Metaphire ferdinandi* (Michaelsen, 1891: 38)  
*Metaphire ferion* (Cognetti, 1913: 298)  
*Metaphire feuerborni* (Michaelsen in Michaelsen and Boldt, 1932: 605)  
*Metaphire floresiana* (Michaelsen, 1934: 108)  
*Metaphire gjellerupi* (Cognetti, 1914: 358)  
*Metaphire houlleti* (Perrier, 1872)  
*Metaphire impudens* (Michaelsen, 1899: 84)  
*Metaphire insignis* (Michaelsen, 1921: 14)  
*Metaphire javanica* (Kinberg, 1866/7)  
*Metaphire kockensis* (Michaelsen, 1930: 2)  
*Metaphire longa* (Michaelsen, 1892: 239)  
*Metaphire musiana* (Michaelsen, 1932: 614)  
*Metaphire musica* (Horst, 1883: 193)  
*Metaphire notizusa* (Michaelsen, 1928)  
*Metaphire pajana* (Michaelsen, 1928: 33)  
*Metaphire peguana* (Rosa, 1890: 113)  
*Metaphire posthuma* (Vaillant, 1868/9: 228)  
*Metaphire quadragenaria* (Perrier, 1872: 122)  
*Metaphire quadripapillata* (Michaelsen, 1899: 93)  
*Metaphire saonekana* (Cognetti, 1913: 39)  
*Metaphire singalangi* (Michaelsen, 1930: 3)  
*Metaphire sintangi* (Michaelsen, 1922: 28)  
*Metaphire tjandiana* (Michaelsen, 1932: 5)  
*Metaphire variabilis* (Horst, 1893)  
*Metaphire weberi* (Cognetti, 1913: 37)  
*Metaphire willeyi* (Benham, 1895)  
*Notoscolex javanica* (Michaelsen, 1910: 93)  
*Perionyx excavatus* Perrier, 1872  
*Perionyx violaceus* Horst, 1893  
*Pheretima (Parapheretima) aberrans* Cognetti, 1911: 2  
*Pheretima (Parapheretima) alkmaarica* Cognetti, 1913: 298  
*Pheretima (Parapheretima) barbara barbara* Cognetti, 1913: 302  
*Pheretima (Parapheretima) barbara barbigua* Blakemore, 2004: 129  
*Pheretima (Parapheretima) beaufortii apotrema* Cognetti, 1913: 297  
*Pheretima (Parapheretima) beaufortii beaufortii* Cognetti, 1911: 3  
*Pheretima (Parapheretima) bernhardi* (Gates, 1948: 149)  
*Pheretima (Parapheretima) hellwigiana* Cognetti, 1913: 300  
*Pheretima (Parapheretima) pluviosa* Cognetti, 1913: 300  
*Pheretima (Parapheretima) rufa* Gates, 1948: 160  
*Pheretima (Parapheretima) utakwana* Cognetti, 1915: 494  
*Pheretima (Pheretima) ambonensis* Cognetti, 1913: 40  
*Pheretima (Pheretima) ceramensis* Cognetti, 1922: 1  
*Pheretima (Pheretima) darnleiensis* (Fletcher, 1886: 966)  
*Pheretima (Pheretima) dubia* (Horst, 1893: 68)  
*Pheretima (Pheretima) habbemana* Gates, 1948: 151  
*Pheretima (Pheretima) korinchiana* Cognetti, 1922: 2  
*Pheretima (Pheretima) leopoldi* Michaelsen, 1930: 4  
*Pheretima (Pheretima) montana* Kinberg, 1867: 102  
*Pheretima (Pheretima) philippina* (Rosa, 1891: 397)  
*Pheretima (Pheretima) poiana* Michaelsen, 1913: 88  
*Pheretima (Pheretima) pura* (Rosa, 1898: 285)  
*Pheretima (Pheretima) racemosa* (Rosa, 1891: 399)  
*Pheretima (Pheretima) sangirensis chica* (Michaelsen, 1896: 207)  
*Pheretima (Pheretima) sangirensis crassicystis* (Michaelsen, 1896: 204)

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*Pheretima* (*Pheretima*) *sangirensis* *sangirensis* (Michaelsen, 1891: 36)  
*Pheretima* (*Pheretima*) *sluiteri* (Horst, 1890)  
*Pheretima* (*Pheretima*) *tosariana* Cognetti, 1913: 38  
*Pheretima* (*Pheretima*) *urceolata* (Horst, 1893: 322)  
*Pheretima* ? *athea* (Rosa, 1896: 520)  
*Pheretima*? *flabellifera* Cognetti, 1911: 2  
*Pithemera* *bicincta* (Perrier, 1875: 1004)  
*Pithemera* ? *liangi* (Michaelsen, 1922: 36)  
*Planapheretima* *celebensis* (Michaelsen, 1899: 32)  
*Planapheretima* *hasselti* (Horst, 1883: 190)  
*Planapheretima* *nieuwenhuisi* (Michaelsen, 1922: 47)  
*Planapheretima* *rufomaculata* (Gates, 1948: 162)  
*Planapheretima* *subulata* (Michaelsen, 1899: 29)  
*Pleionogaster* *horsti* (Beddard, 1886: 300)  
*Polypheretima* *annulata* (Horst, 1883: 195)  
*Polypheretima* *badia* (Ude, 1932: 171)  
*Polypheretima* *bifaria* (Michaelsen, 1924: 18)  
*Polypheretima* *brevis* (Rosa, 1898: 283 or 288)  
*Polypheretima* *elberti* (Ude, 1932: 175)  
*Polypheretima* *elongata* (Perrier, 1872: 124)  
*Polypheretima* *everetti* (Beddard and Fedarb, 1895: 69)  
*Polypheretima* *fakfakensis* (Cognetti, 1908: 1)  
*Polypheretima* *gatesi* Easton, 1979: 44  
*Polypheretima* *grata* (Cognetti, 1914: 362)  
*Polypheretima* *kellneri* (Ude, 1932: 177)  
*Polypheretima* *lesonea* Easton, 1979: 51  
*Polypheretima* *mertoni* (Michaelsen, 1910: 256)  
*Polypheretima* *panarana* (Michaelsen, 1938: 167)  
*Polypheretima* *phacellotheca* (Michaelsen, 1899: 47)  
*Polypheretima* *renschii* (Ude, 1932: 141)  
*Polypheretima* *sempolensis* Easton, 1979: 39

*Polypheretima* *sibogae* (Michaelsen, 1922: 23)  
*Polypheretima* *stelleri* (Michaelsen, 1891: 39)  
*Polypheretima* *swelaensis* (Ude, 1932: 178)  
*Polypheretima* ? *moelleri* (Michaelsen, 1921: 12)  
*Pontodrilus* *litoralis* (Grube, 1855)

## Family Moniligastridae

*Desmogaster* *buettikoferii* (Horst, 1884: 105)  
*Desmogaster* *giardi* Horst, 1899: 293  
*Desmogaster* *horsti* Beddard, 1895: 205  
*Desmogaster* *schildi* Rosa, 1897: 339  
*Drawida* *barwelli* (Beddard, 1886)  
*Drawida* *heterochaeta* Michaelsen, 1922: 3  
*Drawida* *longatria* *longatria* Gates, 1925: 50  
*Drawida* *nepalensis* Michaelsen, 1907: 146  
*Drawida* *parva* (Bourne, 1894)  
*Drawida* *ramnadana* Michaelsen, 1907: 145  
*Eupolygaster* *coerulea* (Horst, 1895: 137)  
*Eupolygaster* *modiglianii* (Rosa, 1896: 503)  
*Hastirogaster* *houtenii* *houtenii* (Horst, 1887: 97)  
*Hastirogaster* *houtenii* *rookmaakeri* (Michaelsen, 1931: 78)  
*Moniligaster* *strahleni* Michaelsen, 1930: 1

## Family Ocnerodrilidae

*Eukerria* *kuekenhali* (Michaelsen, 1908)

## Family Octochaetidae

*Dichogaster* *affinis* (Michaelsen, 1890)  
*Dichogaster* *annae* (Horst, 1893)  
*Dichogaster* *bolau* (Michaelsen, 1891)  
*Dichogaster* *modiglianii* (Rosa, 1896)  
*Dichogaster* *saliens* (Beddard, 1893)  
*Dichogaster* *tamiana* Cognetti, 1911: 6  
*Lennogaster* *pusilla* (Stephenson, 1920: 252)  
*Lennogaster* *pusillus* (Stephenson, 1920)  
*Ramiella* *bishambari* (Stephenson, 1914)



### 3 *Pontoscolex corethrurus* (Müller, 1857) (OLIGOCHAETA: GLOSSOSCOLECIDAE) IN FOREST TRANSFORMATION SYSTEM IN BUNGKU VILLAGE, JAMBI, INDONESIA

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#### Abstract

*Pontoscolex corethrurus* (Müller, 1857) (Oligochaeta: Glossoscolecidae) is a widely distributed exotic earthworm. We showed that *Pn. corethrurus* completely dominated the secondary forest and agricultural plantations in Bungku Village, Jambi Province, Sumatra, Indonesia. Bungku Village in Jambi consists of the forest undergoing transformation into oil palm plantation, rubber plantations, and rubber jungle. Purposive random sampling with hand-sorting method was conducted to extract *Pn. corethrurus*. We found that all of 940 recovered earthworms were *Pn. corethrurus*. Their density was not significantly different in the four systems. Our result showed that *Pn. corethrurus* abundance was significantly influenced by soil physical factor, mineral content, and texture. We propose that anthropogenic practice in Bungku Village caused the condition which does not support the native earthworms. *Pn. corethrurus* which have better tolerance than the native earthworms are favored by anthropogenic practice.

Key words: earthworm; exotic; oil palm; rubber; soil.

#### Introduction

*Pontoscolex corethrurus* (Müller, 1857) (Oligochaeta: Glossoscolecidae) is a widely distributed exotic earthworm (Brown *et al.* 2006, Gonzalez *et al.* 2006, Hendrix *et al.* 2006). This endogeic earthworm is originally native in South America and is the commonest earthworm in Brazil (Hendrix & Bohlen 2002). Nowadays, it is quite dispersed up to South Africa and Asia Pacific regions as alien species (Plisko 2001, Blakemore 2010). Its dispersal is probably related to the introduction of rubber plant, *Hevea brasiliensis*, from Brazil (Murdiyarso *et al.* 2002, Nath & Chaudhuri 2010) or pine seedling (*Pinus* sp.) (Plisko, 2001). Frequently, it becomes invasive competing with the native earthworms or

colonizing the disturbed habitat where the native earthworms are reduced (Gonzalez *et al.* 2006).

Anthropogenic transformation of forest results in unfavorable and reduced resources for native earthworms (Hendrix *et al.* 2006, Marichal *et al.* 2010). *Pn. corethrurus* density increases with the increase in the age of disturbed habitat while the density of native earthworms decreases (Nath & Chaudhuri 2010). The native earthworms tend to disappear and *Pn. corethrurus* fills the niche (Gonzalez *et al.* 2006, Marichal *et al.* 2010). Although direct competition with native earthworms is common, the extirpation of natives is not easily demonstrated (Hendrix *et al.* 2006). On the other hand, Hendrix *et al.* (2006) stated that exotic earthworms invade ecosystem even in the absence of obvious human disturbance. Therefore, it requires more study to conclude that the anthropogenic influence is necessary for *Pn. corethrurus* to successfully invade the area.

Indonesia experienced almost half million hectare net loss of forest area in 2000-2010 (FAO 2010). Central Sumatra had annual deforestation rate of 3.2–5.9% (Achard *et al.* 2002) and Jambi is undergoing a rapid primary forest transformation into agricultural system (Murdiyarso & Wasrin 1995). Bungku Village in Jambi consists of the forest undergoing transformation into oil palm plantation, rubber plantation, and rubber jungle. Here, we showed that *Pn. corethrurus* completely dominated the secondary forest and agricultural plantations in Bungku Village, Jambi Province, Sumatra, Indonesia. Moreover, we also analyzed the soil parameters affecting their abundance.

## Material and Methods

### Study Sites

Sampling was conducted on November 2012 in wet season in Bungku Village, Batanghari Regency, Jambi (1°15'–2°20' south latitude - 120°30'–104°30' east longitude) (Fig. 3.1). This area had average annual temperature of 25.5 °C and cumulative precipitation of 2700 mm (BPPD 2010). Sampling area comprised of 15 year-old oil palm plantation (S 01° 54' 33.8", E 103° 15' 56.3"), 11 year-old rubber plantation (S 01° 54' 39.6", E 103° 15' 59.3"), 19 year-old rubber jungle (S 01° 55' 39.9", E 103° 15' 32.0"), and secondary forest (S 01° 54' 52.1", E 103° 15' 57.3"). The coordinates were taken in the outer side of each system.

Dominant plants in oil palm plantation were oil palm, *Elais guineensis*, and grass (Gramineae). Rubber plantation consisted of only rubber, *H. brasiliensis*. Rubber jungle was dominated by rubber, Asian melastome, *Melastoma candidum*, grass, and billian, *Eusideroxylon zwageri*. Meanwhile, secondary forest was dominated by tempinis, *Sloetia elongata*, medang, *Litsea firma*, and bamboo (Bambusoideae). Vegetation analysis using profile method revealed that the structure of old jungle rubber and secondary forest are similar (Gouyon *et al.* 1993).

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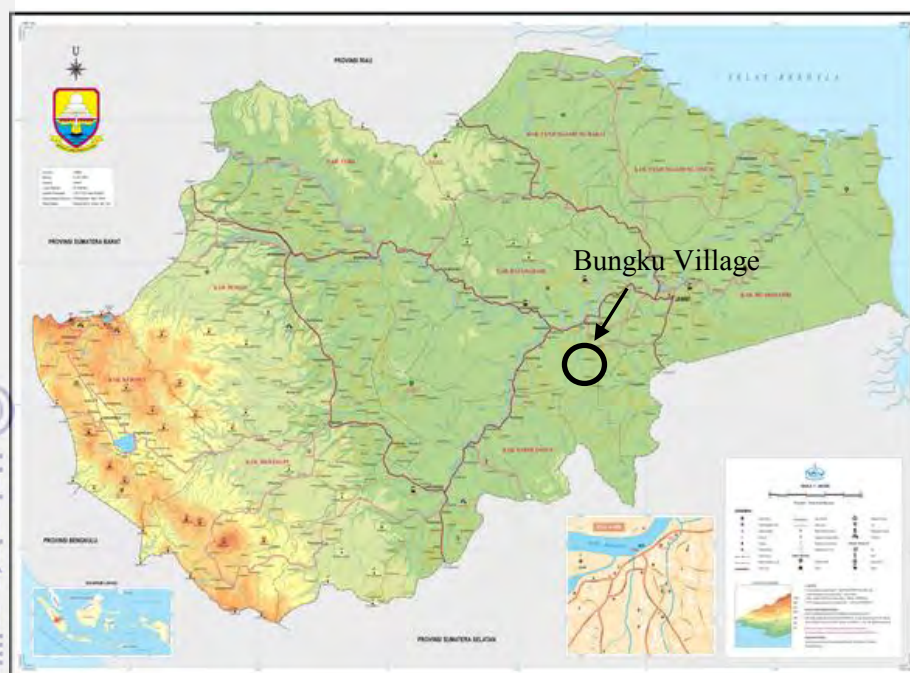


Figure 3.1 Study site in Jambi Province, Indonesia.

### *Pontoscolex corethrurus* Extraction

Purposive random sampling was conducted to extract *Pn. corethrurus*. Three sets of sampling sites, about 20 m apart from each other, were placed in each system. Each set consisted of 25 of 30 x 30 cm and 30 cm depth plots placed randomly 1 m apart from each other, making total of 75 plots in each system. Hand-sorting method was carried out. *Pn. corethrurus* were cleansed with paper towel prior to recording the biomass and fixation in 70% ethanol. Due to insensitivity of the weight scale, we only measured the adult *Pn. corethrurus* biomass. Identification and description of *Pn. corethrurus* were conducted by following Blakemore method (2010). *Pn. corethrurus* with and without clitellum were classified into adult and juvenile, respectively. Meanwhile, *Pn. corethrurus* without anterior part was classified into unknown stage.

*Pontoscolex corethrurus* in this study showed the following characteristics: length 60–80 mm. Width approximately 3 mm. Segments 173–230 with secondary annulations. Unpigmented with yellowish clitellum. Prostomium retracted (preserved specimen). Dorsal pore absent. Setae 8 per segment, quincunx in posterior. Nephropores difficult to see, clear from segment 10/11. Clitellum saddle shaped, 15–22,23. Male pores and female pores difficult to see. The first spermathecal pores in 6/7. Genital markings on 19–21. Septa thick on 6/7, 7/8, 8/9. Dorsal blood vessel single. Hearts in 10 and 11 look strong. Gizzard spherical and muscular in 6. Calciferous glands three pairs, under the thick septa in 7–9. Intestine origin in 13 or 14. Nephridia holoic. Testes probably in 10. Seminal vesicles elongated in 12. Prostate absent. Spermathecae three pairs in 7–9.

## Soil Parameter

Human disturbance may cause changes in soil physical and chemical properties (Guariguata & Ostertag 2001) viz. temperature, pH, water, mineral content, and texture, which are directly related to the *Pn. corethrurus* abundance (Edwards 2004). Soil parameters observed were soil physical factors (temperature, pH, water content), mineral content (C-organic, P, Ca, Mg, K, Na), and texture (sand, silt, clay).

Soil physical factors were assessed in each plot. Soil temperature was measured using soil thermometer. Meanwhile, soil pH and water contents were measured using soil pH and humidity tester.

Soil mineral content and texture were assessed following compositing method. Soils from each set of sampling site were sampled, making total of 12 soil samples for 4 systems (3 samples for each system). Five hundred grams of soil was air dried prior to analyzing its C-organic, P, Ca, Mg, K, Na contents, and texture. The soils were analyzed for organic content and texture following Walkley-Black and Pipette method, respectively. Meanwhile, soil Ca, Mg, K, and Na contents were analyzed using neutral 1 M ammonium acetate (NH<sub>4</sub>OAc) method. Afterward, soil phosphorus was analyzed using solution of HCl 25% (Sarkar & Halder 2005). Soil analysis was conducted in Laboratory of Department of Soil Science and Land Resource, Faculty of Agriculture, Bogor Agricultural University.

## Statistical Analysis

Data analysis was conducted using R 2.11.0 software (Ihaka & Gentleman 1996, R Development Core Team 2010). Kruskal-Wallis test in „agricolae“ package (Mendiburu 2010) was used to assess *Pn. corethrurus* density, adult biomass, and soil parameters in all systems. Soil factors influencing *Pn. corethrurus* abundance was analyzed by constructing generalized linear model as the abundance followed Poisson distribution (Zuur *et al.* 2009). *Pn. corethrurus* abundance as response, soil factors as predictors. Soil factors were transformed logarithmic naturally to meet the normality assumption. Outliers were removed from analysis. Collinearity among soil factors was assessed using Variance Inflation Factors, and the value of 3.00 was set as threshold. The model was simplified using drop1. The final model used was: *Pn. corethrurus* abundance ~ pH + water content + C-organic + Na + salt. Homogeneity of variance was assessed on model residual vs. fitted value and independence of soil factors was assessed on model residual vs. soil factors plot. No clear pattern on those plots indicated that the model met homogeneity of variance and independence assumption.

## Result

### Domination, Density, and Adult Biomass of *Pn. corethrurus* in Four Land Systems

A common effect of anthropogenic disturbance into agricultural system is domination of exotic earthworm like in Tripura, India, where *Pn. corethrurus* successfully dominated rubber plantation with >70% frequency (Chaudhuri *et al.* 2008, Chaudhuri & Nath 2011). We also found *Pn. corethrurus* in Bungku Village. All of 940 recovered earthworms there were *Pn. corethrurus*. Previous study by Bignell *et al.* (2000) found only two earthworm species in neighboring 15 years old monoculture rubber plantation and one species in secondary forest in Pasir Mayang, Jambi. However, they found five species in jungle rubber of Pancuran Gading, Jambi, which contained rubber trees and secondary forest regrowth with liana. Unfortunately, they did not mention the earthworm species. They concluded that earthworms had low diversity in Jambi except in Sengon (*Paraserianthes*) plantation and jungle rubber. In comparison, the other study conducted by Darmawan *et al.* (2015) (presented in this dissertation chapter 4) in undisturbed forest in West Java recovered more than six earthworm species including *Pn. corethrurus*.

*Pontoscolex corethrurus* density was not significantly different in the four systems (Table 3.1). All of our results were lower than previous study in Tripura, India, which found a *Pn. corethrurus* density of 78-88 ind/m<sup>2</sup> (Chaudhuri *et al.* 2008, Chaudhuri & Nath 2011).

The adult biomass  $\pm$  SD of *Pn. corethrurus* in oil palm plantation, rubber plantation, rubber jungle, and secondary forest were  $7.56 \pm 6.25a$ ,  $4.74 \pm 3.49b$ ,  $7.56 \pm 6.23a$ , and  $5.45 \pm 4.15b$  g/m<sup>2</sup> respectively (p-value < 0.01). The values with the same letter are not different.

Table 3.1 Kruskal-Wallis test of *Pn. corethrurus* density in each system. The values are mean of *Pn. corethrurus* abundance/m<sup>2</sup>  $\pm$  SD

System	Stage			Total
	Juvenile	Adult	Unknown	
Oil palm plantation	7.85 $\pm$ 10.30	22.22 $\pm$ 19.55	7.11 $\pm$ 9.95	37.33 $\pm$ 21.51
Rubber plantation	5.78 $\pm$ 8.04	20.44 $\pm$ 17.90	5.93 $\pm$ 8.82	32.15 $\pm$ 20.31
Rubber jungle	8.74 $\pm$ 10.38	23.56 $\pm$ 18.08	4.44 $\pm$ 7.08	36.74 $\pm$ 25.20
Secondary forest	6.67 $\pm$ 9.13	20.00 $\pm$ 13.30	6.67 $\pm$ 9.13	33.33 $\pm$ 18.63
P-value	0.24	0.64	0.41	0.48

## Soil Parameters in Four Land Systems and Their Influence on *Pn. corethrurus* Abundance

Oil palm and rubber plantation had high value of soil phosphorus and potassium as the consequences of being fertilized with NPK (nitrogen, phosphate, potassium) by the landowner (Table 3.2). Conceptually, tree plantations may affect earthworm community structure through alteration of soil physical and chemical properties (Gonzalez *et al.* 1996, Sarlo 2006, Nadeem *et al.* 2007). However, rubber plantation and mixed forest which had similar soil properties consisted of different earthworm community structures in Tripura, India (Chaudhuri & Nath 2011). As earthworm abundance is affected by soil parameters, our result showed that *Pn. corethrurus* abundance was significantly influenced by soil physical factor, mineral content, and texture (Table 3.3).

Table 3.2 Kruskal-Wallis test of soil parameters in each system. Mean  $\pm$  SD, values with the same letter in a row are not significantly different (p-value  $< 0.05$ )

System	Oil palm plantation	Rubber plantation	Rubber jungle	Secondary forest	All systems
Temperature ( $^{\circ}$ C)	29.76 $\pm$ 1.46 <sup>a</sup>	27.81 $\pm$ 1.06 <sup>b</sup>	26.54 $\pm$ 1.14 <sup>d</sup>	27.47 $\pm$ 0.90 <sup>c</sup>	27.90 $\pm$ 1.65
pH	6.67 $\pm$ 0.15 <sup>a</sup>	6.51 $\pm$ 0.18 <sup>b</sup>	6.44 $\pm$ 0.16 <sup>c</sup>	6.47 $\pm$ 0.23 <sup>bc</sup>	6.52 $\pm$ 0.20
Water content (%)	61.47 $\pm$ 20.53 <sup>a</sup>	46.80 $\pm$ 12.88 <sup>c</sup>	38.11 $\pm$ 8.05 <sup>d</sup>	51.88 $\pm$ 12.65 <sup>b</sup>	49.56 $\pm$ 16.51
C-organic (%)	1.91 $\pm$ 0.13 <sup>b</sup>	1.86 $\pm$ 0.17 <sup>c</sup>	1.72 $\pm$ 0.33 <sup>d</sup>	2.79 $\pm$ 0.07 <sup>a</sup>	2.07 $\pm$ 0.47
P (ppm)	97.93 $\pm$ 1.44 <sup>a</sup>	95.10 $\pm$ 3.56 <sup>b</sup>	81.9 $\pm$ 4.31 <sup>d</sup>	93.57 $\pm$ 4.00 <sup>c</sup>	92.12 $\pm$ 7.05
Ca (me/100g)	2.02 $\pm$ 0.31 <sup>a</sup>	4.80 $\pm$ 4.35 <sup>a</sup>	0.66 $\pm$ 0.16 <sup>c</sup>	1.62 $\pm$ 0.47 <sup>b</sup>	2.28 $\pm$ 2.67
Mg (me/100g)	0.61 $\pm$ 0.14 <sup>b</sup>	0.49 $\pm$ 0.15 <sup>c</sup>	0.30 $\pm$ 0.03 <sup>d</sup>	0.94 $\pm$ 0.02 <sup>a</sup>	0.58 $\pm$ 0.26
K (me/100g)	0.15 $\pm$ 0.02 <sup>b</sup>	0.16 $\pm$ 0.01 <sup>a</sup>	0.11 $\pm$ 0.01 <sup>d</sup>	0.14 $\pm$ 0.01 <sup>c</sup>	0.14 $\pm$ 0.02
Na (me/100g)	0.33 $\pm$ 0.05 <sup>b</sup>	0.33 $\pm$ 0.07 <sup>b</sup>	0.19 $\pm$ 0.02 <sup>c</sup>	0.44 $\pm$ 0.01 <sup>a</sup>	0.32 $\pm$ 0.10
Sand (%)	20.18 $\pm$ 2.25 <sup>c</sup>	23.41 $\pm$ 2.61 <sup>b</sup>	26.10 $\pm$ 4.44 <sup>a</sup>	26.77 $\pm$ 10.67 <sup>a</sup>	24.11 $\pm$ 6.54
Silt (%)	47.95 $\pm$ 3.52 <sup>a</sup>	46.22 $\pm$ 4.76 <sup>b</sup>	38.95 $\pm$ 9.14 <sup>d</sup>	41.93 $\pm$ 6.92 <sup>c</sup>	43.76 $\pm$ 7.33
Clay (%)	31.87 $\pm$ 4.19 <sup>a</sup>	30.30 $\pm$ 4.15 <sup>a</sup>	34.95 $\pm$ 8.16 <sup>a</sup>	31.30 $\pm$ 3.80 <sup>a</sup>	32.12 $\pm$ 5.63

Table 3.3 Soil parameters affecting *Pn. corethrurus* abundance

Soil parameter	Slope	Std. Error	Z value	P-value
pH	-2.888	1.168	-2.473	0.013
Water content	0.303	0.110	2.760	0.006
C organic	0.551	0.190	2.901	0.004
Na	-0.505	0.125	-4.049	$< 0.001$
Sand	-0.482	0.124	-3.900	$< 0.001$
Null deviance: 307.16 on 289 degrees of freedom				
Residual deviance: 263.77 on 284 degrees of freedom				
AIC: 1084.20				

## Discussion

Severely disturbed habitat caused by anthropogenic practices such as deforestation or transformation into agricultural system often lead to soil inhabitation by exotic earthworm (Nath & Chaudhuri 2010). If the disturbance is severe, it is possible that the native species be extirpated leaving only the exotic species (Gonzalez *et al.* 2006) as in our study. In that case, the native earthworms were reduced because of failure to adapt to the new environment, and then the niche was colonized by exotic earthworms.

Colonization of *Pn. corethrurus* in Bungku Village might be also associated with the plant species in the area i.e., rubber and oil palm plantations, which do not support the other earthworm species (Sarlo 2006). In addition, *Pn. corethrurus* has better tolerance to fill the niche left by the natives (Gonzalez *et al.* 2006). Most earthworms tolerate narrow range of temperature. However, *Pn. corethrurus* can tolerate approximately 13-27 °C of temperature (Kale & Krishnamoorthy 1979) and even up to 29 °C in the present study. *Pn. corethrurus* is characterized as having constant oxygen consumption without diurnal rhythm and tolerance for low oxygen availability (Chuang & Chen 2008). The epidermal cells of *Pn. corethrurus* consist of more granules, so it can secrete more mucus to provide the protection from UV light as compared to *Amyntas gracilis* and *Metaphire posthuma* (Chuang *et al.* 2006, Gonzalez *et al.* 2008). Parthenogenesis also occurs in *Pn. corethrurus* and it can enhance their colonization (Hendrix & Bohlen 2002). They are also able to enter diapause and regenerate the lost posterior segment regardless of soil moisture (Fragoso & Lozano 1992).

Our result showed no significant difference of *Pn. corethrurus* density in the four systems, and this was not in agreement with previous study which mentioned that earthworm density was higher in forest than plantation (Marichal *et al.* 2010, Chaudhuri & Nath 2011). Concerning the overall lower density of *Pn. corethrurus* than that reported in previous study, we speculate that it might be due to the higher soil pH (6.5) as *Pn. corethrurus* prefers lower pH (< 5.0) (Chaudhuri *et al.* 2008, Nath & Chaudhuri 2010). We also found boar tracks in the secondary forest. Hence, we hypothesize that in secondary forest, predation by wild boars, *Sus scrofa*, caused a lower *Pn. corethrurus* density in Jambi, as predation can become a limiting factor for the exotic earthworms to invade new habitat (Hendrix *et al.* 2006). Consequently, their lower density caused lower biomass. Moreover, we only assessed the adult *Pn. corethrurus* biomass. For comparison, the previously mentioned *Pn. corethrurus* from Tripura, India, had biomass of 26–30 g/m<sup>2</sup> (Chaudhuri *et al.* 2008, Chaudhuri & Nath 2011).

Our result showed that soil pH and water content were important soil physical factors. Most earthworms prefer normal soil pH (Edwards 2004), and few of them can live in acidic soil (Ismail & Murthy 1985). *Pn. corethrurus* is an earthworm which can tolerate or even prefer acidic soil (Nath & Chaudhuri 2010).

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Hence, negative influence of soil pH in our result was in agreement with that theory. For positive influence of soil water content, it is not peculiar as water is essential to maintain *Pn. corethrurus* moisture.

Meanwhile, soil C-organic and Na content were important soil mineral factors. As organic matter is the main source for earthworm diet (Ismail & Murthy 1985, Edwards 2004), it is not surprising to have higher abundance of *Pn. corethrurus* in soil containing higher C-organic. Na showed negative influence on *Pn. corethrurus* abundance. Na is influenced in Na-K pump which regulates internal fluid (Barrett *et al.* 2005). Excess of Na causes unbalance of internal fluid.

High sand fraction was not preferred by *Pn. corethrurus*. Sandy soil cannot hold the water well and earthworms are susceptible to drought (Edwards 2004). Therefore, the negative influence of sand fraction supports the positive influence of soil water content to *Pn. corethrurus* abundance.

In summary, we propose that anthropogenic practice in Bungku Village causes the condition which does not support the native earthworm's survival. *Pn. corethrurus* which have better tolerance than the native earthworms are favored by anthropogenic practice. Therefore, they are able to fill the niche left by natives and completely dominating oil palm plantation, rubber plantation, rubber jungle, and secondary forest in Bungku Village. Their abundance is influenced by soil pH, water, C-organic, sodium, and sand content. Sampling in larger area is needed to study about *Pn. corethrurus* domination in Indonesian disturbed forest.

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#### 4 COMPETITION OF TWO SURVIVED EXOTIC EARTHWORMS (*Ocnerodrilus occidentalis* Eisen, 1878 AND *Pontoscolex corethrurus* (Muller, 1857)) FROM DEFORESTATION IN MOUNT GEDE, INDONESIA

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##### Abstract

The Gause's principle, whereby complete competitors cannot coexist leads to reduced biodiversity and less energy fluxes in a community. Here we will show that the anthropogenic disturbance of natural forests decreases diversity by adversely altering environmental conditions, causing most earthworms to die and leaving eurytopic ones to compete for reduced resources. Among 3787 individuals, we recovered five Oriental earthworm species in Mount Gede: *Drawida nepalensis*, *Notoscolex javanica*, *Pheretima pura*-group, *Polypheretima moelleri*, and *Polypheretima sempolensis*. We also recovered eighteen species which are reported to be have originally been distributed in the Neotropic (including *Ocnerodrilus occidentalis* and *Pontoscolex corethrurus*), Paleotropic, Afrotropic, or Australasia. The agricultural practices which bring exotic earthworms are analogue to transplant experiment of the original Gause's work. Anthropogenic disturbance of forests due to transformation into plantations alters their environment by increasing soil temperature and phosphorous content while decreasing C-organic, and consequently kills many earthworm species. It left *N. javanica* out as the only native which survived the deforestation, while exotics *O. occidentalis* and *Pn. corethrurus* thrive to be the eudominant and competing species. In higher soil temperature, *O. occidentalis* is able to sustain viable population, ousting *Pn. corethrurus*, and „won“ the competition.

Key words: Gause's principle, homogenous plantation, mixed plantation, Shannon's diversity index, stenotopic.

##### Introduction

The Gause's principle, whereby complete competitors cannot coexist leads to reduced biodiversity and less energy fluxes in a community (Gause 1932,

Hardin 1960, Barnes 2014). However, Gause's principle affecting diversity had only been proven in laboratory and, even so, it has recently been shown that the underlying resource competition mechanism results in the coexistence of functionally equivalent species in estuarine ecosystem of phytoplankton (Segura 2013). Here we will show that the anthropogenic disturbance of natural forests decreases diversity by adversely altering environmental conditions, causing most earthworms to die and leaving eurytopic ones to compete for reduced resources.

Indonesia experienced the world's second largest net annual forest area loss in 1990–2000 and the third in 2000–2010 ([FAO] 2010). The forest of Mount Gede in West Java is undergoing land-use change into mixed and homogenous plantations, and we presumed that this process enhances the conversion of „limitless“ into limited resources for earthworms (sensu Darlington 1972). When earthworms are incapable of adapting to the environmental change, they might be expelled and the niche is filled by the species that have wider tolerance (Gonzalez *et al.* 2006, Somniam & Suwanwaree 2009, Chaudhuri & Nath 2011). Coincidentally, the most frequent land-use change of deforestation into agricultural area brings exotic species (Talavera 1996, Hendrix & Bohlen 2002, Tripathi & Bhardwaj 2004, Talavera 2007, Rota 2013) to fill the leftover niche opportunistically if they are eurytopic. However, it is possible for native and exotic species to have an overlapping distribution when the resources are not fully exploited by the natives (Hendrix *et al.* 2006). It is predicted that the extent of deforestation into mixed and homogenous plantations reduces the diversity of the exotic and native earthworms.

Among 3787 individuals, we recovered five Oriental earthworm species in Mount Gede: *Drawida nepalensis*, *Notoscolex javanica*, *Pheretima pura*-group, *Polypheretima moelleri*, and *Polypheretima sempolensis*, which are distributed in India, southern China, Myanmar, and the Sunda Islands. We also recovered eighteen species which are reported to be have originally been distributed in the Neotropic (including *Ocnerodrilus occidentalis* and *Pontoscolex corethrurus*), Paleotropic, Afrotropic, or Australasia (Tsai *et al.* 2000, Hendrix & Bohlen 2002, Blakemore 2010) (Appendix 4.1–4.2). Rarefaction curves were parallel and almost reaching the asymptote indicating that sampling effort reached the estimated maximum species richness (Appendix 4.3). The agricultural practices which bring exotic earthworms are analogue to transplant experiment of the original Gause's work. From the forest area to mixed and homogenous plantations, the predicted decreasing diversity (Huston 1979) is shown by the lowering trend of Shannon's diversity index (Fig. 4.1). It left *N. javanica* out as the only native which survived the deforestation, while exotics *O. occidentalis* and *Pn. corethrurus* thrive to be the eudominant and competing species.

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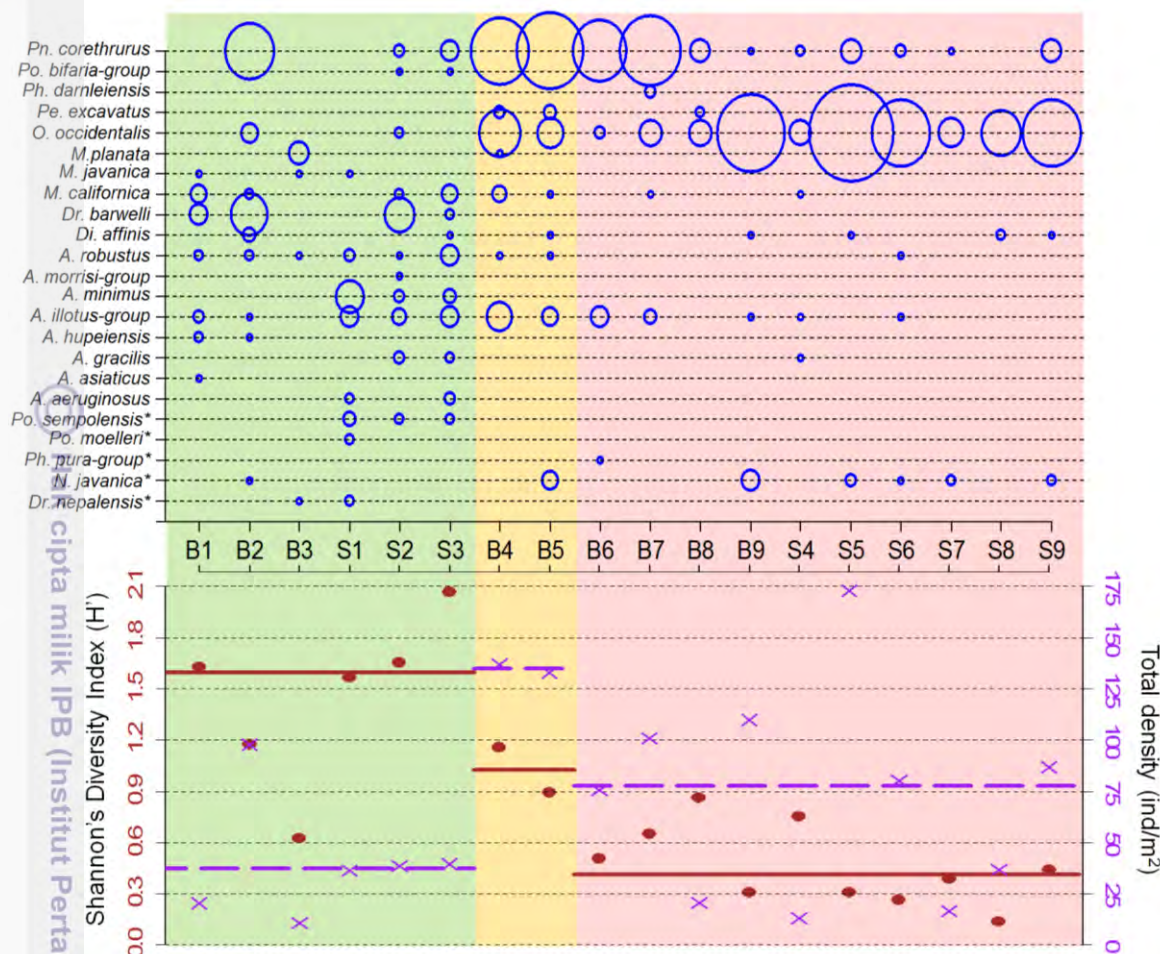


Figure 4.1 Forest (B1–B3, S1–S3) and mixed plantation (B4–B5) areas supported more earthworm species than homogenous plantations (B6–B9, S5–S9). B and S represent areas in Bodogol and Situ Gunung regions. The bigger circle denotes a higher species density. The dots (●) denote Shannon's diversity index and their medians (—) in forest, mixed, and homogenous plantations. Crosses (x) denote total earthworm densities (excluding unknown species) and their medians (— - —). For genera abbreviation: *A* = *Amyntas*, *Di* = *Dichogaster*, *Dr* = *Drawida*, *M* = *Metaphire*, *N* = *Notoscolex*, *O* = *Ocnerodrilus*, *Pe* = *Perionyx*, *Ph* = *Pheretima*, *Pn* = *Pontoscolex*, *Po* = *Polypheretima*. Species with asterisks were natives of the Orient.

## Material and Methods

### Study Sites

As earthworm density reaches maximum value in wet season (Fragoso & Lavelle 1992), sampling was conducted between early July and the end of October 2012 and between early September and the end of December 2013 in the wet season in Mount Gede, West Java, Indonesia. The sampling area included two

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regions, namely Bodogol (abbreviated as „B“, coordinates: S 06° 46' 24.2", E 106° 50' 28.8", 600–700 m asl) and Situ Gunung (abbreviated as „S“, coordinates: S 06° 50' 09.6", E 106° 55' 38.4", 1000–1050 m asl). The mean monthly (from July–December 2012) rainfall of those areas was 226.7 mm. Each region consisted of three forests (B1–B3 and S1–S3) and six adjacent plantation areas (B4–B9 and S4–S9) which are located less than three km from the forest. The plantations in Bodogol consisted of mixed (B4 and B5) and homogenous plantations (B6–B9). Mixed plantations consisted of several plantations cultivated simultaneously. Mixed plantations in Bodogol have been cultivated for about five years, and homogenous plantations in both regions for 10–30 years. The age of the current homogenous plantations were 1–3 months and fertilized with urea, chicken drop, goat dung, and cow dung. Forest areas reflected the least disturbed habitats and homogenous plantations were the most disturbed habitats.

### Earthworm Extraction

Earthworm extraction was conducted using a digging and hand-sorting method. A single plot 900 cm<sup>2</sup> wide and 30 cm deep was set up, as earthworms are generally concentrated in the upper 30 cm (Fragoso & Lavelle 1992, Smith *et al.* 2008). Due to the different topographical conditions, the amount of plots made in each area varied from 10 to 75. Those plots in each area were placed randomly and were separated 100 cm apart from each other. Extracted earthworms were preserved in 70% ethanol prior to identification. Earthworm identification was based on criteria established by Stephenson (1923), Sims & Easton (1972), Easton (1979), and Blakemore (2010). Earthworms in juvenile stage and earthworms without anterior body part were grouped into unknown species.

### Earthworm Diversity Analysis

The number of extracted earthworms has been presented in density (ind/m<sup>2</sup>). Furthermore, the density of unknown species has been omitted from calculations. Shannon's diversity index ( $H'$ ) was used and so was Simpson's dominance index ( $D$ ) to assess diversity and dominance in each area (Magurran 1998). The indices were defined by:

$$H' = -\sum p_i \ln p_i$$

$$D = \sum p_i^2$$

where  $p_i$  is proportion of individual of  $i^{\text{th}}$  species (amount of  $i^{\text{th}}$  species / total number of earthworms). The expression  $1 - D$  for Simpson's dominance index was used, so the higher value reflected lower domination of certain species (Magurran 1998). Shannon's diversity and Simpson's dominance indices used density instead of the absolute number of earthworms (Gamito 2010).

The relative dominance of earthworm species in each area was calculated by this formula:

$$(\text{Species density} / \text{Total earthworm density}) \times 100\%$$

and the resulting dominancy class was followed the criteria established by Engelmann (1973) in which relative dominance  $< 1\%$  = subrecendent,  $1.1-3.1\%$  = recendence,  $3.2-10\%$  = subdominant,  $10.1-31.6\%$  = dominant, and  $> 31.7\%$  = eudominant. Meanwhile, species prevalence in Mount Gede was calculated by the formula:

$$(\text{Number of areas where certain species occurred} / \text{Total number of areas}) \times 100\%$$

where the total number of areas was 6 for forest and 12 for plantation.

The rarefaction curve is based on two regions (Bodogol and Situ Gunung) to assess whether the maximum species richness has been reached. The diversity calculation was performed using package „vegan“ (Oksanen *et al.* 2013) in R.3.0.0 (R Core Team 2013).

### Soil Parameters

The measured soil parameters included physical (temperature and water content) and mineral (C-organic, P, Ca, and K). Physical soil parameters were measured using a soil thermometer and a soil humidity tester in each plot. Meanwhile, soil samples from each area were collected using a compositing method up to 1000 g (see Didden 2001). The samples were air dried prior to analyzing their mineral content. Carbon organic content was analyzed by following Walkley-Black method, phosphorus was analyzed using a solution of  $\text{HCl}$  25%, Ca and K contents were analyzed using neutral 1 M ammonium acetate ( $\text{NH}_4\text{OAc}$ ) (Sarkar & Haldar 2005). The resulting values were brought into the same scale (mg/kg) by multiplying Ca and K by 200 and 390 respectively. Soil analysis was conducted in the Laboratory of Department of Soil Science and Land Resource, Faculty of Agriculture, Bogor Agricultural University.

### Statistical Analysis

#### Soil parameters and their influence on earthworm diversity

Earthworm density, number of species, and soil parameters were pooled in each area, making a total of 18 areas (9 Bodogol and 9 Situ Gunung). The difference of soil parameters in the forest, mixed plantation, and plantation areas were analyzed by Kruskal-Wallis“ rank sum test performed in R.3.0.0 (R Core Team 2013). Soil water content from B3 forest area was omitted from that analysis. It shows a very high value because sampling was done close to a waterfall.

We assessed whether the soil parameters determine Shannon’s diversity indices in each area using linear model (Zuur *et al.* 2009). Shannon’s diversity

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indices from each area were set as a response. Boxplot of the response showed no outlier. The normality of response was tested using Shapiro-Wilk and the result showed that it followed normal distribution ( $p$ -value=0.1174). The predictors were soil physical (temperature and water content) and mineral (C-organic, P, Ca, and K) parameters. Those predictors were transformed logarithmic naturally to convert them into a similar scale and meet the normality assumption. Collinearity between predictors was assessed by the variance inflation factor (VIF) value. The VIF value of 5.00 was set as the threshold. All of the predictors had  $< 5.00$  VIF value, so no predictor was omitted. Then, the model was simplified based on AIC. The homogeneity of variance was assessed in terms of residual vs. fitted value plot, and independence was assessed in terms of residual vs. predictors plot. There was no clear pattern in these plots and therefore no violation of the homogeneity and independence assumptions was found. Linear mixed effect model („nlme“ package (Pinheiro *et al.* 2013) in R. 3.0.0 software (R Core Team 2013)) with random intercept and area as group was constructed to compare the resulting linear model. The comparison was conducted using „RLRsim“ package (Scheipl 2010) in R. 3.0.0 (R Core Team 2013), and the result showed no difference between linear and linear mixed effect model. Since linear model had lower AIC than linear mixed effect model (11.12573 vs. 13.12573), we decided to use linear model.

### Density difference between *O. occidentalis* and *Pn. corethrurus*

The areas without *O. occidentalis* and *Pn. corethrurus* were omitted from the analysis (B1, B3, S1). The difference between *O. occidentalis* and *Pn. corethrurus* density was calculated by subtracting *O. occidentalis* with *Pn. corethrurus* density in each area. Hence, positive value indicates higher *O. occidentalis* over *Pn. corethrurus* density, and vice versa. These values were set as response. Boxplot of the response did not show any outlier. The response was tested using Shapiro-Wilk's and it showed normal distribution ( $p$ -value=0.7114). All of the soil parameters were set as predictor and transformed logarithmic naturally. The response was also transformed logarithmic naturally to bring it into similar scale with the predictors. The collinearity between predictors was assessed by the VIF and all of them had  $< 5.00$  value, therefore no predictor was omitted. Most of *O. occidentalis* densities were lower than *Pn. corethrurus* in Bodogol, but higher in Situ Gunung region. Due to that fact, it would be difficult to get the clear picture of the density difference between *O. occidentalis* and *Pn. corethrurus* if the data were grouped by region. Hence, we used linear model (Zuur *et al.* 2009) to characterize the soil parameters influencing the density difference between *O. occidentalis* and *Pn. corethrurus*. The model simplification was based on AIC. The plot of residual vs. fitted value and predictors did not show clear pattern, hence the assumptions of heteroscedasticity and independence were not violated. This analysis was conducted using R. 3.0.0 software (R Core Team 2013).

## Result

Forests had higher diversity but lower density compared with mixed and most homogenous plantations. The lower diversity index in B3 was caused by high soil water content that reached  $> 70\%$ . Additionally, *M. planata* appeared as the eudominant species in this area with a relative dominance of 83.33%. Hence, it is possible to consider that the *M. planata* prefers or maybe has better tolerance of high water content.

Among homogenous plantations, cucumber plantation (B8) had an unusually high diversity index. This was caused by the presence of two eudominant *O. occidentalis* and *Pn. corethrurus* among three earthworm species. Cabbage plantation (S4) also had a high diversity index, probably due to the low soil water content. In the meantime, the high diversity index in combination of avocado and cassava (B6) and avocado plantation (B7) was probably caused by the presence of bushes functioning as shade.

Most of the recorded soil parameters (Table 4.1) were able to support more earthworm species in forests compared to plantation areas. For instance, soil temperatures in forests (Bodogol area 1–3, Situ Gunung area 1–3) were lower and less fluctuated than in plantations (Bodogol area 4–9, Situ Gunung area 4–9). That trend was probably due to the presence of canopy. However, a linear model analysis (Zuur *et al.* 2009) shows that only soil water (slope = -1.420, p-value = 0.001), P (slope = -0.439, p-value = 0.001), and C-organic content (slope = 0.538, p-value = 0.018) influenced earthworm diversity. The other parameters were excluded due to model simplification. High level of C-organic, and low level of soil water and P in the soil had resulted in the highest diversity index in S3.

Table 4.1 Soil parameters, presented in minimum-maximum value, in forest and plantation areas in Mount Gede were tested by multiple comparison Kruskal-Wallis" rank sum test ( $\alpha = 0.05$ ). Values with the same superscripts in a row are not significantly different. n indicates the amount of the plot

Soil parameters	Area			P-value
	Forest (n=6)	Mixed plantation (n=2)	Homogenous plantation (n=10)	
Temperature ( $^{\circ}\text{C}$ )	21.42 – 22.98 <sup>b</sup>	26.44 – 28.21 <sup>a</sup>	24.90 – 32.58 <sup>a</sup>	0.003
Water content (%)	44.72 – 59.20 <sup>b</sup>	30.60 – 47.40 <sup>b</sup>	41.20 – 69.50 <sup>a</sup>	0.002
C-organic (%)	2.31 – 7.02 <sup>a</sup>	2.47 – 2.51 <sup>ab</sup>	1.49 – 3.14 <sup>b</sup>	0.028
P (mg/kg)	68.7 – 127.80 <sup>b</sup>	418.60 – 429.20 <sup>a</sup>	80.78 – 621.42 <sup>a</sup>	0.041
Ca (mg/kg)	1090.00 – 2524.00 <sup>a</sup>	1120.00 – 1390.00 <sup>a</sup>	1138.00 – 2046.00 <sup>a</sup>	0.435
K (mg/kg)	93.60 – 592.80 <sup>ab</sup>	682.50 – 795.60 <sup>a</sup>	304.20 – 1271.40 <sup>a</sup>	0.051

Soil water content in forests and mixed plantations were the lowest in contrast to homogenous plantations. As forest and mixed plantations had higher

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plant biomass (see Table 4.2), they also had high water uptake which caused lower soil water content (Wang *et al.* 2012). The earthworm's body contains about 80% water (Grant 1955) and earthworms occurred in the greatest number in soil containing 10–40% moisture (Ismail & Murthy 1985, Ganihar 1996, Tripathi & Bhardwaj 2004, Ivask *et al.* 2006, Gonzalez *et al.* 2007, Karmegam & Daniel 2007). Therefore, it is clear that the soil water content in this study, ranging from 30% to 77%, had negative influence to earthworm diversity.

Table 4.2 Sampling areas in Mount Gede. Bodogol region (B) was sampled in three forest (B1–B3), two mixed plantations (B4, B5), and four homogenous plantation areas (B6–B9). Situ Gunung region (S) was sampled in three forests (S1–S3) and six homogenous plantation areas (S4–S9)

Area	Category	Dominant plantation(s) in each area
B1	Forest	<i>Rasamala</i> ( <i>Altingia excelsa</i> ), grasses, bushes
B2	Forest	<i>Calliandra</i> ( <i>Calliandra</i> sp.), grasses, bushes
B3	Forest	Coffee ( <i>Coffea</i> sp.), <i>tepus</i> ( <i>Elateriospermum tapos</i> ), grasses, bushes
B4	Mixed plantation	Coffee ( <i>Coffea</i> sp.), talas ( <i>Colocasia esculenta</i> ), jackfruit ( <i>Artocarpus heterophyllus</i> ), papaya ( <i>Carica papaya</i> )
B5	Mixed plantation	Coffee ( <i>Coffea</i> sp.), talas ( <i>Co. esculenta</i> ), manglid ( <i>Magnolia blumei</i> ), java tea ( <i>Orthosiphon aristatus</i> )
B6	Homogenous plantation	Avocado ( <i>Persea americana</i> ) with some cassava plantations ( <i>Manihot esculenta</i> ), bushes
B7	Homogenous plantation	Avocado ( <i>P. americana</i> ), bushes
B8	Homogenous plantation	Cucumber ( <i>Cucumis sativus</i> )
B9	Homogenous plantation	Cassava ( <i>M. esculenta</i> )
S1	Forest	<i>Rasamala</i> ( <i>Al. excelsa</i> ), <i>tepus</i> ( <i>Et. tapos</i> ), grasses, bushes
S2	Forest	Dammar ( <i>Agathis dammara</i> ), grasses, bushes
S3	Forest	<i>Rasamala</i> ( <i>Al. excelsa</i> ), sago palm ( <i>Cycas</i> sp.), grasses, bushes
S4	Homogenous plantation	Cabbage ( <i>Brassica oleracea capitata</i> )
S5	Homogenous plantation	Cassava ( <i>M. esculenta</i> )
S6	Homogenous plantation	Chili ( <i>Capsicum</i> sp.)
S7	Homogenous plantation	Onion ( <i>Allium cepa</i> )
S8	Homogenous plantation	Groundnut ( <i>Arachis hypogaea</i> )
S9	Homogenous plantation	Chinese chard ( <i>Brassica rapa chinensis</i> )

As for water content, soil P was the lowest in forest areas (Table 4.1). The effect of soil P to earthworm density or biomass was not consistent as in previous studies (Ganihar 1996, Gonzalez *et al.* 2007, Zeithaml & Sklenicka 2009, Iodarche & Borza 2010, Teng *et al.* 2013). This is probably caused by a different range of observed soil P content, or that different earthworm communities had a different response to this factor.

Conversely, forests had the highest C-organic and showed a decreasing trend in mixed and homogenous plantations. Since decaying organic matter is a

source of diet for earthworms, it is not surprising to find a positive correlation between C-organic content with earthworm diversity (Ismail & Murthy 1985, Tripathi & Bhardwaj 2004).

Under unfavorable conditions in the plantation areas, many earthworm species were in low dominance and prevalence (Table 4.3). They were at risk of eradication presumably because of their stenotopic characteristic. *Ph. pura*-group was the least abundant native which was found only in a plantation that combined avocado and cassava (B6). Conversely, *N. javanica* was the most abundant native species. They occurred mostly in mixed plantation (B5) and cassava plantation (B9) (Fig. 4.1), which had a relatively high soil temperature and P content (Appendix 4.4).

Table 4.3 Relative dominance (RD) and prevalence (P) of earthworm species in forests and plantations in Mount Gede. All values are ranging from 0 (worst) to 100 (best). Species with asterisks are natives of the Orient

Species	Forest		Plantation	
	RD (%)	P (%)	RD (%)	P (%)
<i>A. aeruginosus</i>	1.46	33.33	0.00	0.00
<i>A. asiaticus</i>	0.36	16.67	0.00	0.00
<i>A. gracilis</i>	1.82	33.33	0.03	8.33
<i>A. hupeiensis</i>	0.91	33.33	0.00	0.00
<i>A. illotus</i> species-group	9.12	83.33	2.88	58.33
<i>A. minimus</i>	9.49	50.00	0.00	0.00
<i>A. morrisi</i> species-group	0.18	16.67	0.00	0.00
<i>A. robustus</i>	6.20	100.00	0.10	25.00
<i>Di. affinis</i>	1.46	33.33	0.34	41.67
<i>Dr. barwelli</i>	24.64	66.67	0.00	0.00
* <i>Dr. nepalensis</i>	1.09	33.33	0.00	0.00
<i>M. californica</i>	5.66	66.67	0.64	33.33
<i>M. javanica</i>	0.55	50.00	0.00	0.00
<i>M. planata</i>	3.65	16.67	0.03	8.33
* <i>N. javanica</i>	0.18	16.67	2.88	50.00
<i>O. occidentalis</i>	3.28	33.33	59.28	100.00
<i>Pe. excavatus</i>	0.00	0.00	0.95	25.00
<i>Ph. darnleiensis</i>	0.00	0.00	0.10	8.33
* <i>Ph. pura</i> species-group	0.00	0.00	0.03	8.33
<i>Po. bifaria</i> species-group	0.36	33.33	0.00	0.00
* <i>Po. moelleri</i>	0.73	16.67	0.00	0.00
* <i>Po. sempolensis</i>	2.55	50.00	0.00	0.00
<i>Pn. corethrurus</i>	26.28	50.00	32.72	91.67

The exotics *O. occidentalis* and *Pn. corethrurus* apparently had the most eurytopic characteristics as they dominated degraded areas which are not favorable for stenotopic earthworms. Both had the two highest dominance and prevalence and according to Engelmann's (1973) scale, occurred as eudominant species in plantations (Table 4.3, see Appendix 4.5–4.6). Interestingly, the increasing density of one of the two caused lower density of the other (Fig. 4.1). The *O. occidentalis* was likely to have higher density than *Pn. corethrurus* in

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areas which had high soil temperature (slope = 17.369, p-value = 0.003) (Appendix 4.7). Meanwhile, their density difference were not affected by soil K (slope = -1.545, p-value = 0.073). The others soil parameters were excluded due to model simplification. *O. occidentalis* dominated all of the homogenous plantations in Situ Gunung (S4–S9) and two homogenous plantations in Bodogol, namely cucumber (B8) and cassava plantation (B9). *Pn. corethrurus* dominated B2 forest area and almost all of the plantation areas in Bodogol (B4–B8). Previous studies reported that *O. occidentalis* and *Pn. corethrurus* have a wide tolerance and effective adaptation mechanisms to colonize the unfavorable areas. *O. occidentalis* can live in very humid soil and soil which is low in organic matter (Talavera 1990). It also has parthenogenesis strategy (Blakemore 2010). Meanwhile, *Pn. corethrurus* tolerates low oxygen availability (Chuang & Chen 2008). It also has more granules on the epidermal cell to secrete more mucous (Chuang *et al.* 2006), it has parthenogenesis strategy (Hendrix & Bohlen 2002), and is able to enter diapause and regenerate its posterior segment regardless of soil moisture (Fragozo & Lozano 1992).

## Discussion

Humans, deliberately or not, transplant exotic earthworm species by introducing horticultural plantations (Rota 2013, Plisko 2010). The exotics may disperse and live together with natives in forests where resources are adequate (Hendrix *et al.* 2006) and environmental conditions are favorable. Anthropogenic disturbance of forests due to transformation into plantations alters their environment by increasing soil temperature and phosphorous content while decreasing C-organic (as shown in our study), and consequently kills many earthworm species. The inherent growth rates, which are equivalent to the density, of these species can not compete with the frequency of destruction (Huston 1979) which are sudden and massive. The inability to adapt to environmental changes also shows that physiologically the earthworms were stenotopic. The leftover niche is occupied by a few eurytopic earthworms.

This study shows that *O. occidentalis* and *Pn. corethrurus* are the two most successful earthworms in plantations, due to their eurytopic physiological characteristics (see Talavera 1990, Blakemore 2010). Both are endogeic exotic species and they have been shown to occur in many anthropogenically disturbed areas (Talavera 1996, Gonzalez *et al.* 2006, Jian-Xiong *et al.* 2009). *O. occidentalis* origin was uncertain, either it is originates from Central America or Central Africa (Rota 2013), while *Pn. corethrurus* is possibly from Amazonian Brazil (Plisko 2010).

Both species might be expected to compete in the plantations. The competitive exclusion principle was devised in the laboratory (Huston 1979), and here we report that when two species (*O. occidentalis* and *Pn. corethrurus*)

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without niche differentiation occur together, they expel each other in the real world. It has been shown experimentally that the one which survives the competition in replicated trials was not always the same species (Hardin 1960). However, this study shows that wider physiological tolerance may determine the outcome. It is shown that in higher soil temperature, *O. occidentalis* is able to sustain viable population, ousting *Pn. corethrurus*, and „won“ the competition.

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## Appendices

Appendix 4.1 Earthworms recovered (ind/m<sup>2</sup>) from each area in Bodogol. Species with asterisks are natives of the Orient. See Table 4.2 for explanation of the areas. n indicates the amount of the plot. Unknown species was excluded from diversity and dominance indices analysis.

Species	B1 (n=25)	B2 (n=25)	B3 (n=25)	B4 (n=25)	B5 (n=50)	B6 (n=25)	B7 (n=14)	B8 (n=36)	B9 (n=75)
<i>A. asiaticu</i>	0.89	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<i>A. hupeiensis</i>	1.78	0.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<i>A. illoniu</i> species-group	2.67	0.44	0.00	14.67	6.00	7.56	3.17	0.00	0.15
<i>A. robustus</i>	1.78	1.33	0.44	0.44	0.22	0.00	0.00	0.00	0.00
<i>Di. affinis</i>	0.00	3.11	0.00	0.00	0.44	0.00	0.00	0.00	0.59
<i>Dr. barwelli</i>	7.56	30.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00
* <i>Dr. nepalensis</i>	0.00	0.00	0.89	0.00	0.00	0.00	0.00	0.00	0.00
<i>M. californica</i>	5.33	1.33	0.00	4.89	0.67	0.00	0.79	0.00	0.00
<i>M. javanica</i>	0.44	0.00	0.44	0.00	0.00	0.00	0.00	0.00	0.00
<i>M. planata</i>	0.00	0.00	8.89	0.44	0.00	0.00	0.00	0.00	0.00
* <i>N. javanica</i>	0.00	0.44	0.00	0.00	5.11	0.00	0.00	0.00	7.41
<i>O. occidentalis</i>	0.00	6.67	0.00	38.67	16.00	2.67	11.90	11.42	101.33
<i>Pe. excavatus</i>	0.00	0.00	0.00	2.67	4.00	0.00	0.00	1.23	0.00
<i>Ph. darnleiensis</i>	0.00	0.00	0.00	0.00	0.00	0.00	2.38	0.00	0.00
* <i>Ph. pura</i> species-group	0.00	0.00	0.00	0.00	0.00	0.44	0.00	0.00	0.00
<i>Pn. corethrurus</i>	0.00	53.78	0.00	75.11	100.44	64.89	82.54	8.02	0.30
Unknown	7.11	13.33	3.11	9.33	5.78	4.44	0.79	0.00	1.04
Number of earthworm	62	250	31	329	624	180	128	67	748
Density	27.56	111.11	13.78	146.22	138.67	80.00	101.59	20.68	110.81
Number of identifiable species	7	9	4	7	8	4	5	3	5
Shannon's diversity index (H')	1.628	1.175	0.624	1.159	0.893	0.509	0.651	0.864	0.309
Simpson's dominance index (1- D)	0.761	0.596	0.295	0.606	0.410	0.251	0.314	0.541	0.143

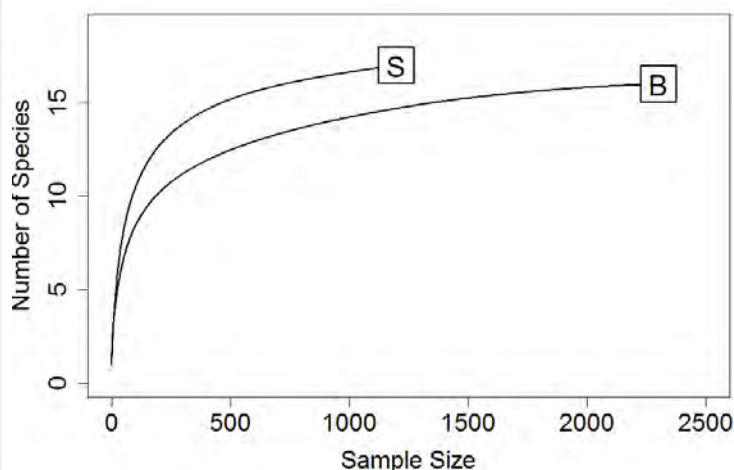
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Appendix 4.2 Earthworms recovered (ind/m<sup>2</sup>) from each area in Situ Gunung. Species with asterisks are natives of the Orient. See Table 4.2 for explanation of the areas. n indicates the amount of the plot. Unknown species was excluded from diversity and dominance indices analysis.

Species	S1 (n=25)	S2 (n=25)	S3 (n=25)	S4 (n=75)	S5 (n=22)	S6 (n=23)	S7 (n=20)	S8 (n=10)	S9 (n=36)
<i>A. aeruginosus</i>	1.33	0.00	2.22	0.00	0.00	0.00	0.00	0.00	0.00
<i>A. gracilis</i>	0.00	2.67	1.78	0.15	0.00	0.00	0.00	0.00	0.00
<i>A. illotus</i> species-group	7.56	4.44	7.11	0.30	0.00	0.48	0.00	0.00	0.00
<i>A. minimus</i>	17.33	2.67	3.11	0.00	0.00	0.00	0.00	0.00	0.00
<i>A. morrisi</i> species-group	0.00	0.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<i>A. robustus</i>	2.67	0.89	8.00	0.00	0.00	0.48	0.00	0.00	0.00
<i>Di. affinis</i>	0.00	0.00	0.44	0.00	0.51	0.00	0.00	1.11	0.62
<i>Dr. barwelli</i>	0.00	20.89	1.33	0.00	0.00	0.00	0.00	0.00	0.00
* <i>Dr. nepalensis</i>	1.78	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<i>M. californica</i>	0.00	1.33	5.78	0.59	0.00	0.00	0.00	0.00	0.00
<i>M. javanica</i>	0.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
* <i>N. javanica</i>	0.00	0.00	0.00	0.00	2.53	0.48	1.11	0.00	1.23
<i>O. occidentalis</i>	0.00	1.33	0.00	10.22	160.10	75.85	15.00	35.56	76.23
<i>Po. bifaria</i> species-group	0.00	0.44	0.44	0.00	0.00	0.00	0.00	0.00	0.00
* <i>Po. moelleri</i>	1.78	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
* <i>Po. sempolensis</i>	3.56	1.33	1.33	0.00	0.00	0.00	0.00	0.00	0.00
<i>Pn. corethrurus</i>	0.00	2.22	8.00	1.93	9.60	2.90	0.56	0.00	8.64
Unknown	24.00	27.55	14.22	0.00	6.57	1.45	0.00	0.00	1.54
Number of earthworm	136	149	121	89	355	169	30	33	286
Density	60.44	66.22	53.78	13.19	179.29	81.64	16.67	36.67	88.27
Number of identifiable species	8	11	11	5	4	5	3	2	4
Shannon's diversity index (H')	1.568	1.652	2.067	0.753	0.310	0.265	0.389	0.136	0.439
Simpson's dominance index (1 - D)	0.710	0.678	0.851	0.375	0.138	0.104	0.184	0.059	0.217

Appendix 4.3 Rarefaction curve in Bodogol (B) and Situ Gunung (S) region.



#### Appendix 4.4 Soil parameter from each area in Bodogol (B1–B9) and Situ Gunung (S1–S9). For soil physical factors: data $\pm$ SD.

Area	Temperature (°C)	Water content (%)	C-org (%)	P (mg/kg)	Ca (mg/kg)	K (mg/kg)
B1	21.96 $\pm$ 0.94	47.92 $\pm$ 26.19	4.30	127.80	2524.00	237.90
B2	21.42 $\pm$ 0.53	44.72 $\pm$ 26.21	3.63	101.60	1334.00	93.60
B3	22.58 $\pm$ 0.53	77.60 $\pm$ 32.54	2.31	103.20	2070.00	319.80
B4	26.44 $\pm$ 3.95	30.60 $\pm$ 21.13	2.47	429.20	1390.00	795.60
B5	28.21 $\pm$ 3.82	47.40 $\pm$ 25.92	2.51	418.60	1120.00	682.50
B6	24.90 $\pm$ 1.42	64.40 $\pm$ 25.26	2.15	92.10	1706.00	1205.10
B7	25.13 $\pm$ 1.80	66.07 $\pm$ 20.30	1.70	81.39	1432.00	1271.40
B8	32.58 $\pm$ 4.42	69.31 $\pm$ 14.79	1.71	80.78	1384.00	1267.50
B9	29.51 $\pm$ 2.74	51.33 $\pm$ 13.47	1.49	621.42	1138.00	994.50
S1	21.69 $\pm$ 0.84	59.20 $\pm$ 13.52	7.02	97.90	1320.00	397.80
S2	22.00 $\pm$ 0.96	51.80 $\pm$ 14.21	4.22	70.40	2074.00	491.40
S3	22.98 $\pm$ 0.89	47.60 $\pm$ 16.02	4.46	68.70	1090.00	592.80
S4	27.25 $\pm$ 4.45	41.20 $\pm$ 17.28	3.14	391.88	1242.00	702.00
S5	27.70 $\pm$ 1.81	59.55 $\pm$ 11.94	2.88	210.57	1532.00	471.90
S6	29.43 $\pm$ 2.51	59.78 $\pm$ 12.01	3.00	219.21	1496.00	702.00
S7	27.95 $\pm$ 1.01	64.25 $\pm$ 6.34	2.79	204.20	1566.00	315.90
S8	27.98 $\pm$ 1.16	69.50 $\pm$ 7.98	2.31	182.90	2046.00	304.20
S9	29.20 $\pm$ 3.21	65.69 $\pm$ 8.63	2.92	508.62	1960.00	686.40

#### Appendix 4.5 Relative dominance (%) of earthworm species in each area from Bodogol. Species with asterisks are natives of the Orient. See Table 4.2 for explanation of the areas.

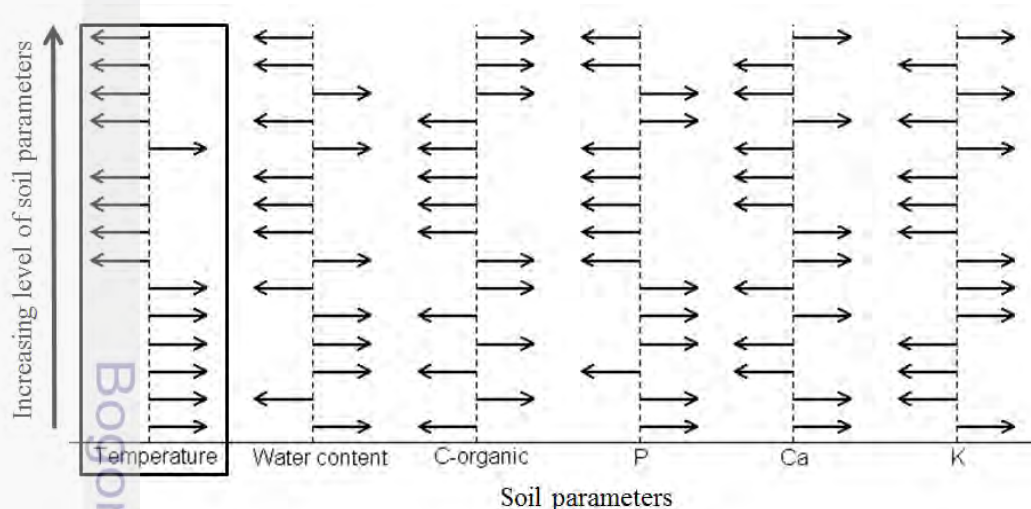
Species	B1	B2	B3	B4	B5	B6	B7	B8	B9
<i>A. asiaticus</i>	4.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<i>A. hupeiensis</i>	8.70	0.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<i>A. illotus</i> species-group	13.04	0.45	0.00	10.71	4.52	10.00	3.15	0.00	0.13
<i>A. robustus</i>	8.70	1.36	4.17	0.32	0.17	0.00	0.00	0.00	0.00
<i>Di. affinis</i>	0.00	3.18	0.00	0.00	0.33	0.00	0.00	0.00	0.54
<i>Dr. barwelli</i>	36.96	30.91	0.00	0.00	0.00	0.00	0.00	0.00	0.00
* <i>Dr. nepalensis</i>	0.00	0.00	8.33	0.00	0.00	0.00	0.00	0.00	0.00
<i>M. californica</i>	26.09	1.36	0.00	3.57	0.50	0.00	0.79	0.00	0.00
<i>M. javanica</i>	2.17	0.00	4.17	0.00	0.00	0.00	0.00	0.00	0.00
<i>M. planata</i>	0.00	0.00	83.33	0.32	0.00	0.00	0.00	0.00	0.00
* <i>N. javanica</i>	0.00	0.45	0.00	0.00	3.85	0.00	0.00	0.00	6.75
<i>O. occidentalis</i>	0.00	6.82	0.00	28.25	12.04	3.53	11.81	55.22	92.31
<i>Pe. excavatus</i>	0.00	0.00	0.00	1.95	3.01	0.00	0.00	5.97	0.00
<i>Ph. darnleiensis</i>	0.00	0.00	0.00	0.00	0.00	0.00	2.36	0.00	0.00
* <i>Ph. pura</i> species-group	0.00	0.00	0.00	0.00	0.00	0.59	0.00	0.00	0.00
<i>Pn. corethrurus</i>	0.00	55.00	0.00	54.87	75.59	85.88	81.89	38.81	0.27

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Appendix 4.6 Relative dominance (%) of earthworm species in each area from Situ Gunung. Species with asterisks are natives of the Orient. See Table 4.2 for explanation of the areas.

Species	S1	S2	S3	S4	S5	S6	S7	S8	S9
<i>A. aeruginosus</i>	3.66	0.00	5.62	0.00	0.00	0.00	0.00	0.00	0.00
<i>A. gracilis</i>	0.00	6.90	4.49	1.12	0.00	0.00	0.00	0.00	0.00
<i>A. illotus</i> species-group	20.73	11.49	17.98	2.25	0.00	0.60	0.00	0.00	0.00
<i>A. minimus</i>	47.56	6.90	7.87	0.00	0.00	0.00	0.00	0.00	0.00
<i>A. morrisi</i> species-group	0.00	1.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<i>A. robustus</i>	7.32	2.30	20.22	0.00	0.00	0.60	0.00	0.00	0.00
<i>Di. affinis</i>	0.00	0.00	1.12	0.00	0.29	0.00	0.00	3.03	0.71
<i>Dr. barwelli</i>	0.00	54.02	3.37	0.00	0.00	0.00	0.00	0.00	0.00
* <i>Dr. nepalensis</i>	4.88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<i>M. californica</i>	0.00	3.45	14.61	4.49	0.00	0.00	0.00	0.00	0.00
<i>M. javanica</i>	1.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
* <i>N. javanica</i>	0.00	0.00	0.00	0.00	1.46	0.60	6.67	0.00	1.42
<i>O. occidentalis</i>	0.00	3.45	0.00	77.53	92.69	94.58	90.00	96.97	87.90
<i>Po. bifaria</i> species-group	0.00	1.15	1.12	0.00	0.00	0.00	0.00	0.00	0.00
* <i>Po. moelleri</i>	4.88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
* <i>Po. sempolensis</i>	9.76	3.45	3.37	0.00	0.00	0.00	0.00	0.00	0.00
<i>Pn. corethrurus</i>	0.00	5.75	20.22	14.61	5.56	3.61	3.33	0.00	9.96

Appendix 4.7 It was more probable to found higher *O. occidentalis* density than *Pn. corethrurus* along increasing of soil temperature (inside rectangle). Arrows pointing left indicates higher *O. occidentalis* density over *Pn. corethrurus* in certain area (see Appendix 4.4 for detailed soil parameters in each area), and vice versa. The areas without *O. occidentalis* and *Pn. corethrurus* (B1, B3, and S1) were omitted.



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## 5 GENERAL DISCUSSION

The increase of human population renders environmental alteration through expanding of land-use change into agricultural systems to yield goods and services. At the same time, it drives the loss of biological diversity (Vitousek *et al.* 1997). On the other hands, humans deliberately or not introducing earthworms along with agricultural plantations (Talavera 1996, Hendrix & Bohlen 2002, Tripathi & Bhardwaj 2004, Talavera 2007, Rota 2013). Seven earthworms are reported for the first time in Indonesia and they are most likely introduced by human.

Deforestation into plantations, which definitely alters the environment, is a consequence of the expanding of land-use change by humans. The noticeable alteration as shown in this study is soil parameters changing. The constant results of this alteration are increasing of soil temperature, pH, and water content, while C-organic content is decreasing. Moreover, the landowners prefer to apply organic rather than inorganic fertilizers. Since earthworm number and biomass are greater in organic compared to inorganic fertilized area (Whalen *et al.* 1998), we believe that the application of organic fertilizers in our study areas does not reduce earthworm diversity. Hence, we propose that the degraded environmental caused by deforestation is not able to support stenotopic earthworms, expelling them from the community or driving them to die, and therefore resulting in diversity reduction.

The relationship between deforestation and diversity as shown in our study is supported with the model proposed by Huston (1979). In the forests, population disturbance may come from predation and mortality. However, the earthworms are able to reach the minimum growth rate to recover their population between the disturbances. This condition leads to high diversity of earthworm. On the other hand, the plantations reflect severely permanent disturbed habitat. The growth rates of most earthworms, which are stenotopic, are not high enough to maintain their population size. Hence, the disturbed habitat leads the survived eurytopic species to reach the equilibrium competition and consequently drives them to compete each other. It is shown in our study where the density of *O. occidentalis* inversely correlates with *Pn. corethrurus* in Mount Gede. *O. occidentalis* is able to sustain viable population over *Pn. corethrurus* in area with higher soil temperature.

The Gause's principle, whereby two species without niche differentiation expel each other, has been devised in laboratory (Mooney & Cleland 2001), and agricultural plantations in our study act as transplant experiment for that principle. When the environmental disturbance is severe, it is possible to leave a single species out as happened in Bungku Village. It is difficult to prove the competition due to lack of previous observation. Nevertheless, *Pn. corethrurus* can survive

over *O. occidentalis* in Bungku Village probably due to lower soil temperature than Mount Gede. The other possibility is *O. occidentalis* has not introduced yet to that area. *O. occidentalis* is believed introduced through avocado plantation (Rota 2013) and there is no avocado plantation in Bungku Village. *Pn. corethrurus* is supposed to be introduced through rubber plantation and rubber plantations are abundant in Bungku Village. Hence, it is not surprising that *Pn. corethrurus* has higher density and it put them in advantage.

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## 6 CONCLUSION

Struggle for existence of earthworms is shown in transplant experiment. Agricultural practices lead to deforestation and drive stenotopic earthworms to die and leave the eurytopics with the overlapping niche compete each other. It is sensible to conclude that deforestations may cause Gause's principle to work in nature and consequently reduce the diversity of earthworms.

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## CURRICULUM VITAE

The author was born in Bogor at 1985. At 2008, he studied *Monocystis* as earthworm parasite and achieved his Bachelor of Science in Bogor Agricultural University. At 2010, he studied bioecology of earthworm *Pheretima darnleiensis* and published an article about morphoogical character of *Pheretima darnleiensis*. He achieved his Master of Science at the same year from Bogor Agricultural University. He continued to pursuit his doctoral at Bogor Agricultural University with scholarship from Directorate General of Higher Education (DIKTI) at 2011. At 2013, he did a collaborative research with Collaborative Research Center, George August Universtat Gottingen, Germany and published a paper about domination of earthworm *Pontoscolex corethrurus*. He was currently doing a research about struggling for existence in earthworms.

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