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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 *P. 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 *P. corethrurus*. We found that all of 940 recovered earthworms were *P. corethrurus*. Their density was not significantly different in the four systems. Our result showed that *P. 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. *Pontoscolex corethrurus* which have better tolerance than the native earthworms are favored by anthropogenic practice.

KEY WORDS earthworm; exotic; oil palm; rubber; soil.

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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* (Willd. ex A. Juss.) Müll. Arg.), 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). *Pontoscolex 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 *P. 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 *P. corethrurus* to sucessfully 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 *P. 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^{o}15’-2^{o}20’ south latitude - 120^{o}30’-104^{o}30’ east longitude) (Fig. 1). This area had average annual temperature of 25.5 ^{o}C and cumulative precipitation of 2700 mm (BPPD, 2010). Sampling area comprised of 15 year-old oil palm plantation (S 01^{o} 54' 33.8", E 103^{o} 15' 56.3"), 11 year-old rubber plantation (S 01^{o} 54' 39.6", E 103^{o} 15' 59.3"), 19 year-old rubber jungle (S 01^{o} 55' 39.9", E 103^{o} 15' 32.0"), and secondary forest (S 01^{o} 54' 52.1", E 103^{o} 15' 57.3"). The coordinates were taken in the outer side of each system.

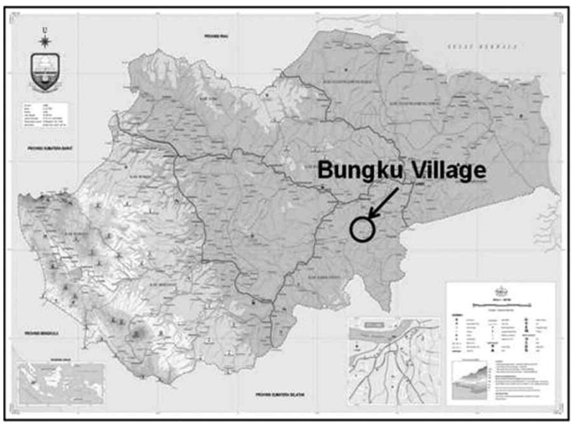

Fig. 1. Study site in Jambi Province, Indonesia.

Dominant plants in oil palm plantation were oil palm, *Elais guineensis* Jacq., and grass (Gramineae). Rubber plantation consisted of only rubber, *Hevea brasiliensis*. Rubber jungle was dominated by rubber, Asian melastome, *Melastoma candidum* D. Don., grass, and billian, *Eusideroxylon zwageri* Teijsm. et Binn. Meanwhile, secondary forest was dominated by tempinis, *Sloetia elongata* Koord., medang, *Litsea firma* (Blume) Hook. f., 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).

Pontoscolex corethrurus ***extraction***

Purposive random sampling was conducted to extract *P. 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. *Pontoscolex 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 *P. corethrurus* biomass. Identification and description of *P. corethrurus* were conducted by following Blakemore method (2010). *Pontoscolex corethrurus* with and without clitellum were classified into adult and juvenile, respectively. Meanwhile, *P. 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 spemathecal 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 *P. 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_4OAc) method. Afterward, soil phosphorus was analyzed using solution of HCl 25% (Sarkar & Haldar, 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 *P. corethrurus* density, adult biomass, and soil parameters in all systems. Soil factors influencing *P. corethrurus* abundance was analyzed by constructing generalized linear model as the abundance followed Poisson distribution (Zuur et al., 2009). *Pontoscolex 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: *P. 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.

RESULTS

Domination, density, and adult biomass of **P. corethrurus** *in four land systems*

A common effect of anthropogenic disturbance into agricultural system is domination of exotic earthworm like in Tripura, India, where *P. corethrurus* successfully dominated rubber plantation with >70% frequency (Chaudhuri et al., 2008; Chaudhuri & Nath, 2011). We also found *P. corethrurus* in Bungku Village. All of 940 recovered earthworms there were *P. 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. in undisturbed forest in West Java recovered more than six earthworm species including *P. corethrurus* (unpublished data).

Pontoscolex corethrurus density was not significantly different in the four systems (Table 1). All of our results were lower than previous study in Tripura, India, which found a *P. corethrurus* density of 78-88 ind/m^2 (Chaudhuri et al., 2008; Chaudhuri & Nath, 2011).

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

Soil parameters in four land systems and their influence on **P. 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 land owner (Table 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 *P. corethrurus* abundance was significantly influenced by soil physical factor, mineral content, and texture (Table 3).

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 *P. 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, *P. corethrurus* has better tolerance to fill the niche left by the natives (Gonzalez et al., 2006). Most earthworms tolerate narrow range of temperature. However, *P. corethrurus* can tolerate approximately 13-27 ^{o}C of temperature (Kale & Krishnamoorthy, 1979) and even up to 29 ^{o}C in the present study. *Pontoscolex corethrurus* is characterized as having constant oxygen consumption without diurnal rhythm and tolerance for low oxygen availability (Chuang & Chen, 2008). The epidermal cells of *P. corethrurus* consist of more granules, so it can secret more mucus to provide the protection from UV light as compared to *Amynthas gracilis* and *Metaphire posthuma* (Chuang et al., 2006; Gonzalez et al., 2008). Parthenogenesis also occurs in *P. 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 *P. 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 *P. corethrurus* than that reported in previous study, we speculate that it might be due to the higher soil pH (6.5) as *P. 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* Linnaeus, 1758, caused a lower *P. 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 *P. corethrurus* biomass. For comparison, the previously mentioned *P. corethrurus* from Tripura, India, had biomass of 26–30 g/m^2 (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). *Pontoscolex corethrurus* is an earthworm which can tolerate or even prefer acidic

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

Table 1. Kruskal-Wallis test of *Pontoscolex corethrurus* density in each system. The values are mean of *P. corethrurus* abundance/m^2 ± SD.

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

Table 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).

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

Table 3. Soil parameters affecting *Pontoscolex corethrurus* abundance.

soil (Nath & Chaudhuri, 2010). 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 *P. 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 *P. corethrurus* in soil containing higher C organic. Na showed negative influence on *P. 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 *P. 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 *P. corethrurus* abundance.

In summary, we propose that anthropogenic practice in Bungku Village causes the condition which does not support the native earthworm's survival. *Pontoscolex 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 *P. corethrurus* domination in Indonesian disturbed forest.

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