

# IMPACT OF DEFORESTATION ON EARTHWORM POPULATIONS IN GUYANA'S RAINFORESTS

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## ABSTRACT

Changes to the landscape of tropical rainforests are potential instigators in population changes experienced by earthworms, which are integral biological components of almost all terrestrial ecosystems. A comparative analysis of earthworm populations was done in the rainforests of Guyana to investigate the impact of deforestation on earthworm populations. Earthworms were sampled in pristine forest sites and deforested sites, which yielded 31 species belonging to 10 families. Deforested sites suffered significantly from low abundance, density, diversity and richness. The population data among the two types of sites were all of statistical significant difference, with the exception of epigeic abundance. Earthworm abundance and richness were found to be significantly negatively correlated to deforestation. Anecic ecotype were the most affected as none were recorded in deforested sites while *P. corethrurus* was found to be the most abundant species in the deforested sites.

**Keywords: deforestation; population ecology; earthworm; rainforest; pedological environment**

## 20 1.0 INTRODUCTION

Earthworms are perhaps the most fundamental pedobiological invertebrates, having a diversity of well over 3500 documented species globally, classified into three ecological groups. They feed on plant residues and the mineral layer of soils, creating both vertical and horizontal burrows as they move. Earthworms serve a cardinal role in modifying the physical structure of soil, Chauhan, 2014, and are fundamental cogs in almost every pedological-terrestrial ecosystem. The effects of deforestation is one that permeates the biosphere, from climate change to biodiversity loss. While research into biodiversity loss has been given

more attention over the past decade, earthworms are one of the overlooked taxa that hasn't been thoroughly explored in this context and as such data on their changing population is limited. The aim of this study was to investigate the impacts of deforestation on earthworm populations through the exploration following hypotheses: (1) The population structure of earthworms among deforested and pristine sites will be significantly different. (2) Deforestation reduces the biodiversity of earthworms in Guyana's rainforests.

## 2.0 MATERIALS AND METHODS

### 2.1 Description of Study Area

Guyana is located on the northeastern part of South America forming part of the Guiana Shield, which accounts for a part of the Amazon biome (EPA, 2015). The twelve sites that were sampled were established within the mountainous rainforests of Guyana's highlands. The climate type, (Peel, *et al.*, 2007), experienced by this region was monsoon and the soil types, (FAO, 1998), were predominantly ferralsol and Acrisol, with Lixisol and Anthrosol occurring less frequently.

### 2.2 Experimental Design

12 sample sites were established within the rainforest ecosystem of Guyana and the respective GPS coordinates were recorded. Of the 12 sample sites, 5 were pristine environments, while the remaining 7 were affected by deforestation. In each of the 12 sites, 15 sampling points of dimensions 0.5m<sup>3</sup> were established along a linear transect at 6m intervals. The soil was removed from each sample point by digging, after which the removed soil was hand sorted for earthworms which were categorized and counted. Ecotypes were denoted by their colouration, and adults were denoted by the presence of a clitellum. 2 adults from each morphospecies were collected and placed in separate labelled ziplock bags containing 95% ethanol. The circumference and length of each morphospecies was recorded along with the type and position of key external features such as segmentation, prostomium, genital opening and setal data. This was then followed by methodological dissections where the number and position of organs such as the seminal vesicles, spermatheca, heart and gizzard, were noted.

### 2.3 Data Analysis

Earthworms were placed into families based on Blakemore's 2006 family key.

The statistical data was analyzed using R version 3.4.4, 2018, where the ANOVA, point-biserial correlation and linear regression functions were utilized. For the point-biserial correlation and linear regression, dummy coding was used for the categorical variable (pristine and deforested), where  $X^1 = 1$  represented the presence of disturbance (deforested) and  $X^1 = 0$  represented the absence of disturbance (pristine).

The biological data was analyzed using: Shannon-Wiener Index, Simpson Index and McIntosh Index.

### 3.0 RESULTS

31 taxonomically distinct species belonging to 10 families were found among the 12 sample sites. Of the 10 families, Glossoscolecidae was the most diverse, containing 10 species while Eudrilidae, Enchytraeidae, Lutodrilidae and Kynotidae were the least diverse, containing 1 species each, Table 1.0. Pristine sites were occupied by 22 species belonging to 8 families while deforested sites were occupied by 10 species belonging to 5 families. 5 of the families found in pristine sites were notably absent from the deforested sites, and 2 of the families found in the deforested sites were absent from the pristine sites, Table 2.0.

Of the 31 species, *P. corethrurus* was found to be the most abundant accounting for 18% of the population, while a species from the Almididae family was found to be the least abundant accounting for 0.05% of the population, Fig 1.0. Of the pristine forest sites, a species from the Ocnerodrilidae family was found to be the most abundant and an Almididae species was found to be the least, while in the deforested sites, *P. corethrurus* was the most abundant and a species from the Acanthodrilidae family was the least, Table 1.0.

Of the two types of sites, pristine sites displayed the higher average abundance of earthworms (820) which was three times higher than the observed abundance of the deforested sites (265), Table 3.0. The abundance among the pristine and deforested sites were of statistical significant difference with a p-value of 0.002.

Pristine forest sites displayed an average density of 55 individuals per  $m^2$  while in the

deforested sites, the average density was 18 individuals per m<sup>2</sup>, Fig 3.0. The density among  
85 the two types of sites were found to be of statistical significant difference with a p-value of 0.002.

Pristine forest sites were found to be three times more species rich (6) than the deforested  
sites (2), Table 5.0. The highest number of species found in a pristine site was 7 and the  
lowest 4, while the highest number of species found in a deforested site was 4 and the  
90 lowest 1. The species richness among the two types of sites were of statistical significant  
difference with a p-value of 0.001. Both types of sites displayed the same epigeic richness  
(1), however, endogeic richness was 4 times higher in pristine sites. Both endogeic and  
anecic richness among the pristine and deforested sites were of statistical significant  
difference with p values of 0.005 and 0.011 respectively.

95 Both types of sites displayed the same pattern of ecotype abundance with endogeic  
earthworms being the most abundant and anecic earthworms being the least. The average  
abundance of each ecotype (epigeic, endogeic and anecic) was higher in the pristine sites  
while the deforested sites had a lower ecotype abundance, with anecic species being  
completely absent, Fig. 4.0.

100 Of the two types of sites, epigeic abundance was not found to be of statistical significant  
difference (0.4), however, endogeic and anecic abundance were found to be of statistical  
significant difference with p-values 0.019 and 0.005 respectively.

Pristine forests displayed higher diversity and evenness as evidenced by the values obtained  
from the biological indices, Table 7.0. The Shannon diversity of the deforested sites were  
105 significantly poor, having an average of 0.56, while the diversity in the pristine sites were  
more than twice as high, Table 8.0. Both types of sites displayed similar evenness. Similarly,  
ecotype diversity was found to be significantly higher in the pristine sites in comparison to  
the deforested sites.

The regression model for disturbance and abundance showed a significant p-value of 0.0023  
110 and an r-squared value of 62%, while the regression model for disturbance and species  
richness showed a smaller p-value of 0.0008 and a higher r-squared value of 69%. Both

abundance and species richness were found to be negatively correlated with deforestation, -0.7885 & -0.8297 respectively.

#### 4.0 DISCUSSION

Eudrilidae, Megascolecidae, Acanthodrilidae, Ocnerodrilidae, Sparganophilidae and Glossoscolecidae are the only previously documented earthworm families to be recorded from Guyana, Brown & Fragoso, 2007. In light of this research, an additional 5 families have been documented, 2 of which can be found in bordering countries, Brazil and Venezuela.

The shield that the dense canopy of rainforests provide effectively protects the pedological environment from direct contact with the elements and as such the clearing of the land removes this barrier, exposing the soil to the full extremes of the elements, Lal, 1987. With the soil being in direct contact with the sun, increase in the ambient temperature of the soil is definite, firstly affecting the epigeic species as they reside in the uppermost layer of the soil. This decline in epigeic abundance was observed where deforested sites had an average of 42% less epigeic earthworms than pristine sites.

The rate of soil water evaporation increases in the cleared land which exacerbates the drying of the soil, subsequently decreasing earthworm populations as they absorb and lose moisture through their skin, Edwards & Bohlen, 1996. The consequence of this phenomenon was observed in deforested sites whose average abundance was 68% lower than that of the pristine sites.

A change in the natural dynamics of the population will occur, as a result of the micro-climate created, favoring drought resistant species, Tripathi & Bhardwaj, 2004. This manifested in the form of *P. corethrurus* dominance, which thrived in the new deforested environment, while the dominant Ocnerodrilidae species of pristine forest sites were absent from the new dynamic.

On the inverse, in the event of heavy rains, soils will become more easily waterlogged, creating an anaerobic environment which forces earthworms, particularly anecic species, out of their burrows where they are susceptible to predation, ergo decreasing anecic populations.

Changes in soil textures will occur as a result of exposure to wind and rain and due to the migration of clay particles into the deeper layers of the soil. This will cause the surface of the soil to be dominated by coarse particles, (Gijsman, 1992), which will negatively impact epigeic species by causing abrasions to their cuticle.

The removal of trees discontinues the addition of organic debris to the soil, while the already existing debris on the forest floor will decompose faster as it is exposed to the elements, Edwards, 2004. The lack of organic matter will see declines in the abundance of epigeic and anecic species, as their limited food supplies cannot support a large population, leading to an increase in interspecific competition which will also decrease the species richness. This decline was observed as the abundance of all ecotypes were lower in the deforested sites.

The species richness of the endogeic ecotype decreased by an average of 75% while anecic abundance and richness decreased by 100% in deforested sites. The deforested sites had an overall average of 67% lower species richness than pristine sites.

The process of deforestation in itself disrupts the pedological environment by altering the integrity of the soil. The use of heavy machinery and the dragging of trees removes or disrupts the topsoil making it easier for it to be blown or washed away and increases the compaction of the top 10cm of soil, Ngeh, 1989. Disruption to the topsoil will directly affect epigeic species, resulting in a population decrease. Compaction can also permeate to the deeper layers of the soil, (Janseen and Wienk, 1990), which can then negatively impact anecic species.

Compaction leads to changes in pore sizes and closure of pores which increases the resistance against burrowing, alters soil water retention and soil aeration capacity, all of which makes it difficult for anecic species to survive. This was the most significant decrease noted as no anecic species were found in deforested sites. Endogeic species on the other hand are able to penetrate compacted soils as a result of their horizontal burrowing, Gijsman, 1992. Despite a 72% decline in endogeic abundance in deforested sites, they remained the most abundant and rich of the 3 ecotypes in the deforested sites.

*P. corethrurus* was the most abundant species and was the only species found in both types

of sites, being the most abundant species in the deforested sites. This species is highly invasive, thriving in disturbed habitats, outcompeting native earthworms, Marichal, *et al.*, 2010. Due to its resilience, its population only suffered a 2.7% decrease in the deforested sites.

## 5.0 CONCLUSION

Deforestation directly and indirectly affects the pedological environment through the creation of adverse micro-climates and altering of the structural integrity of the soil giving rise to many cascade effects. As a result of this, deforestation is a major threat to earthworm biodiversity, causing significant decreases in density, abundance, richness, diversity and ecotype structure. Earthworm abundance and species richness were found to have significant negative correlations with deforestation. The biological data were of statistical significant difference among pristine and deforested sites. Of the three ecotypes, anecic species were the most significantly affected by deforestation, while endogeic species, despite reduced abundance, remained the dominant ecotype. *P. corethrurus* was found in both pristine and deforested sites, assuming dominance in the disturbed environment.

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## LIST OF TABLES

Table 1.0 showing species abundance data

Species	Family	Deforested Abundance	Pristine Abundance	Total
<i>P.corethrurus</i>	Glossoscolecidae	535	550	1085



R8S18	Ocnerodrilidae	0	633	633
R7S4	Megascolecidae	434	0	434
R8S19	Megascolecidae	0	401	401
R8S17	Lumbricidae	0	392	392
R8S28	Megascolecidae	0	371	371
R7S3	Acanthodrilidae	278	0	278
R8S27	Eudrilidae	0	276	276
R8S25	Acanthodrilidae	0	258	258
R7S5	Glossoscolecidae	220	0	220
<i>D.venata</i>	Lumbricidae	0	210	210
<i>Rhinodrilus sp.</i>	Glossoscolecidae	0	198	198
<i>M.potarensis</i>	Glossoscolecidae	0	175	175
<i>Pheritima sp.</i>	Megascolecidae	167	0	167
R10S8	Ocnerodrilidae	159	0	159
R8S23	Glossoscolecidae	0	106	106
R9S06	Megascolecidae	0	102	102
R8S15	Glossoscolecidae	0	81	81
R8S3	Almidae	0	76	76
R8S20	Lumbricidae	0	68	68
R7S2	Glossoscolecidae	66	0	66
R8S22	Glossoscolecidae	0	51	51
R7S1	Lutodrilidae	44	0	44
R8S14	Glossoscolecidae	0	36	36
R8S7	Kynotidae	0	35	35
R10S7	Acanthodrilidae	34	0	34
R8S29	Enchytraeidae	0	32	32
R8S16	Glossoscolecidae	0	20	20
R2S03	Ocnerodrilidae	0	18	18
R8S21	Megascolecidae	0	6	6
R8S24	Almidae	0	3	3

Table 2.0 showing earthworm families

Family	Species	Pristine	Deforested
Glossoscolecidae	10	8	3
Megascolecidae	6	4	2
Lumbricidae	3	3	0
Ocnerodrilidae	3	2	1
Acanthodrilidae	3	0	3
Almidae	2	2	0
Eudrilidae	1	1	0
Lutodrilidae	1	0	1
Enchytraeidae	1	1	0

Kynotidae	1	1	0
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Table 3.0 showing earthworm abundance in Pristine and Deforested sites.

Pristine	Deforested
964	593
616	299
685	221
1282	352
551	119
	193
	80
<i>p value- 0.002</i>	

Table 4.0 showing earthworm density in Pristine and Deforested sites.

Pristine	Deforested
64	39
41	20
46	15
85	23
37	8
	13
	5
<i>p value- 0.002</i>	

225 Table 5.0 showing number of species in Pristine and Deforested sites.

epigeic richness		endogeic richness		anecic richness		total richness	
pristine	deforested	pristine	deforested	pristine	deforested	pristine	deforested
1	1	5	3	1	0	7	4
1	2	4	1	2	0	7	3
2	1	2	0	0	0	4	1
1	2	4	0	2	0	7	2
0	0	3	2	1	0	4	2
	0		2		0		2
	1		0		0		1
<b>1</b>	<b>1</b>	<b>4</b>	<b>1</b>	<b>1</b>	<b>0</b>	<b>6</b>	<b>2</b>
p value- 1		p value- 0.005		p value- 0.011		p value- 0.001	

Table 6.0 showing the abundance of earthworm ecotypes in Pristine and Deforested sites.

epigeic abundance		endogeic abundance		anecic abundance	
Pristine	Deforested	Pristine	Deforested	Pristine	Deforested
35	79	853	514	76	0
50	147	504	152	62	0
611	221	74	0	0	0
392	352	752	0	138	0
0	0	504	199	47	0

	0		193		0
	80		0		0
p value- 0.4		p value- 0.019		p value- 0.005	

Table 7.0 showing values for biological indices

Indices	pristine	deforested	interpretation	Reference
Simpson D	0.087	0.176	closer to 0, higher diversity	Simpson, 1949
McIntosh E	0.891	0.87	closer to 1, equal distribution	McIntosh, 1967
Shannon H'	2.662	1.905	closer to 5, higher diversity	Heip & Engels, 1974

Table 8.0 showing biodiversity data for sites

Deforested	Simpson D	McIntosh E	Shannon H'
DS1	0.3144	0.8764	1.2483
DS2	0.3819	0.8999	1.0242
DS3	1		0
DS4	0.5285	0.929	0.663
DS5	0.6538	0.6498	0.5283
DS6	0.7082	0.5379	0.4655
DS7	1		0
avg	0.6552571429	0.7786	0.5613285714
Pristine	Simpson D	McIntosh E	Shannon H'
PS1	0.1989	0.8892	1.7282
PS2	0.2412	0.857	1.5271
PS3	0.4458	0.6634	0.9467
PS4	0.3483	0.6581	1.3118
PS5	0.3165	0.8725	1.2385
avg	0.31014	0.78804	1.35046

Table 9.0 showing biodiversity data for ecotypes

Deforested	Simpson D	McIntosh E	Shannon H'
epigeic	0.3792	0.9077	1.0281
endogeic	0.3275	0.7218	1.372
anecic	-	-	-
Pristine	Simpson D	McIntosh E	Shannon H'
epigeic	0.2533	0.8976	1.4384
endogeic	0.1628	0.8249	2.036
anecic	0.273	0.8599	1.3581

230 Table 10.0 showing values for linear regression and point-biserial correlation

Function	disturbance x abundance	disturbance x species richness
Linear Regression p-value	0.0023	0.0008
Linear Regression r-	62%	69%

square		
Point-Biserial Correlation	-0.7885	-0.8297

## LIST OF FIGURES

Figure 1.0 showing observed species abundance of earthworms

Species Abundance

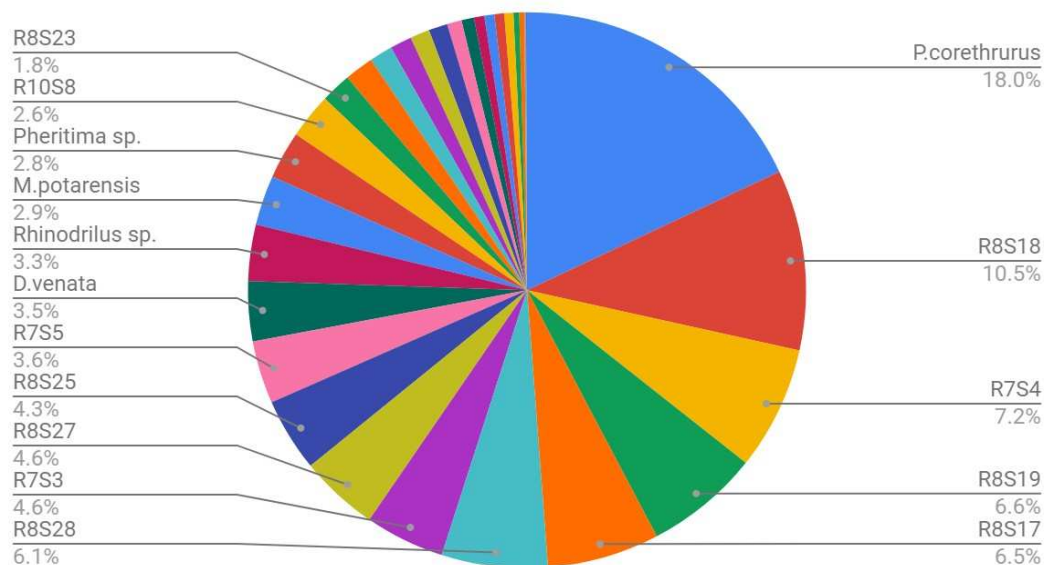


Figure 2.0 showing average earthworm abundance in Pristine vs Deforested sites.

Average earthworm abundance in Pristine vs Deforested sites

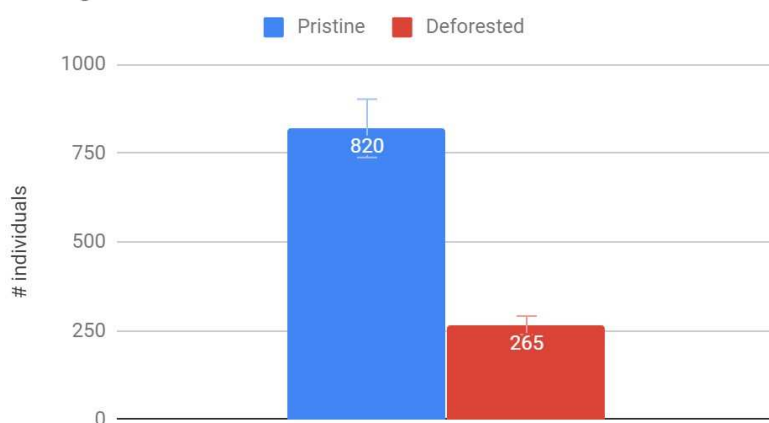
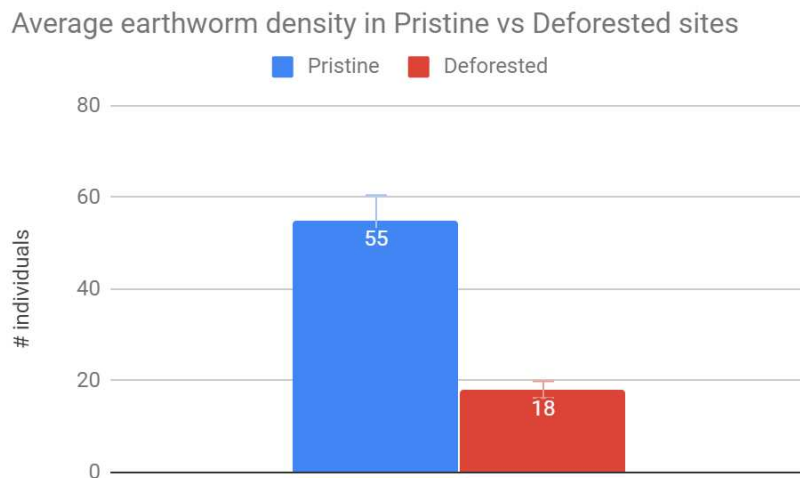


Figure 3.0 showing average earthworm density in Pristine vs deforested sites.



235 Figure 4.0 showing the average abundance of earthworm ecotypes in Pristine and Deforested sites.

