

Earthworm population ecology; Guyana, S A

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Earthworms are regarded as the bio-indicators of soil quality and are perhaps the most significant regulators of soil structure and organic matter content in a variety of terrestrial soil ecosystems, paving the way for sustainable green agriculture and land rehabilitation. Due to the steady increase in industrialization and shifts in global climate, their population is now more susceptible to change/decline as a result of the strains placed on soil ecosystems by agriculture, mining and deforestation. This research aimed to and successfully established the composition of earthworm populations present in Guyana while exploring their relationship with the biogeographical regions and pedobiological components of their respective ecosystem. Earthworms and soil samples were collected from 15 sites per natural region after which they were taxonomically identified following methodological dissections which yielded 68 distinct species. Of the four natural regions, the earthworm population of Highland Region was found to be the most diverse, rich, even and dense. Earthworm abundance, epigeic abundance, endogeic abundance, anecic abundance and species richness among the four natural regions of Guyana, were all of statistical significant difference, likewise, earthworm abundance in the various climate and soil types along with disturbance were of statistical significant difference. It was found that epigeic earthworms were significantly affected by phosphorus (0.01), moisture (0.01) and calcium (0.02) while anecic earthworms were significantly affected by magnesium (0.04), and the degree at which these affect the various ecotype is different among natural regions. This study has proven with conviction that earthworm population structure varies depending on the biogeographical and pedobiological factors present within any respective terrestrial ecosystem.

EARTHWORM POPULATION ECOLOGY: GUYANA, S.A.

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ABSTRACT

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10 earthworm populations present in Guyana while exploring their relationship with the biogeographical regions and pedobiological components of their respective ecosystem. Earthworms and soil samples were collected from 15 sites per natural region after which they were taxonomically identified following methodological dissections which yielded 68 distinct species. Of the four natural regions, the earthworm population of Highland Region was found to be the most diverse, rich, even and dense. Earthworm abundance, epigeic abundance, endogeic abundance, anecic

15 abundance and species richness among the four natural regions of Guyana, were all of statistical significant difference, likewise, earthworm abundance in the various climate and soil types along with disturbance were of statistical significant difference. It was found that epigeic earthworms were significantly affected by phosphorus (0.01), moisture (0.01) and calcium (0.02) while anecic earthworms were significantly affected by magnesium (0.04), and the degree at which these affect the various ecotype is different among natural regions. This study has

20 proven with conviction that earthworm population structure varies depending on the biogeographical and pedobiological factors present within any respective terrestrial ecosystem.

Keywords: *biogeography, pedobiology, physico-chemical parameter, population dynamic*

INTRODUCTION

Guyana is a tropical country located on the north-eastern part of South America. It comprises of four distinct

25 biogeographical zones: Coastal alluvial plain (LCP) which supports mangrove and agricultural systems; Hilly sand and clay region (HSCR) which supports wallaba and dacama forests, Highland region (HR) which supports montane forests; Interior savanna (IS) which is predominantly a savanna habitat.

Earthworms' role in an ecosystem is almost always defined by their feeding and burrowing habits and the soil

horizons they occupy, ergo earthworms occupy different niches within the same ecosystem. This was first noted by Lee in 1959 and then by Bouche in 1971, who determined that earthworms belong to three main ecological categories. *Epigeic* are small earthworms (10-30mm) which are considered as 'litter dwellers' which form no burrows and are highly pigmented dorsally and ventrally, Edwards and Bohlen, 1996. They impart significantly on the decomposition of organic matter which accounts for the humus layer above soils. Because of where they occupy, they are more susceptible to predation and are highly impacted by both environmental and anthropogenic variables, Bouche, 1977. *Anecic* species, (110-110cm), are relatively pigmented dorsally and unpigmented ventrally and they form permanent vertical burrows within the soil, extending well into the C horizon, Lal, 2007. They feed on surface litter/organic debris, which they pull into their burrows. They contribute to the movement of nutrients down through the soil profile, making it more accessible to plant roots, Lavelle and Spain, 2001. *Endogeic* are unpigmented earthworms that form continuous horizontal burrows where they feed on the soil, hence they are termed as geophagous, Jusselme, et al., 2015. These species are responsible for the release of nutrients within the soil which are excreted in their casts. In 1981, Lavelle established three subcategories: polyhumics (small and selectively ingest particles), mesohumics (medium and feeds on the upper 15cm of soil) and oligohumics (large and feed deep in soil where their resources are poor).

The aim of this study was to establish the population structure of earthworms in Guyana through the exploration of three hypotheses: (1) Variations in earthworm population structure among Guyana's geographical zones will be significantly different. (2) Earthworm abundance will be significantly affected by Guyana's biogeographical factors. (3) Earthworm population structure will be significantly correlated with soil physico-chemical factors.

MATERIAL & METHOD

Description of Study Area

The 60 sites that were studied were classified based on their climate, habitat and soil type. The Koppen classification system, (Peel et al., 2007) was utilized to determine the climate type which saw the northern half of the country display equatorial climate, the southern half, tropical savanna climate while the middle of the country displayed monsoon climate. The habitat type was determined following the classification system of the Guyana Forestry Commission, 2011, which led to the observation 6 distinct types: mixed forest, wallaba/dacama forest, montane forest, mangrove forest, savanna and grassland. The soil type was classified with accordance to the FAO

classification system, 1998, which revealed the following soil types: acrisol, aerenosol, anthrosol, ferralsol, lixisol, gleysol, histosol and leptosol.

Experimental Design

- 60 Fifteen sampling sites were randomly established within each of the 4 biogeographical regions of Guyana and their respective GPS coordinates were recorded. In each of the 60 sites, 15 sampling points of 0.5m³ were established along a linear transect at 6m intervals. The soil was removed from each sample point by manually digging after which the removed soil was hand sorted for earthworms which were categorized and counted. Special note was taken to colouration, to determine ecotype, and the presence of a clitellum, to discern adults from juveniles. 2 adults
- 65 from each morphospecie were collected and placed in separate labelled ziplock bags containing 95% ethanol to preserve genetic integrity for identification. The circumference and length of each morphospecie 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.
- 70 Soil samples were taken from each site and stored in labelled ziplock bags after which it was tested for moisture, pH, TDS, salinity, CEC, N, P, Cu, Fe, Zn, S, O.C, K, Ca, Mg and Na via the established standardized methods.

Data Analysis

The statistical data was analyzed using IBM SPSS version 22 and R version 3.4.4, 2018, where the ANOVA, Pearson Correlation and Regression Analysis functions were utilized.

- 75 The biological data was analyzed using: Shannon-Weiner Index, Simpson Index, McIntosh Index, Margalef Index, Menhinik's Index, Berger-Parker Index and Ecological Models, Morris, *et al.*, 2014.

RESULTS

- 68 taxonomically distinct species were identified of which *Pontoscolex corethrurus* was found to be the most abundant, accounting for 11.8% of the population, while a species from the Kynotidae family was found to be the
- 80 least abundant, accounting for 0.01% of the population.

Geography was found to have a statistical significant impact on earthworm abundance ($p=0.0078$). Of the 4 biogeographical regions of Guyana, The Highland Region (HR) was found to have the highest abundance while the Interior Savanna (IS) was found to have the least, (Table 1.0).

Density among ecotypes were found to be of statistical significant difference ($p=4.58E-08$) with epigeics being the

most abundant (accounting for 52.9% of the population), followed by endogeics (accounting for 41.5% of the population) and anecics (accounting for 5.6% of the population), Table 2.0. The highest percentage of epigeics was within the Low Coastal Plain (LCP), 25.2%, while the least was found in the Interior Savanna (IS), 3.1%. The highest abundance of endogeics was in the Highland Region, 16.1%, while the least was in the LCP, 4%.

Geography was found to have a statistically significant impact on density of ecotypes as evidenced by the following p values: epigeic density (7.01E-05), endogeic density (0.015), anecic density (0.001), Table 2.0.

The density among the soil types was found to be of statistical significant difference with a p value of 0.025, with anthrosols being associated with the highest average density per m², Table 3.0 . Of the anthrosols, hortie, also known as black earth, was seen to have the highest density of earthworms. Hydragric anthrol was found to be associated with the lowest density of the anthrosols. On the opposite end of the spectrum were the leptosols, which displayed the lowest average density. Hortie anthrosols were found to be associated with higher species richness (7) while hydragric anthrosols were associated with lower species richness (1).

Of the 7 identified habitat types, farms were found to be associated with the highest average density (78). This was then followed by montane forests and grasslands while the lowest density was associated with savannas, Table 4.0. The density among the habitat types however, was not of statistical significant difference (p=0.061).

Climate was found to have a significant impact on earthworm density as evidenced by the p value, 6.77E-05. Monsoon climate was found to be associated with the highest average density by a landslide, followed by equatorial and tropical savanna, Table 5.0.

For Guyana, there were a total of thirty-five disturbed sites with an average abundance of 321, and twenty-five conserved sites with an average abundance of 432. The average richness for the conserved sites was four while the average richness for the disturbed sites was three. It was found that richness was more heavily impacted by disturbance than abundance as seen in Table 6.0.

A regression analysis was conducted on the variables to determine the relationship among the dependent and independent variables. The analysis on the total density was low, with an r² value of 0.3. To determine if ecotypes are affected differently, earthworms were separated into their various ecotype after which the same analysis was carried out again. It was found that epigeic density and the independent variables had a stronger connection based on the r² value, 0.6. Anecic density and endogeic density was found to have lower r² values.

Additionally it was found that phosphorous, calcium and moisture significantly affected epigeic density while

magnesium was found to significantly affect anecic density, Table 7.0.

DISCUSSION

115 The observed abundance of *P. corethrurus* is attributed to the ecological plasticity of the organism in that it can outcompete other native earthworm species and successfully exploit new niches that have developed as a result of anthropogenic activities, thriving in a multitude of ecosystems. Unlike *P. corethrurus*, the species with the least abundance is found to be associated with only mangrove ecosystems, only two of which were sampled, which explains its low overall abundance.

120 The Highland Region is a montane environment covered in tropical forests and grasslands which creates a unique environment in which detritus is in abundance. Due to the warm temperatures, however, the rate of decomposition increases and coupled with the high precipitation rates, leaching of nutrients occur, Lavelle, 1983. Despite the above stated conundrum, the density in this region is the highest of the pedogeographical regions which is most logically due to: epigeic species being R-strategists, being smaller with high fecundity rates, while most anecic species are K-
125 strategists, being larger with low fecundity rates, (Cosin, et al., 2011). Endogeic species on the other hand feeds on the soil, and together with their selective feeding habits and gut microflora, this ecotype flourishes in this environment, Lavelle and Spain, 2001.

Additionally, the difference in the ecotypes' reproductive strategies explains the major gaps in their abundance. The lacking of anecic species in the LCP and HSCR is due to the high levels of pedological anthropogenic activities,
130 such as logging, and agriculture, which brings them to the surface exposing them to predators.

The Interior Savanna unlike the Highlands is a tropical savanna which experiences dry spells with less precipitation and high temperatures. All of the above are known to have negative consequences on earthworm abundance, Bohlen, 2002, which was reflected in the data collected.

Black earth/ hortic anthrosol (accounting for the highest density), are highly fertile, loose soils due to century's
135 worth of practice of adding organic waste and charcoal to the soil, Sombroek, 1966. This creates a pedobiological environment which can sustain high densities of earthworms which can occupy the same niche as interspecific and intraspecific competition is unlikely to occur. Hydragric anthrols are water saturated soils which creates an anaerobic environment, (Bohlen, et al., 2004), making the occupation of the deeper layers of the soil and the niches it provides almost impossible and as such it is only possible for the surface dwelling epigeic species to thrive at best, hence why
140 only one specie was observed.

Leptosols (lowest density) have high gravel content which causes abrasions on earthworms as stated by Edwards, 2003, and due to its ability to become easily waterlogged, it either drowns or forces earthworms out of their burrows leading to higher mortality rates, Chauhan, 2014, causing lower densities.

The farms sampled were associated with a farming practice which does not utilize pesticides and fertilizers and as such the chemical integrity of the soil is not compromised allowing high densities of earthworms to thrive within this altered ecosystem. On the other hand, the overturning of soil associated with farming tends to disrupt the population as it forces the endogeic species to the surface, increasing the chances of predation, while burying the epigeic species, which are generally unaffected. The degree of impact on anecic species on the other hand depends entirely on the depth at which overturning is done, Edwards & Bohlen, 1996.

The savannas of Guyana are no stranger to high temperatures and low soil moisture content, both of which does not bode well for earthworms as these conditions are stressful not only to the earthworms present, but also for sustainable crop production, Kalu, *et al.*, 2015. When factoring in the physical composition of the soils, whose gravel content is high, the negative impacts are amplified, (Edward, 2003), and as such the density of earthworms inhabiting these areas are relatively low.

Monsoon climate experienced higher levels of precipitation and lower temperature levels, both of which are conducive for sustaining high populations of earthworms, increasing fecundity, soil moisture and aiding degradation of organic matter. Tropical savanna climate on the other hand displays the opposite trend to monsoon, with lower precipitation rates and higher temperatures, and as such does not support high densities of earthworms as they absorb and lose moisture through their skin. The dryness of the soil either causes earthworms to move deeper into the soil, die or enter diapause, Chauhan, *et al.*, 2014.

The types of anthropogenic activities common in the sites sampled were mining, logging and agriculture. All of the above disrupt the pedological ecosystem. Mining causes soil to have poor structure, compaction, drainage, increases acidity and decreases the organic matter content, all of which would negatively affect most pedobiological organisms. Though some species of epigeic earthworms can tolerate acidic soils, the alkaline wastes such as pulverized fly ash from aluminium extraction from bauxite is highly toxic to them (Satchell and Stone, 1977; Southwell and Majer, 1982; Townsend and Hodgson, 1973). Logging reduces density of earthworm populations since it affects the top 15-20 cm of soil, where most earthworms reside. It brings them to the surface exposing them to predators and the sun, Rao, 2013. Soil tillage, has a significant effect on earthworm populations by the

overturning of soils which exposes earthworms to predators and drying temperatures. The use of chemical pesticides, heavy metals, polychlorinated biphenyls and acid precipitations affects earthworm density by decreasing fecundity rate and activity, and increasing mortality rates, Pennstate University, 2008.

CONCLUSION

68 taxonomically distinct species of earthworms were found in Guyana. Of the four natural regions, the earthworm population of Highland Region was found to be the most diverse, rich, even and dense, due to the abundance of organic matter, high precipitation, low temperatures and in some cases, no human disturbance. Based on the data collected, it was determined that earthworm abundance, epigeic abundance, endogeic abundance, anecic abundance and species richness among the four natural regions of Guyana, were all of statistical significant difference. Earthworm abundance in the various climate type, soil type and level of disturbance were of statistical significant difference. This research has made strides proving that human activities are in part responsible for the decline in earthworm populations, the effects of which will be felt by the entire pedological and floral communities. It was found that epigeic earthworms were significantly affected by phosphorus, moisture and calcium while anecic earthworms were significantly affected by magnesium, and the degree at which these affect the various ecotype is different among natural regions. Additional it was observed that various species are associated with a particular habitat, in the case of mangrove forests; while some species, such as *Pontoscolex corethrurus*, tolerate and thrive in soils with high concentrations of heavy metals, low nutritional content and high disturbance levels. *P. corethrurus*' ability to persevere in adverse pedological conditions can be exploited to achieve land rehabilitation for the reestablishment of destroyed ecosystems.

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LIST OF FIGURES

Table 1.0 showing earthworm abundance among Natural Regions: (numerical data in bold represents total)

LCP	HSCR	HR	IS
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431	366	593	319
767	751	299	170
323	302	221	254
400	322	352	187
344	314	199	329
308	82	964	44
181	234	616	26
217	692	685	217
340	213	193	418
305	190	338	217
455	644	1282	207
325	436	429	32
673	161	458	108
278	271	406	292
1090	254	256	255
6437	5232	7291	3075

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Table 2.0 showing earthworm ecotype abundance among Natural Regions : (numerical data in bold represents total)

Low Coastal Plain			Hilly Sand & Clay Region			Highland Region			Interior Savanna		
epigeic	endogeic	anecic	epigeic	endogeic	anecic	epigeic	endogeic	anecic	epigeic	endogeic	anecic
317	114	0	170	196	0	79	514	0	33	255	31
752	15	0	145	606	0	147	152	0	52	100	18
314	9	0	1	301	0	221	0	0	0	245	9
291	109	0	231	91	0	352	0	0	0	187	0
266	78	0	6	308	0	199	0	0	0	248	81
194	23	0	12	70	0	35	853	76	9	35	0
340	0	0	138	96	0	0	554	62	26	0	0
154	27	0	519	173	0	617	68	0	217	0	0
218	90	0	0	213	0	0	193	0	169	89	160
305	0	0	84	106	0	70	224	44	0	81	136
455	0	0	530	114	0	392	752	138	119	0	88
109	216	0	125	311	0	207	96	126	0	32	0
480	193	0	0	161	0	444	0	14	51	57	0
278	0	0	88	183	0	264	142	0	0	177	115
1090	0	0	103	151	0	241	0	15	0	134	121
5563	874	0	2152	3080	0	3268	3548	475	676	1640	759

Table 3.0 showing earthworm density per m² of soil : (numerical data in bold represents average)

acrisol	aerenosol	ferralsol		gleysol	histosol	leptosol	lixisol	anthrosol
39.9	48.8	43.3	25.7	45.9	57.5	26.5	79.1	102.3
46.9	99.7	41.9	42.5	28.9	40.8	5.9	29.5	43.1

61.1	40.3	31.2	22.7	24.1	40.6	4.3	57.2	37.1
54.1	42.9	28.4	33.9	53.3	89.7	14.4	-	145.3
34.1	10.9	25.3	24.9	45.3	-	39	-	171
0	92.3	85.9	43.9	-	-	34	-	45.1
-	36.1	21.5	3.5	-	-	-	-	60.7
-	33.9	58.1	28.9	-	-	-	-	-
-	-	128.5	55.7	-	-	-	-	-
-	-	82.1	30	-	-	-	-	-
-	-	91.3	27.6	-	-	-	-	-
47.22	50.6125	44.4	39.5	57.15	20.68333	55.26667	86.37143	

230 *Table 4.0 showing earthworm density per m²- habitat type*: (numerical data in bold represents average)

farm	dacama/ wallaba forest	grassland	mangrove forest	mixed forest	montane forest	savanna
171	48.8	54.1	57.5	39.9	61.1	42.5
45.1	40.3	99.7	40.6	46.9	34.1	33.9
28.9	10.9	42.9	-	28.4	128.5	24.9
102.3	92.3	45.9	-	25.3	82.1	43.9
43.1	36.1	28.9	-	85.9	91.3	30
60.7	33.9	24.1	-	58.1	25.7	27.6
-	43.3	53.3	-	3.5	22.7	5.9
-	41.9	45.3	-	26.5	55.7	4.3
-	31.2	40.8	-	79.1	29.5	14.4
-	21.5	89.7	-	57.2	-	39
-	-	37.1	-	-	-	34
-	-	145.3	-	-	-	-
75.18333	40.02	58.925	49.05	45.08	58.96667	27.30909

Table 5.0 showing earthworm density per m²- Climate type: (numerical data in bold represents average)

equatorial	monsoon	tropical savanna
48.8	45.3	171
40.3	40.8	45.1
10.9	89.7	25.3
92.3	37.1	85.9
36.1	145.3	58.1
33.9	57.5	128.5
43.3	40.6	82.1
41.9	39.9	91.3
31.2	46.9	-
21.5	28.4	-
102.3	26.5	-

43.1	79.1	-	4.3
54.1	57.2	-	14.4
99.7	61.1	-	39
42.9	34.1	-	34
45.9	25.7	-	-
28.9	29.5	-	-
24.1	60.7	-	-
53.3	-	-	-
49.72703	85.9125	27.41333	

Table 6.0 showing p values for disturbed vs conserved sites : (numerical data in bold represents significant p values)

Locale	Abundance	Richness
LCP	0.873	0.808
HSCR	0.018	0.934
HR	0.0007	0.0002
IS	0.369	0.234
Guyana	0.082	0.033

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Table 7.0 showing p values for density per soil parameter- Regression analysis : (numerical data in bold represents significant p values)

parameter	p value			
	total density	epigeic	endogeic	Anecic
N (mg/kg)	0.279047	0.487461	0.331718	0.108899
P (mg/kg)	0.001554	0.000000704	0.898109	0.973286
Cu (mg/kg)	0.460544	0.074295	0.856568	0.388668
Fe (mg/kg)	0.151151	0.062963	0.988499	0.764801
Zn (mg/kg)	0.560418	0.90418	0.807083	0.210387
Sulphate (mg/kg)	0.065065	0.10025	0.946062	0.458417
O.C (%)	0.501152	0.341241	0.065457	0.215967
K (meq/100g)	0.932224	0.741212	0.901008	0.208551
Ca (meq/100g)	0.742913	0.022083	0.380254	0.080669
Mg (meq/100g)	0.907002	0.33726	0.995499	0.047576
Na (meq/100g)	0.257385	0.082119	0.974206	0.053454
CEC (meq/100g)	0.804083	0.1053	0.727491	0.061107
pH	0.092471	0.451441	0.711236	0.373006
TDS (ppm)	0.639919	0.791936	0.57355	0.119214
Salinity (psu)	0.812268	0.551875	0.453617	0.315611
Moisture (g)	0.68897	0.006758	0.129705	0.23607

Table 1 (on next page)

Earthworm abundance among Natural Regions of Guyana

Each data point represents the total number of earthworms found at each respective site

Table 1.0 showing earthworm abundance among Natural Regions

LCP	HSCR	HR	IS
431	366	593	319
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340	213	193	418
305	190	338	217
455	644	1282	207
325	436	429	32
673	161	458	108
278	271	406	292
1090	254	256	255
6437	5232	7291	3075

Table 2 (on next page)

Earthworm ecotype abundance among Natural Regions of Guyana

Each data point represents the total number of earthworms per ecotype, found at a respective sampling site

Table 2.0 showing earthworm ecotype abundance among Natural Regions

Low Coastal Plain			Hilly Sand & Clay Region			Highland Region			Interior Savanna		
epigeic	endogei c	anecic	epigeic	endogei c	anecic	epigeic	endogei c	anecic	epigeic	endogei c	anecic
317	114	0	170	196	0	79	514	0	33	255	31
752	15	0	145	606	0	147	152	0	52	100	18
314	9	0	1	301	0	221	0	0	0	245	9
291	109	0	231	91	0	352	0	0	0	187	0
266	78	0	6	308	0	199	0	0	0	248	81
194	23	0	12	70	0	35	853	76	9	35	0
340	0	0	138	96	0	0	554	62	26	0	0
154	27	0	519	173	0	617	68	0	217	0	0
218	90	0	0	213	0	0	193	0	169	89	160
305	0	0	84	106	0	70	224	44	0	81	136
455	0	0	530	114	0	392	752	138	119	0	88
109	216	0	125	311	0	207	96	126	0	32	0
480	193	0	0	161	0	444	0	14	51	57	0
278	0	0	88	183	0	264	142	0	0	177	115
1090	0	0	103	151	0	241	0	15	0	134	121
5563	874	0	2152	3080	0	3268	3548	475	676	1640	759

Table 3(on next page)

Earthworm density per m² of soil

Each data point represents the observed density of earthworms per cubic meter of soil type

Table 3.0 showing earthworm density per m² of soil

acrisol	aerenosol	ferralsol		gleysol	histosol	leptosol	lixisol	anthrosol
39.9	48.8	43.3	25.7	45.9	57.5	26.5	79.1	102.3
46.9	99.7	41.9	42.5	28.9	40.8	5.9	29.5	43.1
61.1	40.3	31.2	22.7	24.1	40.6	4.3	57.2	37.1
54.1	42.9	28.4	33.9	53.3	89.7	14.4	-	145.3
34.1	10.9	25.3	24.9	45.3	-	39	-	171
0	92.3	85.9	43.9	-	-	34	-	45.1
-	36.1	21.5	3.5	-	-	-	-	60.7
-	33.9	58.1	28.9	-	-	-	-	-
-	-	128.5	55.7	-	-	-	-	-
-	-	82.1	30	-	-	-	-	-
-	-	91.3	27.6	-	-	-	-	-
47.22	50.6125	44.4		39.5	57.15	20.68333	55.26667	86.37143

Table 4(on next page)

Earthworm density per m²- habitat type

Each data point represents the density per cubic meter of earthworms based on the habitat type

Table 4.0 showing earthworm density per m²- habitat type

farm	dacama/walla ba forest	grassland	mangrove forest	mixed forest	montane forest	savanna
171	48.8	54.1	57.5	39.9	61.1	42.5
45.1	40.3	99.7	40.6	46.9	34.1	33.9
28.9	10.9	42.9	-	28.4	128.5	24.9
102.3	92.3	45.9	-	25.3	82.1	43.9
43.1	36.1	28.9	-	85.9	91.3	30
60.7	33.9	24.1	-	58.1	25.7	27.6
-	43.3	53.3	-	3.5	22.7	5.9
-	41.9	45.3	-	26.5	55.7	4.3
-	31.2	40.8	-	79.1	29.5	14.4
-	21.5	89.7	-	57.2	-	39
-	-	37.1	-	-	-	34
-	-	145.3	-	-	-	-
75.18333	40.02	58.925	49.05	45.08	58.96667	27.30909

Table 5 (on next page)

Earthworm density per m²- Climate type

Each data point represents the density per cubic meter of earthworms based on the climate type

Table 5.0 showing earthworm density per m²- Climate type

equatorial		monsoon	tropical savanna
48.8	45.3	171	28.9
40.3	40.8	45.1	3.5
10.9	89.7	25.3	22.7
92.3	37.1	85.9	55.7
36.1	145.3	58.1	42.5
33.9	57.5	128.5	33.9
43.3	40.6	82.1	24.9
41.9	39.9	91.3	43.9
31.2	46.9	-	30
21.5	28.4	-	27.6
102.3	26.5	-	5.9
43.1	79.1	-	4.3
54.1	57.2	-	14.4
99.7	61.1	-	39
42.9	34.1	-	34
45.9	25.7	-	-
28.9	29.5	-	-
24.1	60.7	-	-
53.3	-	-	-
49.72703		85.9125	27.41333

Table 6 (on next page)

p values for disturbed vs conserved sites

Each data point represents the p-value obtained when comparing the abundance and richness of earthworms among conserved and disturbed sites, per Natural Region.

Table 6.0 showing p values for disturbed vs conserved sites

Locale	Abundance	Richness
LCP	0.873	0.808
HSCR	0.018	0.934
HR	0.0007	0.0002
IS	0.369	0.234
Guyana	0.082	0.033

Table 7 (on next page)

p values for density per soil parameter- Regression analysis

Each data point represents the p-value obtained for the regression analysis of the soil parameters against earthworm density and ecotype density.

Table 7.0 showing p values for density per soil parameter- Regression analysis

parameter	p value			
	total density	epigeic	endogeic	Anecic
N (mg/kg)	0.279047	0.487461	0.331718	0.108899
P (mg/kg)	0.001554	0.000000704	0.898109	0.973286
Cu (mg/kg)	0.460544	0.074295	0.856568	0.388668
Fe (mg/kg)	0.151151	0.062963	0.988499	0.764801
Zn (mg/kg)	0.560418	0.90418	0.807083	0.210387
Sulphate (mg/kg)	0.065065	0.10025	0.946062	0.458417
O.C (%)	0.501152	0.341241	0.065457	0.215967
K (meq/100g)	0.932224	0.741212	0.901008	0.208551
Ca (meq/100g)	0.742913	0.022083	0.380254	0.080669
Mg (meq/100g)	0.907002	0.33726	0.995499	0.047576
Na (meq/100g)	0.257385	0.082119	0.974206	0.053454
CEC (meq/100g)	0.804083	0.1053	0.727491	0.061107
pH	0.092471	0.451441	0.711236	0.373006
TDS (ppm)	0.639919	0.791936	0.57355	0.119214
Salinity (psu)	0.812268	0.551875	0.453617	0.315611
Moisture (g)	0.68897	0.006758	0.129705	0.23607