Implications of ecological parameters on earthworm diversity and abundance in southwestern Nigeria

Aladesida, A. A.[1]* and Owa, S. O.[2]
[1]Department of Pure and Applied Zoology, Federal University of Agriculture, PMB 2240 Abeokuta, Ogun State
[2]Department of Biological Sciences, Landmark University, Omu Aran, Kwara State
*Corresponding author: aaladesida@gmail.com, aladesidaaa@funaab.edu.ng

Abstract

A survey on the diversity and abundance of earthworms in southwestern Nigeria was carried out. Earthworm and soil samples were collected from thirty different locations within the sub-region. Earthworms were identified and soil samples were analysed for mineral and metal loads, using standard procedures. Taxonomic analysis of collected earthworm samples revealed 24 species belonging to eight families namely Moniligastridae, Megascolecidae, Acanthodrilidae, Octochaetidae, Ocnerodrilidae, Eudrilidae and Almidae. These include some genera and species that are reported for the first time from Nigeria. Analysis of earthworm biomass showed that *Libyodrilus violaceus* had the highest biomass (104.4g/m^2) while *Hyperiodrilus africanus* had the highest density (160 worms/m^2). Earthworm biomass correlated negatively but significantly with pH ($p<0.01$). Analysis of earthworm abundance in relation to soil types indicates that *E. eugeniae* was present in all seven soil types studied, while only *Alma millsoni* and *H. lagosensis* can be used as indicators of ferruginous tropical soils and red-yellow ferralsols. Earthworms from this study revealed affinity for various combinations of sand and loam soils. The present results revealed a decline in earthworm abundance when compared with previous works. This work revealed the need to harness the habitat factors, which support earthworm abundance for use in both earthworm and soil conservation efforts.

Keywords: Earthworms, eudrilid, non-eudrilid, southwestern Nigeria, taxonomy, distribution, abundance

Accepted: 09 August, 2021.

Introduction

Earthworms are ubiquitous, being among the most widely distributed invertebrates, occurring over most of the earth, and preferring moist soil rich in calcium and organic matter. They inhabit burrows for protection from adverse weather and predators and may penetrate far below the surface to avoid extreme heat, cold, or drought (Storer *et al* 1977). Earthworms are found in both the temperate and tropical regions and are known to occupy every soil niche of forests, woodland, shrublands and grasslands.

In reviewing the classical work of Charles Darwin on earthworms, Feller *et al* (2003) reported that earthworms play important roles in the physical and chemical weathering of rocks. According to them, Darwin found several small stones or grains of sand in the gizzards of many earthworms, which are sometimes combined with the hard calcareous concretions formed by calciferous glands. These coarser particles are apparently ingested and utilized by the worms to help triturate the ingested soil organic matter and leaves, and to facilitate digestion. These will, by particle attrition and passage through the gizzard and the gut, break up the larger particles, thereby contributing to the physical weathering of soils. Madge (1969) also found that earthworms literally eat their way through the soil, and the ingested earth is passed through the digestive tract and deposited at the surface in small mounds or 'castings'. That these activities of earthworms play important roles in increasing soil fertility and productivity is now universally acknowledged (Edwards and Lofty 1977; Foth 1978; Lee 1985; Edwards 1988; Day 2000; Dominguez *et al* 2000; Ndegwa and Thompson 2001; Ayanlaja *et al* 2001; Chaoni *et al* 2003; Owa *et al* 2003, 2004a and 2004b). Earthworms are known to increase soil porosity and soil aeration, bringing about decomposition of leaf and other litters, improve soil nitration and nutrient by excretion of nitrogenous wastes as detoxification of some waste materials in soil (Mba 1983; Owa and Olojo 2003).

http://dx.doi.org/10.4314/tzool.v19i1.3
© *The Zoologist, 19*: *14*-22 December 2021, ISSN 1596 972X.
Zoological Society of Nigeria

Another major area in earthworm research is their use in biodegradation of domestic wastes. This process, known as vermicomposting is in great use in many developed countries of the world but has not been exploited in Nigeria due to the gaps in knowledge of suitable species and their ecology (Diver 1993; Harper and Greaser 1994; Aladesida 2005; Aladesida 2010).

The processes of vermicomposting and vermiculture hold a lot of potentials for Nigeria and other developing nations of the world in the area of waste management and agriculture. The earthworms act on organic waste through a combination of efforts, (Mba 1983; Bhawalker and Bhawalkar 1993) which involve the enteric microbes in the earthworm gut and secretions by the worms. The mucus coated egested material, known as vermicast, which is richer in nutrient and useful microbes than the parent soil has been shown to have tremendous effects on plant growth (Bhawalker and Bhawalkar 1993; Owa *et al* 2004a). Dynes (2003) and Owa *et al* 2004b) also noted that this egested material, i.e. vermicast is rich in auxins and cytokinins which are plant growth hormones.

Earthworm casting activities lead to dragging of leaf litter to below the soil surface, thereby saving them from wild bush fire and converting them into humus (Schulmann and Tiunov 1999). Their enteric microflora not only facilitates conversion of litter to humus, some of those prokaryotic symbionts are known to convert those litter materials to indo-butyric acids, IBA, (an auxin) which is a plant growth hormone (Lynch and Poole 1979). Earthworm burrowing and casting activities result in making phosphorus and nitrate more available in soil (Sharpley *et al* 1979). The result of their ingesting and voiding soil grains is finer granulation, better soil aggregate formation, and increase in the total surface area for improved adsorptive properties of the soil (Lavelle 1988).

The present study looked at the impact of soil properties and climate factors on earthworm abundance and diversity in southwest Nigeria and the implications of these for agriculture and vermiculture practices.

Materials and methods

Study area and sampling locations

Thirty sampling locations were selected within the study area, which includes Edo, Ekiti, Kwara, Lagos, Ogun, Ondo, Osun and Oyo States of Nigeria. The study stretched as far as Jebba, Kwara State, which served as the northern limit. The thirty locations (Figure 1) were chosen randomly, giving room for an extensive coverage of the various vegetation zones within the study area. The vegetation zones covered were coastal forest and mangrove, deltaic swamp forest, secondary forest, flood plain complex, forest savanna mosaic and secondary moist lowland forest. This led to considering factors such as nearness to water bodies and agricultural land. The idea was to give room for collecting samples along riverbanks streams and puddles, while also giving thought to earthworm populations in the soils under cultivation.

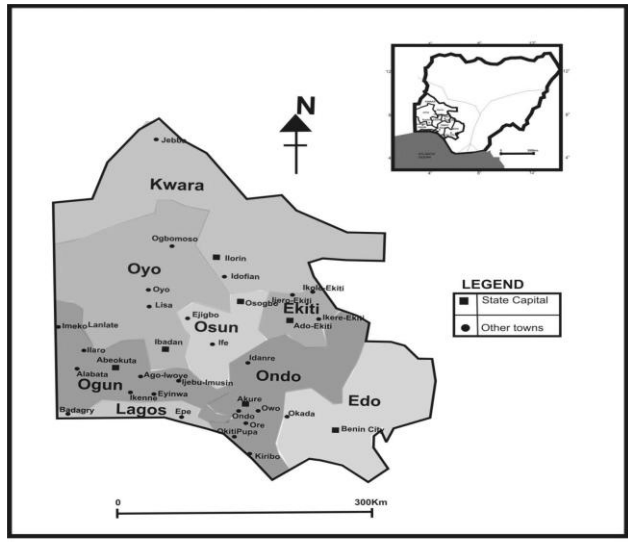

Figure 1. Map of Study area showing the sampling locations with an inset of map of Nigeria

Earthworm collection and identification

Earthworm collection was carried out in the thirty selected sampling locations. Trips were made between the months of May and October; these months fell within the rainy season during which it was possible to collect the different developmental stages of earthworm species. This was important because earthworms generally aestivate after these months.

Earthworms were collected using digging and hand-sorting method (Reynolds 1977; Owa 1992; Monebi and Ugwunba 2012), which allowed determination of soil volume with little loss of worms that may migrate in other directions when the alternative chemical extraction methods are employed. Ten quadrats each of $0.25m^2$ were dug from each sampling location. Each quadrat was dug to a depth of 30cm, below which earthworms are not normally found. The quadrats were dug in soil blocks, placed on wooden sorting trays; the soil was broken loose to expose the earthworms, which due to the light are betrayed by their movements, and were picked up. Collecting or digging the soil in blocks helped reduce damage to the earthworms during digging.

The earthworms were killed and preserved in formoacetic alcohol (F.A.A) prepared on volume bases of 10% formalin, 2% acetic acid, 50% alcohol and 38% distilled water. This, according to Owa (1992) causes minimal shrinkage, leaving the worms pliable and easy to dissect. Collections from each quadrat was kept in separate bottles with labels. Notes were taken on the field showing details of the habitat and other soil fauna encountered during the survey.

Earthworm identification was done using external characteristics such as type and shape of prostomium, position of the gonopores, position and shapes of clitellium; position and form of papillae, where present; presence, form and position of penial setae; and arrangement and form of somatic setae. The internal diagnostic characters included presence, position and number of gizzards, ventral oesophageal sacs and pouches; number and position of the reproductive structures such as testes, ovaries, seminal vesicles, spermathecae and prostates. As an example, the proximity of the spermatheca to the ovarian system is an important diagnostic feature for the Eudrilidae (Owa 1992; Blakemore, 2009, 2010).

Soil collection

Soil samples were collected from the same sampling locations and quadrats from which the earthworms were collected. From a quadrat, soil samples were taken from the top, middle and bottom levels. The soil samples for each location were mixed together, air-dried and stored in plastic soil bags; thus preventing microbial activity from breaking down soil humus during the short laboratory storage preceding analysis. Air-drying continued and was completed in the laboratory.

Soil analysis

Using the methods of AOAC (2019), soil samples were analysed for pH, Ca, Na, K, Mg, Cu, Fe, Zn, Mn, total nitrogen, available phosphorus, organic matter, organic carbon and CEC in the Soil Laboratories of the Department of Plant Science and Applied Zoology (Now Department of Applied Zoology), Olabisi Onabanjo University, Ago-Iwoye and that of the Institute of Agricultural Research and Training, Moore Plantation, Ibadan, Oyo State.

Data analysis

Analysis of variance (ANOVA) was used to test statistical difference between the different habitats. The relationship between environmental variables and the biomass and abundance of earthworm was tested using Pearson's correlation. Some climatic factors were also related with the earthworm biomass and abundance to test if there were relationships between these components.

Results

Earthworm abundance and Biomass

During the study, 24 earthworm species belonging to 5 families were identified (Table 1). *Hyperiodrilus africanus* had the highest maximum density (160/m^2) while, *Dichogaster pointicus* had the highest mean density (84/m^2) (Table 2). Analysis of variance shows that the mean densities of earthworm differed significantly among species ($p<0.05$). *Libyodrilus violaceus* had the highest maximum biomass (104.4g/m^2), while *Hyperiodrilus millsoni* had the highest mean biomass (30.92g/m^2).

There was strong and positive correlation between earthworm density (r=0.71), biomass (r=0.81) and mean annual rainfall (Table 3). Atmospheric temperature had a negative and insignificant relationship with earthworm density and biomass (Table 3).

Relationship between earthworm and abundance and soil chemical properties

pH

Earthworm density was highest at pH 7.01, but least at 6.9, while biomass was highest at highest at pH 6.4, but least at 7.01. The present results indicate that the species found in this study occur mostly in acidic soils; the frequency of occurrence been highest under pH 6.40 and 6.80. Correlation analysis shows an insignificant negative relationship between pH and earthworm diversity (r=-0.06, p=0.45). A similar relationship exist between pH and earthworm density (r =-0.08, p=0.25). In contrast, the relationship of pH with earthworm biomass though also negative is significant at 0.01 level (Table 3). These relationships show that pH plays some importance in determining earthworm diversity and abundance.

Soil macronutrients

Sodium and magnesium show a positive but insignificant relationship with earthworm density while K and Ca were negatively but insignificantly correlated. However, when related to biomass, sodium shows a significant and positive relationship (r=0.18, P=0.01) and calcium, a negative and insignificant relationship (r=-0.08, p=0.29). Potassium has a negative but significant relationship with soil macronutrients (r=-0.15, p= 0.04), while magnesium has a positive but insignificant correlation to soil macronutrients (r=0.09, p=0.19).

Soil micronutrients

Iron and zinc correlated positively and significantly with earthworm diversity (r=0.15, p=0.04) for Fe; r=0.03 for Zn). While manganese has a significant but negative correlation with density (r = -0.16, p = 0.03) but copper correlated insignificantly (r = -0.04, p = 0.55). When correlated to density and biomass, iron shows negative and insignificant relationships while manganese is positively but insignificantly correlated to both. Zinc shows a significant but negative correlation to biomass and an insignificant and negative relationship to density. Copper has negative significant correlation with density (r=-0.22, p=0.002) but negative insignificant relationship with biomass.

Table 1: Earthworm species described and their distribution within the study area

Earthworm Species	Family	Status	Distribution
Adodrilus stephana	Megascolecidae	Gen. *et.* species *novo*	Ado-Ekiti
Alma millsoni	Glosscoscolecidae	Existing taxon	Ago-Iwoye, Akure, Ejigbo, Epe, Idanre, Idofian, Ife, Ijebu-Imusin, Ikere-Ekiti, Ilaro, Imeko, Kiribo, Okitipupa, Ondo, Ore, Owo
Dichogaster modiglanii	Acantodrilidae	Existing taxon	Epe, Kiribo
Dichogaster ondoensis	Acantodrilidae	Species *novo*	Ondo, Eyinwa, Ijero-Ekiti, Ikole-Ekiti, Akure
Ekitidrilus alabataensis	Ocnerodrilidae	Gen. *et.* species *novo*	Ado-Ekiti, Alabata
Eudriloides	Eudrilidae	Existing taxon	Eyinwa
Eudrilus eugeniae	Eudrilidae	Existing taxon	Lisa, Ogbomoso, Ife, Badagry, Ikenne, Ilaro, Alabata, Benin City, Kiribo, Okitipupa, Ore, Ondo, Akure, Ago-Iwoye, Eyinwa, Ikole-Ekiti, Ijero-Ekiti, Ikere-Ekiti, Epe
Eudrilus millemosbyae	Eudrilidae	Existing taxon	Ikole-Ekiti, Kiribo
Heliodrilus lagosensis	Eudrilidae	Existing taxon	Lanlate, Lisa, Ogbomoso, Ikole-Ekiti, Ago-Iwoye, Ijebu-Imusin, Owo, Ore
Heliodrilus lagosensis oreensis	Eudrilidae	Species *novo*	Ore
Hyperiodrilus africanus	Eudrilidae	Existing taxon	Idofian, Ogbomoso, Ife, Ejigbo, Ikole-Ekiti, Ago-Iwoye, Ikenne, Eyinwa, Alabata, Ilaro, Kiribo
Hyperiodrilus millsoni	Eudrilidae	Existing taxon	Ijebu-Imusin
Imekodrilus hexagastricus	Moniligastridae	Gen. *et.* species *novo*	Imeko
Iridodrilus roseus	Eudrilidae	Existing taxon	Idofian, Idanre, Ado-Ekiti, Benin City, Okitipupa, Ondo, Ijebu-Imusin, Alabata, Imeko, Lisa, Ogbomoso, Ikole-Ekiti
Iridodrilus preussi	Eudrilidae	Existing taxon	Jebba, Oyo, Ado-Ekiti, Idanre, Imeko, Lanlate, Akure, Ondo
Kerria metandrica	Ocnerodrilidae	Species *novo*	Akure
Libyodrilus mekoensis	Eudrilidae	Existing taxon	Alabata, Imeko, Ilaro
Libyodrilus violaceus	Eudrilidae	Existing taxon	Ilaro, Ikole-Ekiti, Ife, Ondo, Epe, Badagry
Malodrilus jebbaensis	Eudrilidae	Species *novo*	Jebba
Microscolex metandrica	Acantodrilidae	Species *novo*	Ore, Akure, Lisa
Nemertodriloides iwoyensis	Eudrilidae	Gen. *et.* species *novo*	Ago-Iwoye
Yorubadrilus ogbomosoensis	Eudrilidae	Gen. *et.* species *novo*	Ogbomoso
Paranematogenia eyinwaensis	Ocnerodrilidae	Gen. *et.* species *novo*	Eyinwa
Stuhlmania okadaensis	Eudrilidae	Species *novo*	Okada

Organic matter

Organic matter content of the soils related weakly and insignificantly with earthworm density and biomass. However, the difference in means for organic matter was significant for earthworm biomass at $p = 0.05$.

Available phosphorus

Available phosphorus of the soils correlated weakly with earthworm density and biomass.

Cation exchange capacity

Cation exchange capacity correlated negatively and insignificantly with earthworm density but significantly with biomass ($r=-0.15$, $p=0.04$). Analysis of variance showed that mean cation exchange capacity varied significant between sites.

Table 2: Earthworm abundance and soil physicochemical parameters in the sampled in the study area

Soil Parameters	**CFM**	**DSF**	**SF**	**FPC**	**FSM**	**SMLF**	**Total**
	Mean ± S.E.	**Mean ± S.E.**	**Mean ± S.E.**	**Mean ± S.E.**	**Mean ± S.E.**	**Mean ± S.E.**	**Mean ± S.E.**
Density (indv./m^2)	61.33 ± 14.18^{a}	96.50 ± 34.02^{a}	83.04 ± 10.26^{a}	58.67 ± 17.36^{a}	78.97 ± 11.03^{a}	64.00 ± 10.04^{a}	78.66 ± 6.21^{a}
Biomass (g/m^2)	33.15 ± 10.38^{a}	33.23 ± 7.77^{a}	37.61 ± 6.01^{a}	26.19 ± 12.42^{a}	38.65 ± 9.43^{a}	17.06 ± 6.54^{a}	34.61 ± 3.97^{a}
pH	6.40 ± 0.00^{a}	6.74 ± 0.01^{b}	6.70 ± 0.02^{b}	6.70 ± 0.00^{b}	6.76 ± 0.03^{b}	6.82 ± 0.03^{b}	6.72±0.01
Na (g/Kg)	0.99 ± 0.01^{d}	0.56 ± 0.04^{a}	0.64 ± 0.01^{ab}	0.70 ± 0.00^{bc}	0.80 ± 0.03^{c}	0.60 ± 0.02^{ab}	0.70±0.01
Ca (g/Kg)	1.05 ± 0.05^{a}	1.26 ± 0.00^{c}	1.16 ± 0.02^{abc}	1.10 ± 0.00^{ab}	1.21 ± 0.02^{bc}	1.12 ± 0.04^{ab}	1.17±0.01
K (g/Kg)	1.21 ± 0.05^{b}	1.23 ± 0.01^{b}	1.21 ± 0.02^{b}	0.90 ± 0.00^{a}	1.24 ± 0.02^{b}	1.27 ± 0.03^{b}	1.22±0.01
Mg (g/Kg)	1.13 ± 0.04^{a}	1.24 ± 0.02^{b}	1.18 ± 0.02^{ab}	1.28 ± 0.00^{b}	1.18 ± 0.02^{ab}	1.23 ± 0.02^{b}	1.19±0.01
Fe (mg/Kg)	1.27 ± 0.01^{bc}	1.16 ± 0.01^{a}	1.20 ± 0.02^{ab}	1.40 ± 0.00^{d}	1.23 ± 0.01^{abc}	1.31 ± 0.02^{c}	1.23±0.01
Zn (mg/Kg)	1.25 ± 0.03^{a}	1.46 ± 0.00^{b}	1.43 ± 0.02^{b}	2.10 ± 0.00^{c}	1.53 ± 0.03^{b}	1.60 ± 0.06^{b}	1.47±0.02
Mn (mg/Kg)	0.91 ± 0.01^{b}	1.23 ± 0.05^{d}	0.86 ± 0.04^{b}	0.40 ± 0.00^{a}	1.00 ± 0.03^{bc}	1.17 ± 0.02^{cd}	0.96±0.02
Cu (mg/Kg)	1.03 ± 0.01^{ab}	1.16 ± 0.02^{abc}	0.91 ± 0.04^{a}	1.40 ± 0.00^{c}	1.15 ± 0.04^{abc}	1.22 ± 0.08^{bc}	1.06±0.03
%N	1.04 ± 0.01^{cd}	0.44 ± 0.13^{a}	0.76 ± 0.06^{abc}	1.20 ± 0.00^{d}	0.89 ± 0.06^{bcd}	0.58 ± 0.08^{ab}	0.78±0.03
%C	1.86 ± 0.06^{c}	1.10 ± 0.20^{b}	1.55 ± 0.08^{bc}	0.54 ± 0.00^{a}	1.36 ± 0.06^{b}	1.22 ± 0.15^{b}	1.40±0.05
%OM	3.03 ± 0.05^{c}	1.89 ± 0.34^{b}	2.62 ± 0.13^{bc}	0.93 ± 0.00^{a}	2.35 ± 0.11^{bc}	2.10 ± 0.26^{b}	2.39±0.08
Av. P (mg/kg)	11.20 ± 0.09^{c}	10.10 ± 0.00^{b}	11.29 ± 0.21^{c}	8.75 ± 0.00^{a}	12.01 ± 0.19^{c}	11.81 ± 0.13^{c}	11.39±0.11
CEC (cmol/kg)	4.23 ± 0.002^{ab}	4.37 ± 0.00^{bc}	4.30 ± 0.04^{bc}	4.055 ± 0.00^{a}	4.50 ± 0.04^{c}	4.28 ± 0.06^{bc}	4.35±0.02

CFM- Coastal Forest and Mangrove; DSF-Deltaic Swamp Forest; SF-Secondary Forest; FPC-Flood Plain Complex; FSM-Forest Savanna Mosaic; SMLF-Secondary and Moist Lowland Forest

Table 3: Pearson's correlation of earthworm abundance and soil parameters

	Den	**Biom**	**pH**	**Na**	**Ca**	**K**	**Mg**	**Fe**	**Zn**	**Mn**	**Cu**	**%N**	**% OC**	**% OM**	**Av. P**	**CEC**	**MAR**	**NRD**	**MAT**	**MAMT**
Den	1																			
Biom	0.43*	1																		
pH	-0.15	-0.36*	1																	
Na	0.31	0.21	0.14	1																
Ca	-0.03	-0.04	-0.03	0.13	1															
K	-0.12	-0.15	-0.05	0.04	0.59**	1														
Mg	-0.14	0.02	-0.02	-0.42*	-0.32	-0.43*	1													
Fe	-0.17	-0.16	0.15	0.04	-0.05	-0.12	-0.00	1												
Zn	0.22	-0.31	0.17	0.08	0.17	-0.09	-0.07	0.40*	1											
Mn	0.15	0.01	-0.01	-0.16	0.25	0.27	0.19	-0.32	-0.17	1										
Cu	-0.36*	-0.08	-0.19	-0.09	0.45*	0.20	-0.16	0.21	0.15	0.05	1									
% N	0.12	0.04	0.10	0.57**	-0.15	-0.17	-0.02	-0.02	0.03	-0.09	-0.28	1								
% OC	0.30	0.08	0.02	0.47**	-0.13	-0.04	-0.11	-0.19	-0.11	-0.00	-0.46*	0.59**	1							
% OM	0.31	0.09	0.04	0.44*	-0.12	-0.03	-0.10	-0.24	-0.13	0.03	-0.43*	0.56**	0.98**	1						
Av. P	-0.05	-0.02	0.08	0.34	-0.23	-0.12	0.24	-0.29	-0.37*	0.07	-0.34	0.49**	0.41*	0.39*	1					
CEC	-0.03	-0.12	0.01	0.41*	0.77**	0.70**	-0.22	-0.04	0.12	0.23	0.25	0.18	0.11	0.11	0.16	1				
MAR	0.71*	0.81**	0.00	-0.01	-0.16	0.02	-0.02	-0.17	-0.20	0.31	-0.18	0.03	0.71*	0.80*	-0.10	-0.11	1			
NRD	-0.55	-049	0.21	-0.30	0.04	0.17	0.10	-0.01	0.00	0.40*	0.00	-0.13	-0.33	-0.23	-0.01	0.05	0.33	1		
MAT	0.130	0.38*	-0.19	0.14	-0.11	-0.26	0.30	0.21	0.12	-0.16	-0.00	0.34	-0.15	-0.15	-0.09	-0.11	-0.11	-0.36*	1	
MAMT	-0.140	-0.15	-0.26	0.07	-0.04	-0.13	0.06	0.16	0.26	-0.37*	0.04	0.28	-0.09	-0.12	0.18	-0.01	-0.65**	-0.33	0.48**	1

**Correlation is significant at the 0.01 level (2-tailed).
*Correlation is significant at the 0.05 level (2-tailed).
OC=Organic Carbon; OM=Organic Matter; Av. P- Available Phosphorus; CEC=Cation Exchange Capacity; MAR = Mean Annual Rainfall; NRD = Number of Rainy Days; MAT – Mean Annual; Den=Density; Biom=Biomass

Discussion

Earthworm diversity in southwest Nigeria

The genera *Malodrilus*, *Stuhlmania* and *Eudriloides* have been identified in east and central Africa only (Reynolds and Cook 1993). Their presence in this region of Africa (West Africa) cannot be clearly explained. Usually, the movement of soil animals like earthworms across national boundaries is attributable to movement of agricultural goods, the case of this study cannot be substantiated since Nigeria rarely imports agricultural goods from east and central Africa. However, Aladesida (2010) had described a new taxon of *Malodrilus* (*Malodrilus jebbaensis*) from Jebba, Kwara State Nigeria, which may be an indication that these genera are distributed beyond the previously recorded regions of Africa.

Eudrilus eugeniae and *Iridodrilus roseus* show a spread, which conform to the report of Owa (1992). These species are here noted to have a wide distribution within southwest Nigeria. *Eudrilus eugeniae* in particular seem to traverse so many fronts as reported by Owa (1992) and Appelhof (2003). Several studies also reported its consideration as protein source in animal feed (Dynes 2003; Sogbesan and Ugwumba 2008; Monebi and Ugwumba 2012).

The non-eudrilid earthworm genera described in this study are, however, being reported from Nigeria for the first time, except *Dichogaster* and *Alma*.

Patterns in the abundance of earthworms and ecological factors

Previous studies on the effect of ecological and habitat factors on earthworm have shown that density and abundance depend on some of these factors, while some habitat factors are equally affected by earthworms' activities. The present result shows a positive and strong relationship between amount of rainfall and earthworm abundance, but no relationship was observed with number of rain days. Though Owa (1992), Tabu *et al* (2001) and English and Costello (2005) had earlier reported correlations with number of rainy days, the present deviation is suspected to be due to the increased depletion of forest and plant cover, sources of food, and cover from direct sunlight for earthworms.

The results on temperature difference and its effects on earthworm abundance may not be directly applied since the temperature here is that of the atmosphere, whereas soil temperature has vivid effect on earthworms. However, this aspect of the soil could not be measured in the field due to the absence of equipment. However, though atmospheric, the temperature measured here showed that earthworm abundance responds inversely to mean maximum temperature but directly to the annual mean temperature. The implications of this are that high temperatures reduce earthworm abundance. The results of cross-tabulation show that beyond 32°C earthworm abundance decreased drastically. At the mean temperature of 26°C earthworm abundance showed the highest occurrence, a situation which suggest to intending earthworm breeders the range of temperature under which to keep their cultures.

The relationship between earthworm abundance and soil pH shows that earthworms tolerate a wide range of pH, but mostly acidic soil. Curry (2004) and English and Costello (2005) reported that the best soil pH for optimum survival of earthworm is 5.0-7.4 and outside this range, it is difficult to find earthworm. In this study, earthworms were found in soils with pH of 6.4-7.2, which agrees with previous studies. Macronutrients play vital roles in the metabolic activities of living organisms. Earthworms get their doses of these nutrients from the soil. The results of this study show a contrast from the works of Nielson (1951), Satchel (1955), Spannagel (1960), Kleinschmit (1962) and Edwards and Lofty (1977) in the relationship between Ca and earthworm abundance. While these earlier authors reported positive and significant relationship, the present results, indicating inverse relationship, agree with those of Owa (1992). The calciferous gland, the supposedly calcium store, has been a subject of research and re-examination. While literature from temperate regions report that this gland is actually a storage house for calcium, reports by Owa (1992) contradicts this position, this is further corroborated in the present study as none of the calciferous glands observed had any calcium stored up in them. However, this situation may not be unconnected with the low calcium content of tropical soils.

Other macronutrients, Na, K and Mg were equally insignificantly correlated to earthworm density as against earlier reports by Curry (2004). However, records on analysis of earthworm casts show that earthworm cast had higher amount of these nutrients than the surrounding soil. Aladesida *et al* (2014) had earlier reported that comparatively, the analyses of castings and their surrounding soils have shown that castings contain eleven times more potassium and three times more exchangeable magnesium and 1½ times more calcium than the surrounding soils.

The relationship between copper and earthworm abundance observed in this study contradicts that of Owa (1992) who found a positive correlation between abundance and copper content of the soil. The relationship here was negative, further justifying the lack of copper-containing haemocyanin in earthworms.

Many animals need Fe in the transport of oxygen during cellular respiration. To survive in the soil earthworms need Fe in good quantity since the oxygen tension in soil is lower than in the atmosphere. Although Owa (1992) observed a positive significant relationship between Fe and earthworm abundance, the present study shows the reverse. The reason for this is not readily known but the possible causes could be leaching and agricultural activities common in most of the visited localities. It is expected that such activities could lead to loss in soil nutrients.

While most authors reported positive significant correlations between earthworm abundance and total nitrogen, the present results are contrary. However, several studies have reported that earthworm abundance increased due to application of nitrogenous fertilizers (Zajonc 1975; Edwards and Lofty 1977; Tabu *et al* 2001). The condition is however, true only to certain threshold as found by Gerard and Hay (1979). According to these authors, beyond a certain level, total soil nitrogen showed a negative relationship with earthworm abundance. The situation can also be related to the inability of animals to store nitrogen. Also, nitrogen compounds increase soil pH, according to Appelhof (2003), the earthworms show preference for acidic soils, however, when protein content rises above 10-12%, earthworm survival and abundance reduces. Another possibility is that N commonly exits as urea or ammonia in an aquatic animal. The latter is toxic at certain threshold.

The only record on comparison of earthworm abundance and available phosphorus in soil is that of Owa (1992), in which the relationship was positive. The present results are contrary and this situation may again be connected to the depletion in soils quality.

Organic matter content has always been linked with earthworm abundance. However, in the present study though positive, the relationship of organic matter with earthworm abundance was insignificant. The insignificant relationship is here suggested as being due to habitat destruction and environmental degradation by bush burning and other human activities, which may lead to organic matter depletion. Tabu *et al* (2001) reported that practices such as continuous cultivation, use of pesticides and mechanized farming result in decline in soil organic matter, hence earthworm population. Another possible factor is the points of sampling the earthworms. Since earthworms show preference for some leaf litter against others (English and Costello 2005), though sampling in the present study was not biased towards a particular plant cover, if the collections were made around plants, which are not palatable to earthworms, the present result would inevitably be the case.

Conclusion

It is an established knowledge that wanton destruction to the soil environment by agro-chemicals, mechanized farming and deforestation are fast depleting the earth's faunistic resources. Aladesida (2005) noted the need to develop strategies for the breeding of earthworms in order to save the natural populations of earthworms from over exploitation by fishermen, other users and anthropogenic perturbations.

The present results show clearly a decline in earthworm abundance in southwestern Nigeria when compared with Owa (1992) and by inference, Nigeria as a whole. The trends observed with respect to soil chemical properties are an indication of a decline in the nutrient load of the soils in the study area. This situation calls for urgent attention in the areas of soil use, agricultural practices and pollution. Some of the sampling locations, such as Oyo, Idofian, Lisa, Badagry, Ilaro, Kiribo and Lanlate, showed signs of flooding, extensive bush burning or both which over the years had led to loss of plant cover and top soil. If efforts are not made to check the practice of bush burning and erosion, more havoc will be inflicted on our soil fauna in the future.

The present study reveals there is still a wide gap in our knowledge of earthworms of Nigeria, largely because previous workers had focused on the family Eudrilidae. With the number of new genera and species recorded for the first time in Nigeria, the present result shows that there is a need for more efforts at checking the status of earthworm diversity in other regions of the country.

For intending earthworm breeders, the present study provides a baseline on species available for possible consideration. The habitat parameters such as pH and soil textural types, which support earthworm survival are also available for such breeders.

References

Aladesida, A.A. 2005. Ethnozoology of earthworms along the coastal areas of southwestern Nigeria. M.Sc. Dissertation submitted to the Department of Plant Science and Applied Zoology, Olabisi Onabanjo University, Ago-Iwoye, Nigeria.

Aladesida, A.A. 2010. Earthworm taxonomy, distribution and abundance in Southwestern Nigeria. Ph.D. Thesis submitted to the Department of Plant Science and Applied Zoology, Olabisi Onabanjo University, Ago-Iwoye, Nigeria.

Aladesida, A.A., Dedeke, G.A., Ademolu, K.O. and Museliu, F. 2014. Nutrient analysis of three earthworm cast-types collected from Ikenne, Ogun State, Nigeria. *J. Nat. Sci. Engr. Tech. 13*: 36-43.

Appelhof, M. 2003. Worms Eat My Garbage: How to Set Up and Maintain a Worm Composting System. (2nd ed.). Flower Press, London, 162pp.

Association of Analytical Chemists International 2019. Official methods of Analysis (21st ed.), USA.

Ayanlaja, S.A., Owa, S.O., Adigun, M.O., Senjobi, B.A., and Olaleye A.O. 2001. Leachate from Earthworm Castings Break Seed Dormancy and Preferentially Promote Radicle Growth in Jute. *HortScience, 36*(*1*): 143-144.

Bhawalkar, U.D. and Bhawalkar, U.V. 1993 Vermiculture biotechnology. In: P.K. Thampan (ed.), *Organic Soil Health and Crop Production*. Peekay Tree Crops Development Foundation, Cochin, 65-85.

Blakemore, R.J. 2009. Cosmopolitan earthworms: a global and historical perspective. In: D.H. Shain (ed.), *Annelids in Modern Biology*, 257–286.

Blakemore, R.J. 2010. Cosmopolitan Earthworms: An Eco-Taxonomic Guide to the Peregrine Species of the World (4th ed.). VermEcology, Yokohama, Japan, 850pp.

Chaoni, H.I., Zibilske, L.M., and Ohno, T. 2003. Effects of Earthworm Casts and Compost on Soil Microbial Activity and Plant Nutrient Availability. *S*oi. *Biol*. *Bioch*. *35*: 295-302.

Curry, J.P. 1998. Factors affecting earthworm abundance in soils. In: C.A. Edwards (ed.), *Earthworm Ecology*. CRC Press LLC, Boca Raton, Florida.

Day, L. 2000. The City Naturalists Earthworms. Article SFA of CM. pp. 2-3. http://www.nysite.com/nature/fauna/earthworm.htm

Diver, S 1993. Vermiculture: Indian experience and experiments. The Food and Agriculture Organization Library Bulletin Service AGRISL%IRMFAO01BITNET@vm.cnuce.cnr.it

Dominguez, J., Edwards, C.A. Webster, M. 2000. Vermicomposting of sewage sludge: effect of bulking materials on the growth and reproduction of the earthworm *Eisenia andrei*. *Pedobiologia*. *44*: 24-32.

Dynes, R.A. 2003. Earthworms technology information to enable the development of earthworm production: A report for the Rural Industries Research and Development Corporation (RIRDC), Australia, 39pp.

Edwards, C.A. 1988. Breakdown of Animal, Vegetable and Industrial Organic Wastes by Earthworms. In: C.A. Edwards and E.F Neuhauser (ed.) *Earthworms in Waste and Environmental Management*. SPA Academic Publishing The Hague, Netherlands, 21-31.

Edwards, C.A. and Lofty, J.R. 1977. Biology of earthworm, Chapman and Hall, New York NY 333pp.

Feller, C., Brown, G.G., Blanchart, E., Deleporte, P., and Chemyanskii, S.S. 2003. Charles Darwin, Earthworms and the Natural Science: Various lessons from past to future. *Agric. Eco. Env*. *99*: 29-49.

Gerard, B.M. and Hay, R.K.M. 1979. The effect on earthworms of ploughing, tined cultivation, direct drilling and nitrogen in a barley monoculture system. *J. Agric. Sci. 93*: 147–155.

Harper, J. K. and Greaser, G. L. 1994. Agricultural Alternatives: Earthworm Production. U.S. Department of Agriculture Extension Bulletin.

Foth, H.D. 1978. Fundamentals of Soil Science (6th ed). John Wiley, New York.

Kleinschmit, J. 1962. Untersuchung von Kalkdungungsversuchsflachen im Lehrforstamt Escherode. *Forstarchiv*, 33: 25–29.

Lavelle, P. 1988. Earthworm activities and soil system. *Biol. Fertil. Soils. 6*: 237-251.

Lee, K.E. 1985. Earthworms: Their Ecology and Relationships with Land Use. Academic Press, Sydney, Australia.

Lehman F.R. 2005. Earthworm species composition and distribution in the Upper Pennicula of Michigan.https://underc.nd.edu/assets/216504/fullsize/lehman2005.pdf .

Lynch, J.M and Poole, N.J. 1979. Microbial ecology: a conceptual approach. Blackwell Scientific Publications, Oxford, 115pp.

Madge, D.S. 1969. Field and Laboratory Studies on the Activities of Two Species of Tropical Earthworms. *Pedobiol. 9*: 188-214.

Mba, C.C. 1983. Utilization of *Eudrilus eugeniae* for disposal of cassava peel. In: J.E. Satchell (ed.). Earthworm Ecology: From Darwin to Vermiculture Chapman and Hall, London, 315-321.

Monebi, C.O. and Ugwumba, A.A.A. 2012. Utilization of the earthworm, *Eudrilus eugeniae* in the diet of Heteroclarias fingerlings. *Int. J. Fish. Aqua 5*(*2*): 19-25. https://doi: 10.5897/IJFA12.092.

Ndegwa, P.M. and Thompson, S.A. 2001. Integrating composting and vermicomposting in the treatment of bioconversion of biosolids. *Bioresour. Technol. 76*: 107-112.

Nielson, R.L. 1951. Effect of soil minerals on earthworms. *N. Z. J. Agric. 83*: 433-435.

Owa, S.O. 1992. Taxonomy and distribution of Nigeria Earthworms of the family Eudrilidae and their use as possible indicators of soil properties. Ph.D. Thesis submitted to the Department of Zoology, Obafemi Awolowo University, Ile-Ife.

Owa, S.O. and Olojo F. 2003. Limicolous earthworms of streams and river banks in Ago-Iwoye, SW Nigeria. *J. Appl. Sci. 6(3):* 3726-3737.

Owa, S.O., Dedeke, G.A., Morafa, S.O.A. and Yeye, J.A. 2003 Abundance of earthworms in Nigerian ecological zones: implications for sustaining fertilizer-free soil fertility. *Afr. Zool. 38*(*2*)*:* 235-244.

Owa, S.O., Moreyibi, H.O., Dedeke, G.A., Olojo, F.O. and Fashunwon, O.O. 2004a. Earthworm created microenvironment around roots of lowland rice. *J. Sci., Engr. Tech. 11*(*1*)*:* 5261-5270.

Owa, S. O., Moreyibi, O. H., Morafa, S. O. A. and Dedeke, G. A. 2004b. Contributions of earthworms to soil temperature and its physicochemical implications on crops. *J. Sci. Engr. Tech*. *11*(*1*): 5343-5350.

Reynolds, J.W. 1977. The earthworms Lumbricidae and Sparaanophilidae of Ontario. Royal Ontario Museum Life Sciences Miscellaneous Publications.

Reynolds, J.W. and Cook, D.G. 1993. Nomenclatura oligochaetologica. Supplementum tertium. A catalogue of names, descriptions and type specimens of the Oligochaeta. New Brunswick Museum Monographic Series (Natural Science) No. 9, 33pp.

Satchel, J.E. 1955. Some aspects of earthworm ecology. In: D.K McE Kevan (ed.), *Soil Zoology* Butterworth Scientific Publications, London, 180-201.

Schulmann, O.P. and Tiunov, A.V. 1999. Leaf litter fragmentation by the earthworm *Lumbricus terrestris* L. *Pedobiologia 43*: 435-458.

Sharpley, A.N., Syers, J.K. and Springett, J.A. 1979. Effects of surface casting earthworms on the transport of phosphorus and nitrogen in surface runoff from pasture. *Soi. Biol. and Bioch*. *11*: 459-461.

Sogbesan, O.A. and Ugwumba, A.A.A. 2008. Nutritional values of some non-conventional animal protein feedstuffs used as fishmeal supplement in aquaculture practices in Nigeria. *Turk. J. Fish. Aquat. Sci. 8*: 159-164.

Spannagel, G. 1960. Humusbildung unter dem Einfluss von Kalk in Verbindung mit der Entwicklung einer reichen Bodenfauna. *Trans. rth Int. Congr. Soil Sci.* 695–701.

Storer, T.I., Usinger, R.L., Nybakken, J.W., and Stebbins, R.C. 1977. Elements of Zoology (4th ed). McGraw Hill.

Tabu, I.M., Obura, R.K. and Swift, M.J. 2001. Macrofauna abundance and diversity in selected farmer perceived soil fertility niches in Western Kenya. http://clayuca.org/tsbf_institute/managing_nutrient_cycles/AfnetCh34.pdf

Zajonc, I. 1975. Variations in meadow association of earthworms caused by the influence of nitrogen fertilizers and liquid manure irrigation. In: J. Vanek (ed.), *Progress in Soil Zoology*. Czechoslovakia Academy of Science, Prague, 497-503.

Citation: Aladesida, A.A. and Owa, S. O. 2021. Implications of ecological parameters on earthworm diversity and abundance in southwestern Nigeria.
http://dx.doi.org/10.4314/tzool.v19i1.3