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Diversity and abundance of soil mesofauna and microbial population in South–Western Nigeria

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The study was carried out to examine the diversity and abundance of soil mesofauna and microbial population in three (3) Forest Reserves in Southwestern Nigeria (Oluwa, Omo and Akure forest reserves). Soil samples were collected from the study areas and the mesofauna present were isolated and identified. The bacteria count and fungi count were also obtained and identified. The pH was also determined likewise the soil physical properties were obtained. It was observed that the diversity and abundance of bacteria were significantly higher ($p< 0.05$) in Oluwa Forest Reserve and significantly lower in Omo Forest Reserve. There were no significant differences ($p>0.05$) in the fungi diversity and abundance in the study habitats. The results for the soil pH show that 5.83, 5.93 and 6.40 values were obtained for Omo, Akure and Oluwa forest reserves respectively. Also, there were no significant differences in the soil physical properties recorded from the study habitats. The Shannon- Weiner diversity index for the mesofauna for Omo, Oluwa and Akure Forest Freserves were 1.69, 0.19 and 1.82 respectively. Furthermore, the species evenness for Omo Forest Reserve is 0.19, while it was 0.19 and 0.20 for Oluwa and Akure Forest Reserves respectively. This shows that species diversity of mesofauna in Omo and Akure Forest Reserves were significantly ($p<0.05$) higher than what was obtained from Oluwa Forest Reserve. The correlation coefficient values indicated that there was no significant correlation between soil pH and bacteria count in both Oluwa and Akure Forest Reserve ($R^2 < 50\%$). But, there is a significant correlation between soil pH and bacteria count in Omo Forest Reserve ($R^2 > 50\%$). Likewise, there were no significant correlation between the soil pH and fungi count and between the soil pH and mesofauna in all the three Forest types / habitats.

Key words: Mesofauna, forest reserve, habitat, diversity, micro-organism.

INTRODUCTION

Nigeria ecological zone can be broadly divided into savanna and rainforest. The savanna region covers an area of 75,297 km^2 and is made up of Sudan, Sahel, Guinea and Derived savanna. The rainforest which accounts for only 2% of the country's forest area is located in the southern part of the country and it is composed of humid lowland forest, fresh water swamp and mangrove forest. Each of these ecological zones has their own peculiarities and supports a wide range of plant and animals species. But the tropical rainforest has been the richest in abundance and diversity of plant and animal species. The occurrence of soil arthropods outnumbers the arthropods of all other compartments of many biomes (Badejo and Ola-Adams, 2000). Stork (1988) estimated that the number of arthropods in one hectare of rain forest is 42.2 million and the major soil arthropods groups include (Collembola (48%), Acari (18%), Formicidae (16%) followed by Coleopteran, Psocoptera and Hemiptera.

Soil mesofauna are soil micro-arthropods and can be classified using it's functional role in the soil as proposed by Moore et al. (1988). Focusing on the litter decomposition process at the ecosystem level, soil mesofauna are involved in a variety of functions such as comminution, litter microbial grazing and microbial dissemination. Most tropical soil fauna live in the top 10 cm of mineral soil where organic matter is decomposed and the final products such as water, CO_2 and mineral salt are available for crops through their roots. Badejo et al. (1995) reported that soil mesofauna are involved in the decomposition of plant residue when he carried out a study on the effect of mulching with plant residue on soil micro-arthropods population of maize plants in a tropical rain-forest zone in Nigeria. The identification of soil micro-

organisms magnification to see and resolve their structures. The common divisions of the soil micro-organisms are the bacteria, fungi, yeast, mold, protozoa etc and they have deoxyribonucleic acid (DNA) and the ribonucleic acid (RNA). Mirco-organisms are present in high populations in the soil and in varying number in the air.

The aim of this study therefore was to examine and compare the influence of different habitat or forest type on the diversity and abundance of bacteria, fungi and mesofuna as well as to examine the relationship between them and soil pH.

MATERIALS AND METHODS

The study area

This study was carried out at three forest sites. namely: Oluwa Akure and Omo Forest Reserves. Omo Biosphere Reserve is one of the 31 Biosphere Reserves in 127 countries within the Afrotropical Realm. It is located between latitudes 6°35' to 7°05'N and 4°19' to 4°10'E in the Ijebu area of Ogun State in southwestern Nigeria. It is in the mixed moist, semi-evergreen rainforest zone in the Congolian sub-unit of the Guinea-Congolian Centre of Endemism or Phytochorion (Isichei, 1995). This reserve covers 130,500 ha of land about 20 km from the Atlantic coast 460 ha of land in the north central part of the reserve had been designated as a Strict Natural Reserve (SNR) since 1946. Oluwa natural forest is within Oluwa Forest Reserve. It is located between 6°55'-7°20' and longitude 3°45'- 4°32', with an area of 87,816 ha.

Akure Forest Reserve located in Ifedore Local Government Area, Ondo State, Nigeria. This reserve was selected for the study because of the presence of a permanent sample plot demarcated in 1935 by Forestry Research Institute of Nigeria as strict reserve (representing undisturbed natural forest ecosystem).

The climate and site condition

Raining season in Oluwa and Omo starts in March and ends in November, but intensive rainfall begins from April to October. Annual rainfall ranges from 1,700 to 2,200 mm. Dry season lasts from December to February, with little rains during the period. Annual temperature and average daily relative humidity is about 26°C and 80%, respectively. Average elevation in Oluwa is 100 m while that of Omo is 123 m a.s.l. The soils of Oluwa and Omo are predominantly ferruginous tropical soils and are typical of the variety found in the intensively weathered areas of basement complex formations in the rainforest zone of South-western Nigeria. They are representative of soils in the Ondo Association, which is comprised of well-drained, mature, red stony and gravely soils in the upper parts of the sequence, grading into the hill wash overlying original parent material or hard-pan layers in the valley bottom (Smith and Montgomerry, 1962). The texture of the topsoil in both reserves is mainly sandy loam, which gradually becomes heavier as one digs deeper into the soil (Onyekwelu et al., 2006). The subsoil consists of clay with gravel occurring at 30-60 cm depths, especially in Omo.

DATA COLLECTION

Laying of plot

Field work was carried out in April 2008. In each of the Forests Reserve, one hectare (100 x 100 m) forest land was mapped out and sub-divided into plots of 20 x 20 m. Using fifty percent sampling intensity, twelve plots were randomly selected. On each plot, soil samples were collected from five points and were carefully labeled. Soil samples were collected at surface (surface soil 0-10 cm soil layer). The soils samples were immediately brought to the laboratory where the mesofauna present were isolated and identified using the floatation method.

Mesofauna isolation and identification

Mesofauna: Enumeration of Soil Collembola: Etraction of soil collembola was done using Berlese funnel extraction technique. From each sample plot, excavate 25 x 25 x 5 cm deep sample of soil (including any plant litter on surface – plant litter NOT included in the 5 cm depth) and gently place in plastic bag. In order to minimize crushing of soil fauna, extract the soil sample was extracted by marking out the soil margins of 25 x 25 cm with the end of a trowel. A trench of 25 cm long by 30 cm deep was dug along one edge and the 4 edges were cut vertically of the 25 x 25 markings to a 10-15 cm depth. Then the trowel was insert horizontally under the 25 x 25 markings at a 5 cm depth and sample was lifted into a bag:

1. Samples were removed from bag and place in Berlese extractor. As the dirt was placed in extractor, clouds were break up so that the arthropods can emigrate properly from a sample of even consistency. Any earthworms were removed to a separate specimen vial (worm skin mucus is terribly sticky and if the worms are not removed all of the little critters get stuck on the worm skin). The clods were break apart without squashing the soil.

2. 25 watt light bulb was turn on, extraction were carried out for 48 h. A jar was placed (see H in illustration below) containing a small amount of antifreeze under the Berlese funnel. Antifreeze has the benefit that it does not evaporate. The extracted samples (critters, dirt, and alcohol or glycol) were placed into one (or more as needed) labeled small vials. Few drops of cooking oil were added to top of vial, enough to form a thin meniscus. Cap was replaced; the mixture was agitated to force the oil into microdrops throughout the solution. The oil was let slowly (10 min) rise to the top carrying nearly all the arthropods with it. Pipette the critters from the oil layer into a Petri plate; the excess oil and glycol from the petri plate were removed. The critters were sorted into piles of similar species. Identification were made as: springtail A, B, C…mite A, B, C, beetle A, B, C, etc (Berthlet, 1967). Species were counted and data was put into spreadsheet.

Bacteria isolation, identification and counting

The standard procedures for determining the total number of soil microbes were adopted for bacteria and fungi culturing (Alexander, 1982). Suspension of the soil samples was prepared with sterile water and a serial dilution of five factors was made for accurate counting. Then 1 ml of the appropriate dilution was carefully transferred to sterilized Petri dishes containing sterile molten nutrient agar at about 37°C. This was mixed and allowed to solidify. It was then incubated for 24 h. The bacteria that grew into colonies were sub-cultured to obtain pure culture for easy identification. Identification was done according to Bergeys manual of determinative bacteriology.

For fungi culturing, serial dilution of the suspension was also transferred into Petri dishes containing sterile, molten malt extract agar. This was kept in an incubator at 30°C for 5 days. Fungi that grew were sub-cultured to obtain pure culture for easy identification. Microscopic characterization was done for identification. The soil pH was determined with the aid of glass electrode pH meter in the soil

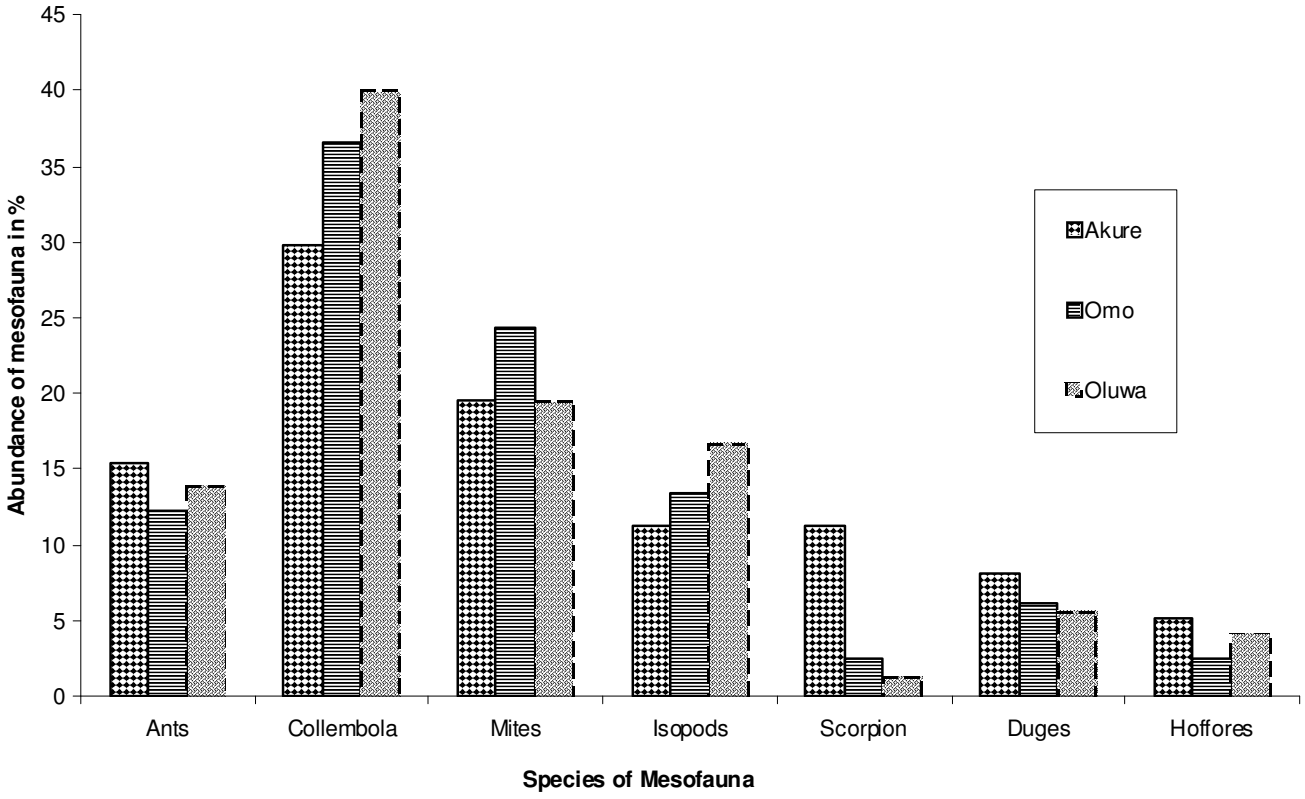

Figure 1. Relative abundance of soil mesofauna in the study habitat.

Table 1. Diversity and abundance of Mesofuna in the study area.

Forest habitat	H^1-diversity index	Evenness (E)	Abundance (M^2)	Mean pH ± SE
Omo	1.69	0.19	8,500	5.83 ± 0.10
Oluwa	1.65	0.19	7,300	6.40 ± 0.18
Akure	1.82	0.20	10,000	5.97 ± 0.08

H^1Shannon-Weiner diversity index.

solution of 0.01 mol L^{-1} calcium chloride.

RESULTS

The diversity and abundance of soil mesofauna of the study habitat is presented in Table 1. The diversity value for Akure Forest Reserve (1.82) was significantly higher than the rest of the studied habitat. This is followed by Omo Forest Reserve (1.69), while the least value was obtained from Oluwa Forest Reserve (1.65). The specie evenness values also show that Akure Forest Reserve had the highest (0.20) while both Oluwa and Omo Forest Reserves had the common evenness value of 0.19. The species abundance also follow the same pattern of 10,000, 8,500 and 7,300 individuals per m^2 in Akure, Omo and Oluwa Forest Reserves respectively.

Figure 1 present percentage relative abundance of mesofauna in the study habitat. Soil collembola had the highest percentage abundance which ranged between 39 to 45% in the study habitats. This is followed by mites which ranges between 19.5 and 24.5%. The least specie is hoffores with value ranging between 2.5 and 5.5%. Abundance of collembola was found to be the highest in the study habitat followed by mites and the least is scorpion Figure 2. While Akure Forest Reserve has the highest mesofauna followed by Omo Forest Reserve while Oluwa has least abundance of mesofauna.

A total of sixteen species of bacteria were identified in The study habitat (Table 2). Eleven species were represented in Omo Forest Reserve, Fourteen in Oluwa Rreserve while twelve were represented in Akure Forest Reserve. *Pseudo-monas fluorescence, Rhizobium japoniicom, Gloano-bacter oxydon, Staphylococcus*

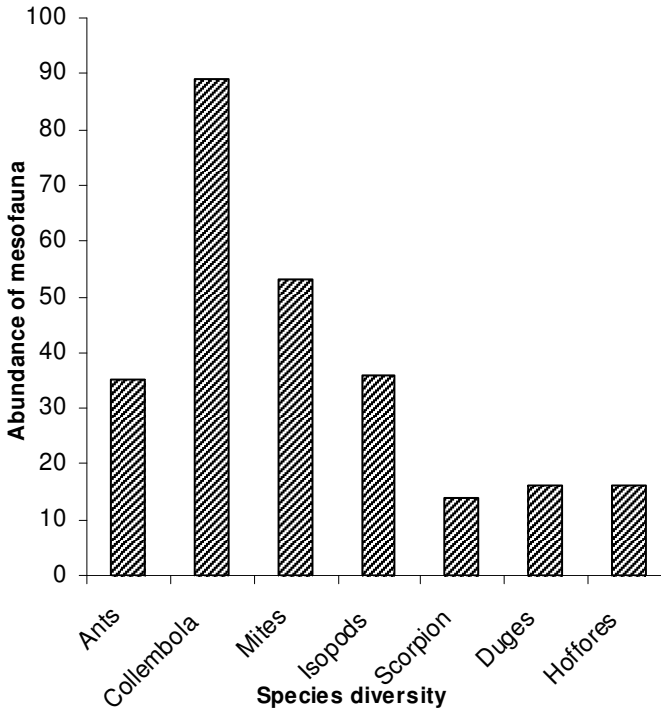

Figure 2. Abundance of different Mesofauna in the study habitat.

aureus and *Rhizobium trifolis,* species were present in all the study habitats and they are termed specie generalist. Seven species were present in two of the habitats. *Actnu-slobacter paraparture* was present in Omo Forest Reserve alone and *Thro-baallus polyrys* was present in Oluwa forest alone these are known as species specialist- (Table 2). Abundance of mesofauna is presented in Figure 3 and it shows that Akure Forest reserve has the highest abundance while the least was found in Oluwa Forest Reserve.

Bacterial abundance in Omo Forest Rreserve ranged between 0.86 x 10^4 and 2.10 x 10^4, while bacteria abundance in Oluwa Forest Reserve ranged between 1.0^4 x 10^4 and 3.11 x 10^4. Finally the abundance of bacteria in Akure Forest Reserve ranged between 4.0 x 10^4 and 13.3 x 10^4 (Table 3).

There were significant ($p \leq 0.05$) differences in the bacteria abundance in the study habitats. There were no significant differences in bacteria abundance between Omo and Akure Forests Resaves. While bacteria abundance in Oluwa Forest Reserve was significantly ($p \leq 0.05$) lower than any of the other studied forest habitat (Table 4).

Fifteen species of culturable fungi were found in the study habitat. Fourteen species were found in Akure forest reserve, eleven in Oluwa Forest Reserve, while nine were present in Omo Forest Reserve.

Diversity of fungi is represented in Table 5, *Penicillium spp, Glomus albidum, Candida albicans, Fusarium spp,*

Table 2. Shows the culturable bacteria diversity in the study areas.

Name of Bacteria	Forest Reseves		
	Omo	Oluwa	Akure
Pseudomonas fluorescence	Δ	Δ	Δ
Pseudomonas aeruginosa	-	Δ	Δ
Acillus subtilis	Δ	Δ	-
Acinetobacter nosocomial	Δ	-	-
Eschena coli	-	Δ	Δ
Protens vulgana	-	Δ	Δ
Rhizobium japoniicom	Δ	Δ	Δ
Xanthomonas campestris	Δ	Δ	-
Gluconobacter oxydan	Δ	Δ	Δ
Beijennckia indica	-	Δ	Δ
Staphylococcus aureus	Δ	Δ	Δ
Rhizobium trifolii	Δ	Δ	Δ
Kerli spp	Δ	-	Δ
Thiobacillus polymyxa	-	Δ	-
Alcaligenes faecalis	Δ	Δ	-
Total present	11	14	12

Key: Δ = Present , - = Absent.

Table 3. Abundance of culturable bacteria species in the study areas, in colony forming unit per gram ((cfu/g) with a dilution.

SN / Soil samples	Forest reserves		
	Omo	Oluwa	Akure
1	1.18 x 10^4	3.04 x 10^4	4.0 x 10^4
2	1.26 x 10^4	3.11 x 10^4	5.4 x 10^4
3	1.22 x 10^4	2.87 x 10^4	12.1 x 10^4
4	0.86 x 10^4	1.38 x 10^4	13.3 x 10^4
5	0.98 x 10^4	1.04 x 10^4	4.54 x 10^4
6	1.02 x 10^4	1.41 x 10^4	4.0 x 10^4
7	2.03 x 10^4	1.52 x 10^4	5.2 x 10^4
8	2.10 x 10^4	1.88 x 10^4	6.1 x 10^4
9	2.00 x 10^4	1.77 x 10^4	9.0 x 10^4
10	1.00 x 10^4	3.06 x 10^4	6.1 x 10^4
11	0.96 x 10^4	3.02 x 10^4	7.0 x 10^4
12	0.98 x 10^4	1.76 x 10^4	4.0 x 10^4

Table 4. Mean separation for the influence of different habitat on bacteria count.

SV	(X) ± S.E
Omo	5.0908 ± 0.0065[a]
Akure	5.1225 ± 0.16746[a]
Oluwa	5.3033 ± 0.0489[b]
Sig.	.179

Figures with the same alphabet are not significantly different form each other.

Table 5. The diversity of culturable fungi species in the study area.

Name of fungi	Omo Forest Reserve	Oluwa Forest Reserve	Akure Forest Reserve
Penicillium spp	Δ	Δ	Δ
Aspergillus niger	Δ	-	Δ
Streptomyces spp	Δ	Δ	-
Oidiodendron spp.	-	Δ	Δ
Glomus albidum	Δ	Δ	Δ
Gonatobotrys simplex	-	Δ	Δ
Aureobascidium pathulae	-	-	Δ
Candida albicans	Δ	Δ	Δ
Mucor mucedo	-	-	Δ
Trichoderma vivide	Δ	-	Δ
Fusarium spp	Δ	Δ	Δ
Turola herbarium	Δ	Δ	Δ
Staphyloccous coccosporum	-	Δ	Δ
Monilia spp	Δ	Δ	Δ
Raillietina echinobothrida	-	Δ	Δ
Total present	9	11	Δ = Present , - = Absent

Table 6. Abundance of culturable fungi species in the study area.

SN / Soil samples	Forest reserves		
	Omo	Oluwa	Akure
1	0.16×10^2	0.18×10^2	0.28×10^2
2	$0.19. \times 10^2$	0.06×10^2	0.24×10^2
3	0.19×10^2	0.46×10^2	0.09×10^2
4	0.12×10^2	0.02×10^2	0.09×10^2
5	0.14×10^2	0.14×10^2	0.04×10^2
6	0.10×10^2	0.12×10^2	0.28×102^2
7	0.24×10^2	0.52×10^2	0.14×10^2
8	0.20×10^2	0.43×10^2	0.24×10^2
9	0.14×10^2	0.14×10^2	0.16×10^2
10	0.12×10^2	0.08×10^2	0.09×10^2
11	0.18×10^2	0.17×10^2	0.34×10^2
12	0.18×10^2	0.14×10^2	0.43×10^2

Turola herbarium, and *Monilia spp* were found in the three studied Forest Reserve and they are termed species generalist. The species that were restricted to a single habitat includes, *Aureobascidium pathulae* and *Mucos mucedo* and they were found only in Akure Forest reserve.

The abundance of fungi is presented in Table 6. Abundance of fungi species in Omo Forest Reserve ranged between 0.12×10^2 and 0.24×10^2, and that of Oluwa ranged between 0.06×10^2 and 0.46×10^2, while that of Akure Forest Reserve ranged between 0.09×10^2 and 0.43×10^2. However, the ANOVA result shows that there were no significant differences in the fungi count.

The regression analysis shows that there exists a strong relationship between soil pH and bacteria abundance in Omo Forest Reserve ($R^2 = 0.516$) meaning an increase or decrease in soil pH has significant effect on their abundance of bacteria in Omo Forest Reserve (Table 8). All other regression equation did not show positive relationship because their values were very low (Tables 7 and 9).

DISCUSSION

From the result obtained, it can be seen that collembola (Springtal) who is the most abundant mesofauna identified in the three (3) habitats. This is similar to the works of Kampichler et al. (2000), who reported that Collembola (Mesofauna) was the most abundant hexapods in soil and attain high densities of up to 100,000 individuals per m^2. They live in wet as well as in dry eco-systems and contribute functionally to different tropic levels within the terrestrial food web (Rusek, 1998). They can exert a significant influence on mineralization process and nutriaent cycling via tropic interaction with decomposer microorganisms (fungi and bacteria) (Lussenhop, 1992). Various soil factors (that is, soil type, plant cover and intensity of soil cultivation) directly influence the soil micro arthropod community with respect to number and composition (Andren and Lagerlof, 1983) and their spatial distribution (Farrar and Crossely, 1983).

There is prominent disparity in the abundance of mesofauna among the three forest reserves studied (Figure 3).Mite densities are presented in Figures 1 and 2, unlike other groups which contain predatory and parasitic forms, this group comprises of exclusively phytophagous and detritivorous feeders whose direct influence on decomposition processes and nutrient cycling in the soil has been documented (Wallwork, 1976). The

Table 7. Summary of the regression analysis between soil pH and Mesofauna.

Forest type	Y	R	R^2	f-Ratio
Omo	0.0308 x + 5874	0.129	0.0167	0.69
Oluwa	0.0542x + 6.2268	0.258	0.0669	0.42
Akure	0.0165x + 5.8127	0.1576	0.0235	0.64

Table 8. Summary of the regression analysis between soil pH and bacteria in the study area.

Forest type	Y	R	R^2	f-Ratio
Oluwa	-1.6927x+15.377	0.4947	0.2440	0.102
Omo	2.1035x – 4.8834	0.7159	0.516	0.005
Akure	0.1442x+ 5.1989	2.588	0.067	0.393

Table 9. Summary of the regression analysis between soil pH and fungi count in the study area.

Forest type	Y	R	R^2	f-Ratio
Oluwa	-0.3406x + 7.1511	0.2389	0.0571	0.45
Omo	1.9364x + 1.5488	0.5604	0.3142	0.05
Akure	0.799 X + 3.2703	0.2712	0.0736	0.39

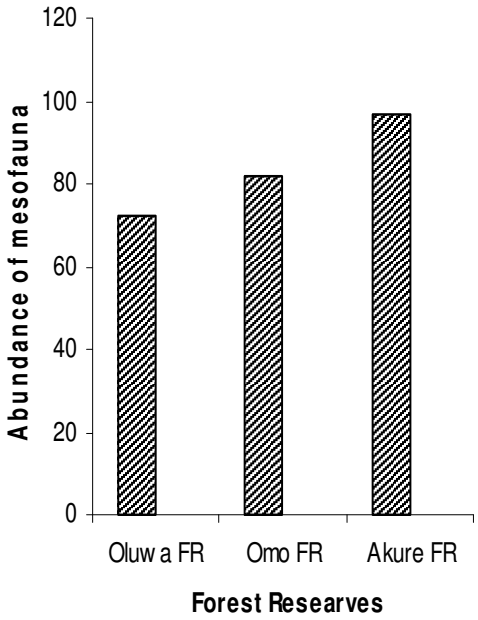

Figure 3. Abundance of Mesofauna in the study area.

findings of Tian et al. (1998) that microarthropods have a buffering effect in regulating leaf decomposition and nutrient release, a process which is mediated by land-use history, lends to this conclusion. Previous studies in similar environments have also shown that soil disturbance during cultivation reduces soil microathropod densities (Badejo, 1990). Also the results from the Shanon-weiner diversity index values indicate that Akure Forest Reserve had a higher diversity index than what is obtainable in other forest reserves studied. This observation is similar to the works of Adeduntan (2007), who reported that Akure Forest Reserve had a higher diversity and abundant of insect-herbivores. However the specie evenness values show that there are little variations in the occurrence of the mesofuana in the three (3) Forest Reserves. The summary of regression analysis shows that there is no significant ($p< 0.05$) interaction between soil pH and mesofauna in the three habitats because the selected habitat are similar in term of nature of their strictness in reservation. It was further observed that the pH of more strict Forest Reserved is higher than others, likewise the soils of more strict reserved are more fertile. This suggests that soil pH might play a significant role in influencing the soil fertility of Forest Reserves and hence, the diversity and abundance of soil mesofauna are also affected. The result of this finding is similar to Badejo and Ola-Adams (2000) who reported that the soil pH of the strict natural reserve of Omo is higher than its surrounding plantations (cultivated land).

Bacteria species like *P. flourescens, R. japoniam M. capsulatus, S. aborea* were found in the three habitats. These species are habitat generalists and are well adapted to change in environmental conditions. Also fungi species like *Penicillium spp, Fisarium spp, S. minutes*

were all found in the three habitats. The regression analysis shows that soil pH interacted within bacteria abundance in Omo Forest Reserve positively (R^2 = 0.51) meaning an increase in soil pH will lead to significant increase on bacteria abundance.

The Regression analysis shows that there is no significant difference in the fungi count in the three habitats. This is supported by the works of Smith et al. (1994) who noted that soil fungi have a broader pH tolerance.

Conclusion

i. Soils of strict natural reserve had lower pH values which implies higher acidity which made it more conducive for bacteria to inhabit, while mesofauna abundance and diversity are significantly affected by change in soil pH.
ii. Soil collenbola (springtail) and mites were the most abundant mesofauna identified in the 3 habitats which directly influence decomposition processes and nutrient cycling in the soil.
iii. There are little variation in the occurrences of mesofauna in the studied Forest Reserves in terms of Abundance and diversity.

REFERENCES

Adeduntan SA (2007). Diversity and Abundance of Insect herbivore in Akure Reserve Ondo State, Nigeria. A Ph.D thesis submitted to the department of forestry and wood technology, Federal University of Technology, Akure, Ondo State, Nigeria p. 26-29.

Alexander M (1982). Most Probable Method for Microbial Populations. In: Page, A. C. ,R. H. Miller, and D. R. Keeney (ed). Methods of soil Analysis: Part 2. Chemical and Microbiological Properties 2nd Edn. Madson, ASA pp. 815-820.

Badejo MA (1990). Seasonal abundance of soil mites (Acarina) in two contrasting environments. Biotropica, Washington 22(4): 382-390.

Badejo MA, Tian G, Brussaard L (1995). Effects of various mulches on soil micro-arthropods under a maize crop. Bio Fertility soils 20: 295-298.

Badejo MA, Ola-Adams BA (2000). Abundance and diversity of soil mites of fragmented habitats in a biosphere reserve in Southern Nigeria. Pesq. agropec. bras., Brasília 35(11): 2121-2128.

Berthlet P (1967). The metabolic activity of mites (Acarinna) in different forest floors. In petrusenical (ed) secondary productivity of terrestrial ecosystem Warsaw:pww. 2: 709-725.

Isichei AO (1995). Omo biosphere reserve: current status, utilization of biological resources and sustainable management. Paris : UNESCO, 1995. 48p. (South Cooperation on Environmentally Sound Socio-Economic Development in the Humid Tropics. Working Paper, 11).

Kampichler CS, Dzeroski TI, Wieland R (2000). Application of machine learning techniques, relationship between habitat features and Collembola community soil Biol. Biochem. 32: 197-209.

Moore JC, Walter DE, Hunt HW (1988). Arthropod regulation of micro and meso-biota in below ground detrital webs. Annual review of Entomology 33: 419-439.

Onyekwelu JC, Mosandi R, Stimm B (2006) Productivity, site evaluation and state of nutrition of Gmelina arborea plantations in tropical rain forest zone in South-western Nigeria. Forest Ecol. Manage. 229: 214-227.

Rusek DB (1998). Collembola distribution has influenced by soil types. J. Entomol. 45: 26-35.

Smith AJ, Montgomerry RF (1962). Soil and Land use in Central Western Nigeria. Govt. Printer, Ibadan Nigeria p. 265.

Stork NE (1988). Insect diversity, facts, fiction and speculation. Biol. J. Linnaean soc. 35: 321-337.

Tian G, Adejuyigbe CO, Adeoye GO, Kang BT (1998). Role of soil microarthropods in leaf decomposition and N release under various land-use practices in the humid tropics. Pedobiologia, Jena 42: 33-42.

Wallwork JA (1976). The distribution and diversity of soil fauna. London: Academic p. 355.