Tree Density and Leaf Litter as Drivers of Ground-Active Arthropod Diversity in Zoological Garden, Southeastern Nigeria

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Abstract

Ground-active arthropods are vital contributors to ecosystem functioning and serve as sensitive indicators of habitat quality. However, their diversity within managed wildlife environments such as zoological gardens remains poorly studied, particularly in tropical Africa. This study assessed the diversity and habitat drivers of ground-active arthropods in the Zoological Garden of the University of Nigeria, Nsukka. Arthropods were sampled using pitfall traps across four plots differing in vegetation structure, tree density, and leaf litter depth between June and September 2024. Specimens were identified to the lowest possible taxonomic level, and diversity indices including Menhinick's Richness index (Dmg), Shannon–Wiener diversity (H′), and Pielou's evenness (J′) were calculated. A total of 1,140 individuals representing nine arthropod orders, 16 families, and 21 species were recorded. Plots characterised by higher tree density and deeper leaf litter supported greater arthropod abundance. Exploratory regression analyses indicated positive relationships of arthropod abundance with tree density ($R^2 = 0.90$, $p = 0.03$) and leaf litter depth ($R^2 = 0.96$, $p = 0.01$). These findings highlight the importance of vegetation complexity and litter accumulation in sustaining arthropod biodiversity within zoological gardens.

Keywords: ground-dwelling arthropods; diversity indices; leaf litter; tree density; urban ecosystems; zoological gardens

Introduction

Arthropods are the diverse, functional and significant group of terrestrial organisms (Wilson, 2000), occupying nearly all ecological niches and contributing to essential ecosystem processes such as nutrient cycling, litter decomposition, pollination, seed dispersal, and pest regulation (Losey and Vaughan, 2006). Their sensitivity to environmental change makes them effective bioindicators for assessing habitat quality, ecological disturbance, and ecosystem health (McGeoch, 1998; Gerlach et al., 2013).

Ground-active arthropods, including ants, beetles, spiders, millipedes, cockroaches, crickets, and termites plays important role in decomposition of organic matter, soil structure, and mediating trophic interactions (Lavelle et al., 2001). Their abundance and community composition are strongly shaped by habitat structure, microclimate, vegetation complexity, soil properties, resource availability, and anthropogenic disturbance (Magura et al., 2015). Consequently, studies of ground-active arthropod communities provide valuable insights into ecosystem condition and inform habitat management strategies (Rainio and Niemelä, 2003).

Zoological gardens are managed wildlife environments that often contain a mosaic of microhabitats formed by vegetation patches, animal enclosures, walkways, water bodies, and varying levels of human activity (Fernandez-Juricic and Jokimäki, 2001). This structural heterogeneity can enhance arthropod diversity, particularly where vegetation complexity and leaf litter accumulation are maintained (Jones and Leather, 2012). However, intensive management practices such as litter removal, trampling, and vegetation simplification may negatively affect arthropod communities (McIntyre, 2000; Niemelä et al., 2011). Despite their potential ecological value, zoological gardens in tropical regions remain poorly studied with respect to arthropod diversity.

In Nigeria, information on ground-active arthropod diversity within zoological gardens is particularly scarce. The Zoological Garden of the University of Nigeria, Nsukka, provides a semi-natural urban habitat characterised by heterogeneous vegetation structure and varying degrees of anthropogenic disturbance, making it an ideal system for examining arthropod–habitat relationships. The baseline data from such environments are essential for biodiversity conservation, ecological monitoring, and the sustainable management of urban green spaces.

This study aimed to assess the composition and diversity of ground-active arthropods across plots differing in vegetation structure and litter depth, and evaluate the influence of tree density and leaf litter depth on arthropod abundance and diversity within the zoological garden.

Materials and Methods

Study Area

The study was conducted in the Zoological Garden of the University of Nigeria, Nsukka (6°51′–6°53′ N; 7°24′–7°26′ E), southeastern Nigeria. The garden covers approximately 3.5 ha and lies at an elevation of about 397 m above sea level. The area experiences a tropical wet season during the study period and is characterised by mixed tree cover, shrubs, ornamental plants, and patches of managed grassland.

Sampling Period

Arthropod sampling was conducted during the wet season between June and September 2024. This period coincides with the peak of vegetation growth and increased organic matter input, which enhances habitat complexity and resource availability for ground-active arthropods. The wet season is also characterised by increased surface activity of ground-dwelling arthropods within leaf litter microhabitats, improving the efficiency of pitfall trapping. Restricting sampling to a single season ensured standardized sampling conditions across plots and minimized short-term climatic variability.

Plot Characterisation

Four sampling plots were established within the garden as representative habitat units differing in vegetation structure, tree density, leaf litter depth, and disturbance intensity. Each plot covered approximately 0.87 ha and was separated from adjacent plots by buffer zones of 10 m to minimise edge effects. Leaf litter depth was measured using a graduated ruler inserted vertically through the litter layer to the mineral soil at multiple points within each plot, and the results were expressed as the mean ± SE. Tree density was estimated by direct counts of trees ≥10 cm diameter at breast height within plots.

Arthropod Sampling and Identification

Each plot was subdivided into four quadrants, with one pitfall trap placed at the centre of each quadrant (16 traps in total). Pitfall traps measured 14.4 cm in depth and 9.5 cm in diameter and were fitted with raised covers to prevent flooding. Traps contained 300 ml of 30% ethylene glycol as a preservative. Traps were operated continuously and emptied twice monthly over the four-month sampling period. Collected specimens were preserved in 75 % ethanol solution (Danjuma and Ibrahim, 2019), transported to Entomology Museum, Department of Crop Protection Ahmadu Bello University, Zaria, Nigeria, and identified to species level using identification book by Triplehorn and Johnson (2005) and through morphological examination and comparison with authenticated reference collections at the Museum.

Data Analyses

Species composition were determined by direct counts of individuals per species. Relative abundance of arthropods per order, rank abundance per species, and functional groups abundance were calculated as the percentage contribution of each order, species, or functional group to the total number of individual arthropods sampled. Species richness per plot was calculated using Menhinick's Richness index (Dmg), calculated as:

$$\mathrm{Dmg} = \frac{n}{\sqrt{N}}.$$

where: Dmg= species richness, n= number of different species represented in a plot, N= total number of individual organisms in a plot. Species diversity was quantified using the Shannon–Wiener diversity index (H′), calculated as:

$$H' = -\sum (pi \ln pi)$$

where pi is the proportion of individuals belonging to the ith species relative to the total number of individuals in the sample. Community evenness was assessed using Pielou's evenness index (J′), calculated as:

$$J' = H'/\ln(S)$$

with values approaching 1 indicating a more even distribution of individuals among species.

Exploratory simple linear regression analyses were used to examine relationships between total arthropod abundance and habitat variables (tree density and leaf litter depth). Given the limited number of sampling plots (n = 4), regression results were interpreted as descriptive indicators of ecological trends rather than as confirmatory or predictive tests. All analyses were conducted in Excel statistical software version 2016 and R version 4.4.1 at a significance level of α = 0.05.

Results

Species Composition and Relative Abundance

A total of 1,140 ground-active arthropod individuals representing nine orders, 16 families, and 21 species were recorded across the four sampling plots (Table 1). Hymenoptera was the most abundant order

TABLE 1

Species Composition of Ground-Active Arthropods within the Zoological Garden, University of Nigeria, Nsukka

Order	Family	Species	Common Name	N	FG
Araneae	Theridiidae	*Latrodectus geometricus*	Brown widow spider	80	Predator
Dictyoptera	Blattidae	*Periplaneta americana*	American cockroach	68	Detritivore
Dictyoptera	Blattidae	*Pycnoscelus surinamensis*	Surinam cockroach	60	Detritivore
Subtotal				**128**	
Coleoptera	Nitidulidae	*Carpophilus dimidiatus*	Sap Beetle	78	Detritivore
Coleoptera	Scarabaeidae	*Gymnopleurus fulgidus*	African dwarf dung beetle	44	Detritivore
Subtotal				**122**	
Diptera	Calliphoridae	*Chrysomya putoria*	African blowfly	20	Saprophagous
Diptera	Stratiomyidae	*Hermetia illucens*	Black soldier fly	22	Saprophagous
Diptera	Muscidae	*Musca domestica*	Housefly	16	Saprophagous
Diptera	Calliphoridae	*Lucilia cuprina*	Green bottle fly	18	Saprophagous
Diptera	Tabanidae	*Tabanus taeniola*	African horsefly	18	Herbivore
Diptera	Sarcophagidae	*Sarcophaga exuberans*	Flesh fly	34	Saprophagous
Diptera	Calliphoridae	*Chrysomya megacephala*	Oriental latrine fly	52	Saprophagous
Subtotal				180	
Hemiptera	Pentatomidae	*Nezara viridula*	Southern green shield bug	90	Herbivore
Hemiptera	Aradidae	*Brachyrhynchus membranaceus*	Flat Bug	96	Herbivore
Subtotal				**186**	
Hymenoptera	Formicidae	*Camponotus maculatus*	Carpenter ant	100	Predator
Hymenoptera	Formicidae	*Camponotus sericeus*	Golden carpenter ant	60	Predator
Hymenoptera	Formicidae	*Camponotus perrisii nigeriensis*	Nigerian carpenter ant	40	Predator
Hymenoptera	Formicidae	*Pheidole megacephala*	African big-headed ant	22	Omnivore
Subtotal				**222**	
Isopoda	Porcellionidae	*Armadillidium vulgare*	Common pill woodlouse	76	Detritivore
Ixodida	Ixodidae	*Amblyomma variegatum*	Tropical bont tick	90	Parasite
Orthoptera	Gryllidae	*Gymnogryllus lucens*	Cricket	56	Omnivore
Grand Total				**1140**	

Keys: N = Abundance Per Species, Family or Order; FG = Functional Group with relative abundance of 17.9%, followed by Diptera (15.5%), Hemiptera (15.0%), Coleoptera (10.7%), Dictyoptera (10.3%), Ixodida (7.9%), Araneae (7.01 %), Isopoda (6.7%), while Orthoptera recorded the least relative abundance of 4.9%[DE17.1]. (Figure 1). The dominance of Hymenoptera was largely driven by formicid species, particularly *Camponotus maculatus*.

Species Rank and Functional Group Abundance

The rank abundance of arthropod species analyses showed that Camponotus maculatus had the highest abundance (N = 100), followed by Brachyrhynchus membranaceus (N=96), Nezara viridula and Amblyomma variegatum (N=90, each), while Musca domestica had the least abundance (N=16) (Figure 2). The functional group abundance revealed that Saprophagous had the highest abundance (N=6), followed by Detritivores (N=5), while parasitic had the lowest abundance (N=1) (Figure 3).

Diversity Patterns Across Plots

Arthropod diversity varied among sampling plots. Plot A, characterised by high tree density and deep leaf litter, exhibited the highest diversity (Dmg = 21; H′ = 1.55; J′ = 0.95). Plot C showed moderate diversity (Dmg = 18; H′ = 1.22; J′ = 0.85), whereas Plot B recorded lower diversity values (Dmg = 12; H′ = 0.97; J′ = 0.75). Plot D, which experienced the highest

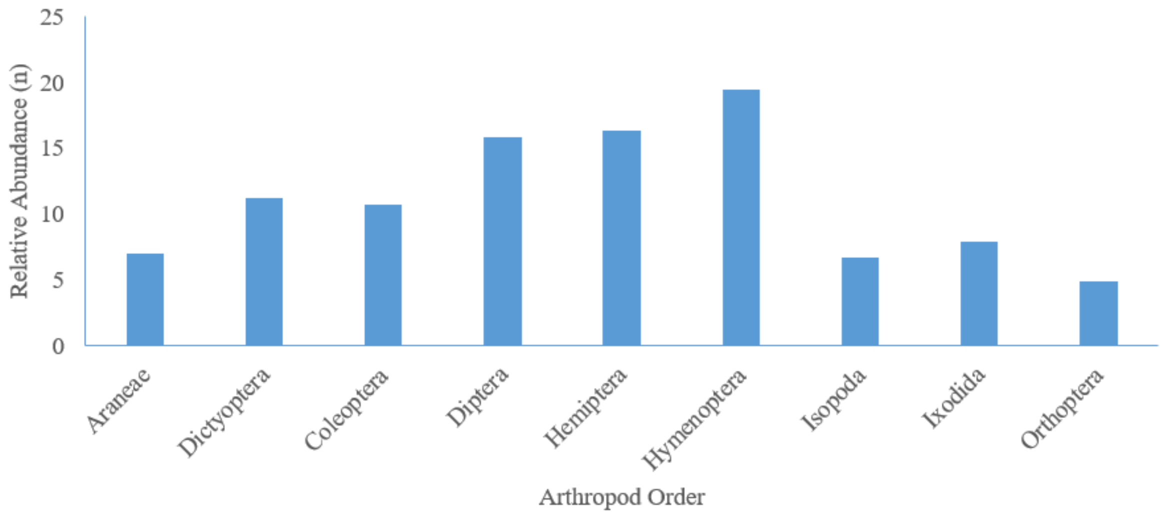

Figure 1 Relative Abundance of Arthropod Order at Zoological Garden, University of Nigeria, Nsukka

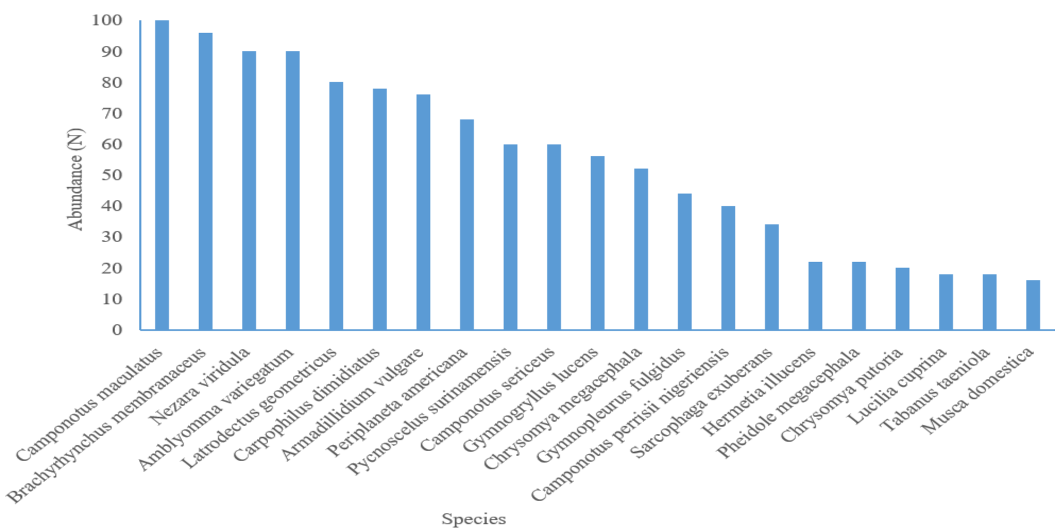

Figure 2 Species Rank Abundance of Arthropods at Zoological Garden, University of Nigeria, Nsukka

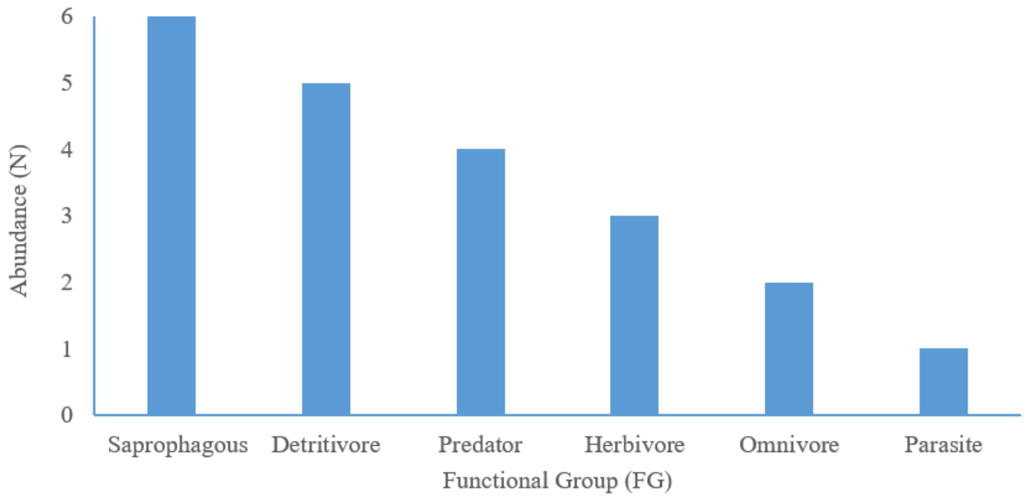

Figure 3 Functional Group Abundance of Arthropods within the Zoological Garden, University of Nigeria, Nsukka

disturbance and had sparse vegetation and minimal litter, exhibited the lowest diversity (S = 7; H′ = 0.50; J′ = 0.65) (Figure 4).

Relationships Between Arthropods and Habitat Variables

Exploratory linear regression analyses indicated a strong positive relationship between arthropod abundance and tree density across plots ($R^2 = 0.90$, $p = 0.03$; Figure 5). Similarly, arthropod abundance increased with increasing leaf litter depth ($R^2 = 0.96$, $p = 0.01$; Figure 6). These relationships suggest that vegetation structure and litter accumulation are important drivers of ground-active arthropod communities within the zoological garden.

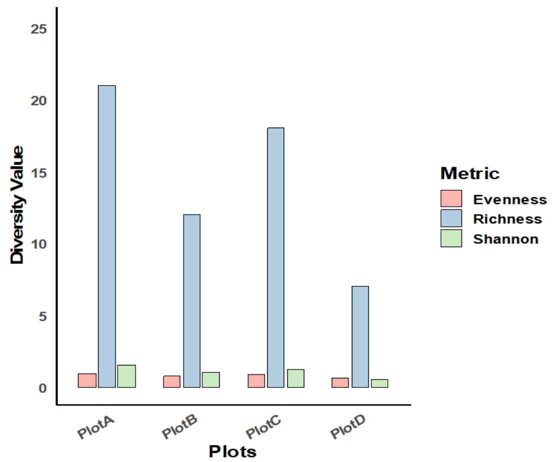

Figure 4 Diversity Metrics Across Plots within the Zoological Garden, University of Nigeria, Nsukka

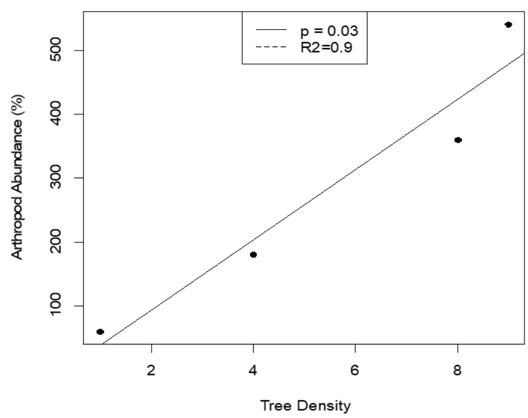

Figure 5 Linear Regression Showing Relationship of Tree Density with Arthropod Abundance in the Zoological Garden, University of Nigeria, Nsukka

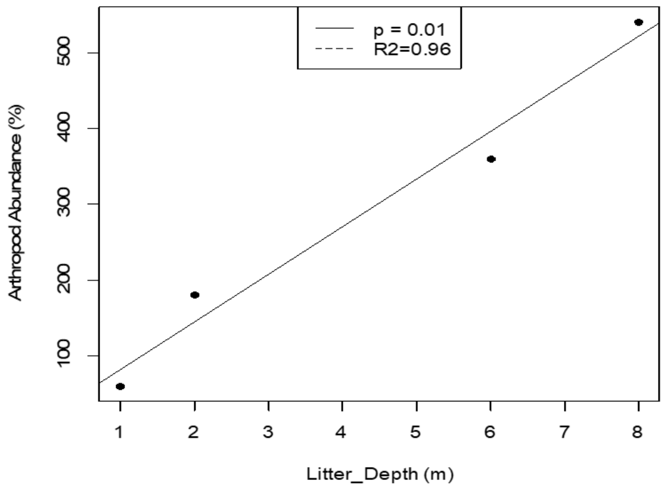

Figure 6 Linear Regression Showing Relationship of Litter Depth with Arthropod Abundance in Zoological Garden, University of Nigeria, Nsukka

Discussion

This study demonstrates that vegetation structure and leaf litter depth strongly influence the abundance and diversity of ground-active arthropods within a managed zoological garden environment. The dominance of Hymenoptera driven by *Camponotus maculatus* aligns with the studies of Esenowo et al. (2014) and Fredrick (2016), highlighting the ecological success of ants in heterogeneous and disturbed habitats due to their behavioural flexibility, broad diet, and efficient foraging strategies.

The high representation of saprophagous and detritivorous arthropods reflects the availability of organic matter derived from leaf litter, animal waste, and decaying vegetation within the garden. These arthropods plays a critical role in nutrient cycling and soil formation, emphasizing the functional importance of arthropods in maintaining ecosystem processes even within managed urban green spaces.

Plots with higher tree density and deeper litter layers supported greater species richness and evenness, likely due to improved microclimatic increased habitat complexity, and enhanced resource availability. Leaf litter provides shelter, oviposition sites, and food resources, while diverse tree cover contributes to habitat heterogeneity and structural complexity. In contrast, highly disturbed plots near visitor pathways and entrances showed reduced diversity, likely resulting from trampling, litter removal, and vegetation simplification. Although regression analyses revealed strong positive associations between arthropod abundance and habitat variables, these results are exploratory due to the limited number of sampling plots. Nonetheless, the observed trends align with established ecological theory and previous empirical studies linking vegetation complexity and litter depth to increased arthropod diversity.

Conclusion

Tree density and leaf litter depth are key drivers of ground-active arthropod diversity within zoological gardens. Plots characterised by dense vegetation and substantial litter accumulation supported higher arthropod abundance, richness, and evenness, whereas heavily disturbed areas exhibited simplified communities. These findings emphasize the ecological value of maintaining structural heterogeneity and minimising disturbance in managed urban green spaces. Promoting litter retention and diverse vegetation cover can enhance the conservation value of zoological gardens and contribute to urban biodiversity conservation.

Limitation of The Study

The present study reflects wet-season conditions within the zoological garden, when ground-active arthropod activity and resource availability are typically high. Consequently, the observed patterns represent peak-season dynamics. Seasonal comparisons, particularly with the dry season, were beyond the scope of this study and warrant further investigation.

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Ethical Statement

No protected or endangered species were involved in this study. Arthropod sampling was conducted in accordance with institutional guidelines, and no specific ethical approval was required for invertebrate sampling.

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