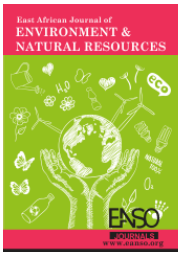

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Original Article

Seasonal and Periodical Assessment of the Abundance and Diversity of Epigaeic Invertebrates in an Urban Forest Remnant, Dar es Salaam, Tanzania

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ABSTRACT

Urban Forest (UF) refers to a complex human-environment system encompassing urban and peri-urban vegetation such as gardens, rivers and coastal corridors, and uninhabited yards. Human beings benefit from a healthy UF in a variety of ways such as recreation, disasters management, and the lessening of the effects of environmental deterioration (caused by the ongoing anthropogenic activities) like air pollution and ozone concentration affecting many epigaeic fauna. Epigaeic Invertebrates (EIs) are above ground foraging or litter dwelling invertebrates carrying important roles in UFs ecosystems such as ecosystem engineers and pests' natural enemies. The present study assessed the influence of dry and wet seasons and different periods of a day (morning, afternoon, and evening hours) towards the abundance and diversity of ground dwelling invertebrates around urban forest remnant in Dar es salaam city, Tanzania. Data collection used pitfall trap, baited traps, and dry leaf litter sifting methods. A total of 10,363 EIs individuals were collected with 133 morpho species, 87 families and 18 orders (Hymenoptera dominated by 71.4%). Wet season had significantly higher abundance (6,360 individuals with 121 morpho species) than dry season (4,003 individuals and 88 morpho species), possibly due to the higher availability of food resources during rainy times. However, quite unexpectedly dry season had higher species diversity, probably due to the over dominance of a very aggressive Formicidae species in wet season that displaced some intolerable species. Also, the overall variations of species diversity and abundance between morning, afternoon, and evening hours were significantly different but higher in the morning. This suggested that EIs were active at different times of the day but were more attracted to the morning sunshine and decreased as the land became hotter. This study depicts urban forests to be among world ecosystems with relatively high levels of EIs biodiversity and hence an urgent call for their conservation efforts before it is too late.

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INTRODUCTION

Urban Forest (UF) can simply be defined as a complex human-environment system including all plants located in urban and peri-urban areas which include urban protected areas, watersheds, street trees and shrubs, gardens, rivers and coastal corridors, and vegetation in green spaces like uninhabited places and yards (Khanal & Straka, 2021; FAO., 2016; Uforest, 2023). A healthy UF provides us with varieties of benefits such as recreation and storm water management, lessening air pollution, reducing ozone concentrations, cooling effects, (Berland *et al*., 2017; Price, 2003; Rahman *et al*., 2015; Nowak & Dwyer, 2007) free from cardio-metabolic conditions and mental disorders (Kardan *et al.*, 2015). Nevertheless, many anthropogenic activities do affect UF in many ways which include pollution, quarry mining, uncontrolled burning and clearing of trees and other vegetation for various reasons such as settlement, charcoal making, and farming (Senkoro, 2015; Mohamed, 2016). As a result, many towns end up having very few remnants urban forests. Distorting urban forests is directly affecting varieties of epigaeic fauna since they are among world ecological systems with relatively high levels of biodiversity (Alvey, 2006) which include epigaeic invertebrates (Mohamed, 2016) such as the collembolans, mites, carabid beetles, earthworms, soil-dwelling ants (Kotze *et al.*, 2022) snails, slugs, spiders, millipedes, woodlice, and rove beetles (Braschler *et al.*, 2021).

Epigaeic Invertebrates (EIs) constitute a very diverse group of above ground foraging fauna (invertebrates) carrying very important roles in urban forests ecosystems such as bio-indicators, decomposers, ecosystem engineers, and natural enemies for a variety of urban pests and the invasive species (Kotze *et al.*, 2022; Jones, 2010) with a very high recovery rate to natural and man-made disasters like fire (Pryke, 2008). EIs have diversities of habitat types and trophic levels (from herbivores, carnivores to detritivores). They also act as a food source to varieties of organisms in the higher trophic levels and hence have great influence to urban ecosystem functions with a significant impact on many organisms predominantly when there are changes in their abundances (Jones & Leather, 2012) and diversities. EIs abundances and diversities are determined by many ecological factors among which are seasons and periods of the day (Mohamed, 2016) as they both determine their activeness in an ecosystem. The present study set out to assess the influence of dry and wet seasons

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and different periods of a day (morning, afternoon, and evening hours) towards the abundance and diversity of ground dwelling invertebrates around urban forest remnant in Dar es salaam city, Tanzania.

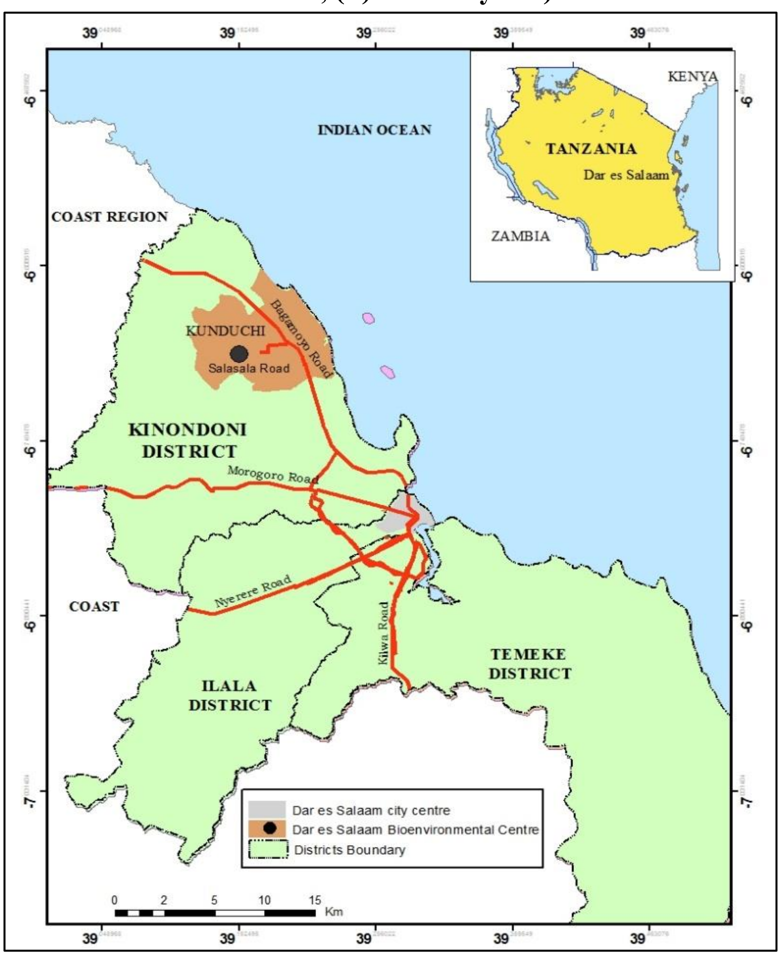
STUDY AREA AND METHODS

Study Area

The study was carried out between November, 2014 and May, 2015 in an urban forest remnant formerly called Dar es salaam Bioenvironmental Centre (DBC). It is located at $6^0$41'20.33" S $39^0$11'10.60" E along the coast of Indian Ocean at Kilimahewa village, Kunduchi ward, Kinondoni district in the Dar es Salaam city, Tanzania (*Figure 1*). The site covers an area of seven hectares and lies within an elevation of 80-90 m asl. It is characterized by a relatively stable (tropical) climatic condition frequently influenced by breeze from the Indian Ocean which it overlooks.

This remnant urban forest faces some pressure from a rapidly growing human population in the Dar es Salaam city and the accompanying human activities, including burning and clearing of vegetation (Senkoro, 2015). The DBC was privately owned by the late Prof. RBM Senzota as both conservation and research centre from which several undergraduates and postgraduates' researches were successfully conducted. Despite these scientific benefits, many conservation efforts mainly concentrate on larger government forest reserves and national parks, while ignoring the biodiversity of numerous privately owned small patches in cities (Braschler *et al.*, 2020).

Figure 1: Map of Dar es Salaam city showing location of the Urban Forest Remnant (Dar es Salaam Bioenvironmental Centre, (●) the study site).



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Data Collection Methods

For a standardized collection of the epigaeic invertebrates; pitfall traps, baited traps, and dry leaf litter sifting methods were used both in the dry and wet seasons.

Data collection was conducted for a total of eighteen days: nine (seven successive days for pitfall traps and baited traps, two subsequent days for dry leaf litter sifting which was conducted after every other day) in each of the dry season in November 2014 and wet season in May 2015. Dry leaf litter sifting trap was not used to evaluate data related to periods of the day since it was only collected in single period of the day (morning only) for minimizing the disturbance effects around the study site. The collected specimens were taken to the laboratory for sorting out and identification purposes.

Identification was conducted with the help of invertebrate experts in the Department Zoology and Wildlife Conservation at the University of Dar es Salaam and using various field guides and other identification books which include McGavin, 1992; McGavin, 1993; Picker *et al.*, 2004, Scholtz & Holm, 1996; and White, 1983.

Pitfall Traps

Pitfall trapping remain the most efficient, popular, and appropriate technique for sampling epigaeic invertebrates such as carabid & histerid beetles, surface foraging ants, millipedes, and earthworms (Shayya & Lackner, 2020; Cajaiba *et al.*, 2017; Cooling, 2012; Jones, 2010; Samways *et al.*, 2010; Thomson *et al*., 2004). The method can sample some species that may be missed by other methods (Nyundo & Yarro, 2007), and it is simple to use and less expensive (Niba & Yekwayo, 2016). Thus, pitfall traps technique was adopted to sample epigaeic invertebrates' fauna in this study despite its proneness to contention during data interpretation.

There were two transects, each was one hundred (100) meters long with 25 pitfall traps in a distance of five meters from one another. The pitfall traps were made up of plastic containers of one-liter volume with diameter of 8 cm at the base, 12 cm at the mouth and 14.8 cm in height.

The traps were placed flush with the ground surface and filled halfway with water mixed with a detergent soap. Trap contents were emptied in a nylon bag with 75% ethanol. Traps were checked and emptied three times a day (within one hour); early in the morning (from 9.00 am), during afternoon (from 2.00 pm), and in the evening (from 6.00 pm). The same pitfall traps setup was used in each of the dry and wet seasons.

Dry Leaf Litter Sifting Method

Dry leaf litter sifting method is one of best and successful methods used for collecting litter-dwelling species like the ground foraging invertebrates such as ants in many fields (Wiezik *et al*., 2015; Santos *et al.*, 2008; Jacobs *et al.*, 2011; Samways *et al.*, 2010) and several beetle species under family histeridae collected through sifting soil detritus (Shayya & Lackner, 2020). Hence, in the present study the dry leaf litter sifting method was used to collect epigaeic invertebrates for assessing their seasonal preferences.

Dry leaf litter and debris were collected in a 1 m x 1 m quadrat from which five quadrats were sampled per day. A total of twenty quadrats were sampled, ten quadrats in each of the dry and wet seasons. The quadrats were randomly located within the study sites and the distance between quadrats was not less than fifteen meters.

To minimize disturbance effects in the study site, the collection was only conducted in the morning hours from 9.00 am to 11.00 am. This made leaf litter method not to be used in analysing data related to periods of the day involved both mornings, afternoon, and evening. The collected litter and debris were poured into a piece of white cloth from which all specimens were retrieved separately by hand, forceps, and aspirator into a nylon bag (half

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filled with 75% ethanol) ready to be taken to the laboratory for identification.

Baited Traps

Sugar and honey were used as bait for collecting epigaeic invertebrates basing on their effectiveness in similar studies conducted by Crane and Baker (2011); Müller and Schlein (2011); and Yousefi *et al.* (2020). Bottles of 0.5 litre by volume with mouth diameter of 2.2 cm were used to put the baits (sugar and honey) and left open on the ground for attracted epigaeic invertebrates to enter. Brown sugar from Kilombero Sugar Company and Tan HONEY harvested from Tabora region in Tanzania were used as baits. Collection of the specimens was done three times a day (within one hour); early in the morning (from 9.00 am), during afternoon (from 2.00 pm) and in the evening (from 6.00 pm).

Sugar Baited Traps

Ten (10) mls of sugar solution made from 1 kg of sugar dissolved in three (3) litres of water were poured into a bottle of 0.5 litre by volume. Epigaeic invertebrates were attracted and entered into the bottles from which they were emptied into nylon bags containing 75% ethanol and taken to the laboratory for identification.

There were four transects (two in each of the dry and wet seasons), each transect was a hundred (100) meters long. A total of one hundred (100) baited bottle traps were used; fifty (50) in each of the two seasons. The distance between one trap and another was five (5) meters.

Honey Baited Traps

Ten (10) mls of honey was poured inside a bottle of 0.5 litre by volume. Epigaeic invertebrates were attracted into the bottle from which they were emptied in a nylon bag containing 75% ethanol, ready to be taken to the laboratory for identification.

There were four transects (two in each of the dry and wet seasons), each transect was a hundred (100) meters long. A total of one hundred (100) baited bottle traps were used; fifty (50) in each of the two seasons. The distance between one trap and another was five (5) meters.

Data Analysis

Mann-Whitney U-test (Zar, 2010) was used to compare the abundances of collected Epigaeic Invertebrates between dry and wet seasons while between periods of the day (morning, afternoon, and evening) the Kruskal-Wallis test (H) (Zar, 2010) was used.

Shannon Wiener diversity index (Zar, 2010) was used to compute species diversity of dry and wet seasons; a special (t) test (Zar, 2010) was also used to compare species diversity between the two seasons. The Paleontological Statistics software package (PAST) (Hammer *et al.*, 2001) was used to compute all of the compositional analyses.

RESULTS

Abundance of Epigaeic Invertebrates between Seasons

A total of 10,363 Epigaeic Invertebrates individuals were collected during the study, out of which 4,003 (38.6%) individuals were collected during the dry season and 6,360 (61.4%) individuals were collected during the wet season (*Table 1*, *Figure 2*).

Despite, higher abundance of Epigaeic Invertebrates during the wet season compared to the dry season, the difference was not statistically significant (*Figure 2*, Mann Whitney U = 219, $p = 0.071$, $n_1 = 25$, $n_2 = 25$).

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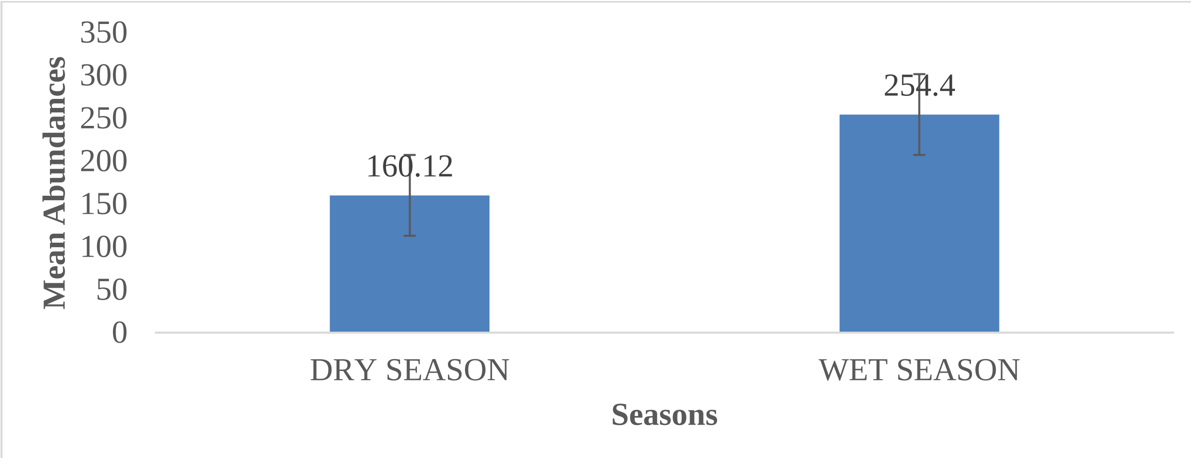
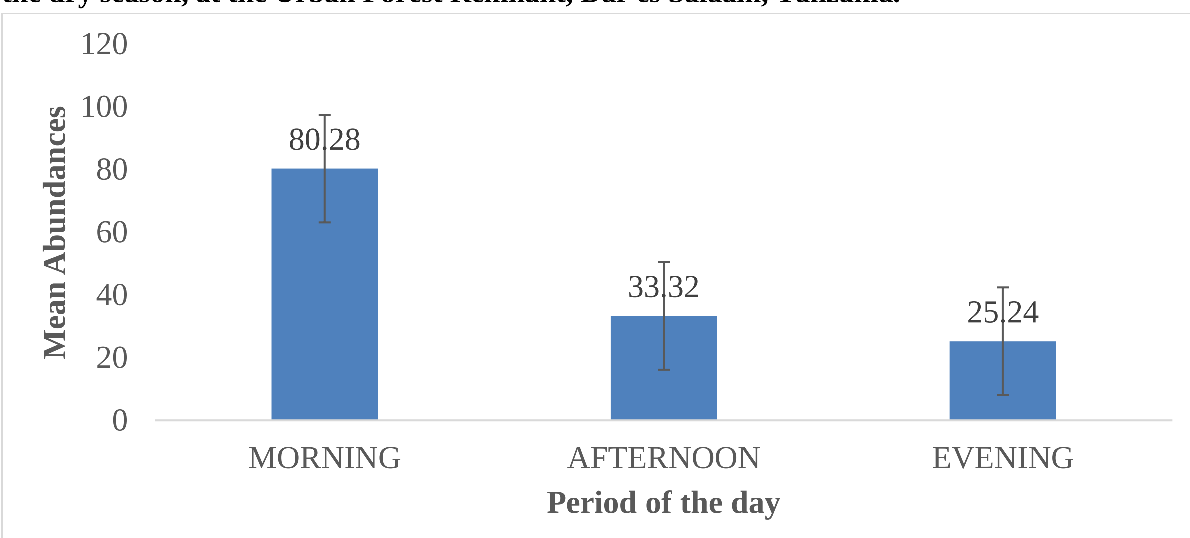
Figure 2: Mean abundances of Epigaeic Invertebrates during the dry and wet seasons, at the Urban Forest Remnant, Dar es Salaam, Tanzania



Abundance of Epigaeic Invertebrates between Periods of the Day

During the dry season, the abundances of Epigaeic Invertebrates individuals were significantly different between morning and afternoon hours (*Figure 3*; Mann Whitney U = 127, p = 0.0003, n_1 = 25, n_2 = 25) as well as morning and evening hours (Mann Whitney U = 112, p = 0.0001, n_1 = 25, n_2 = 25), the difference was not statistically significant between afternoon and evening hours (Mann Whitney U = 288, p = 0.64, n_1 = 25, n_2 = 25). The overall variations in abundance of Epigaeic Invertebrates individuals between morning, afternoon and evening were very significantly different (Kruskal-Wallis H =18.99, p < 0.0001).

Figure 3: Mean abundances of Epigaeic Invertebrates individuals between period of the day, during the dry season, at the Urban Forest Remnant, Dar es Salaam, Tanzania.



During the wet season, the abundances of Epigaeic Invertebrates individuals were not significantly different between morning and afternoon hours, as well as between afternoon and evening hours (*Figure 4*; Mann Whitney U = 219.5, p = 0.073, n_1 = 25, n_2 = 25 and Mann Whitney U = 248, p = 0.21, n_1 = 25, n_2 = 25 respectively). The abundances were significantly different between morning and

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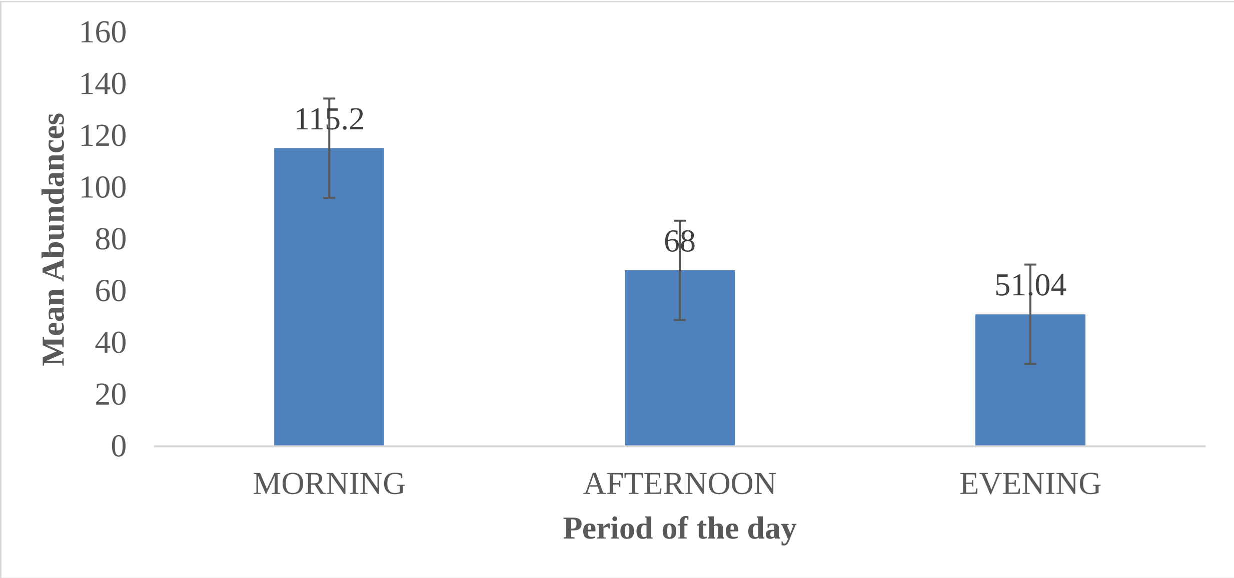
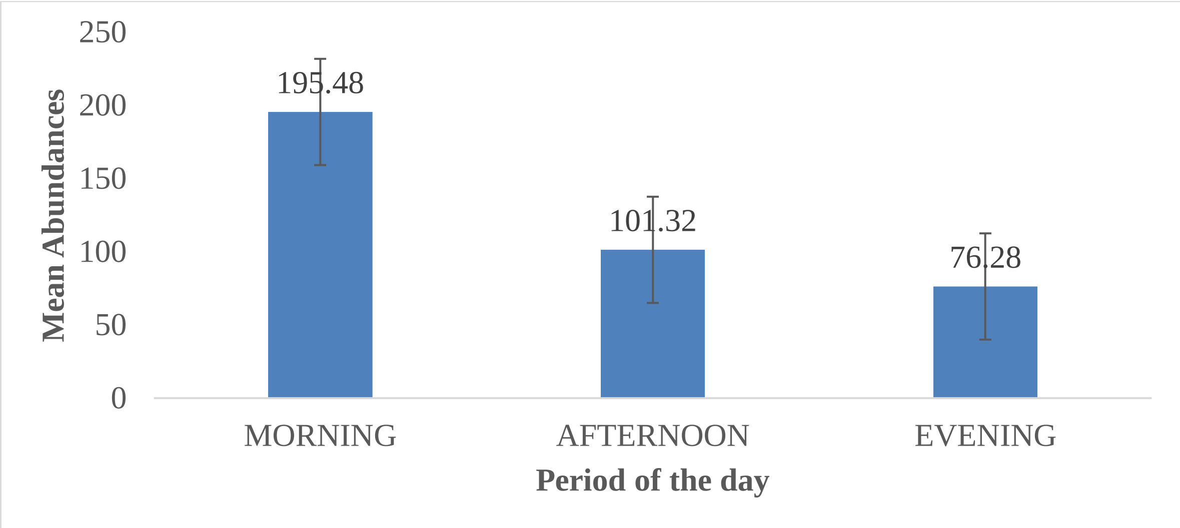
evening hours (Mann Whitney U = 161.5, p = 0.003, n_1 = 25, n_2 = 25). The overall variations in abundance of Epigaeic Invertebrates individuals between morning, afternoon, and evening periods were significantly different (Kruskal-Wallis H = 8.993, p = 0.011).

Figure 4: Mean abundances of Epigaeic Invertebrates individuals between period of the day, during the wet season at the Urban Forest Remnant, Dar es Salaam, Tanzania.



Overall, for both dry and wet seasons, the abundancies of Epigaeic Invertebrates individuals were significantly different between morning and afternoon hours as well as between morning and evening hours (Figure 5; Mann Whitney U= 189.9, p = 0.017, n_1 = 25, n_2 = 25 and Mann Whitney U= 116, p = 0.0001, n_1 = 25, n_2 = 25 respectively). They were not significantly different between afternoon and evening hours (Mann Whitney U= 247, p = 0.21, n_1 = 25, n_2 = 25). The overall variations in abundancies of Epigaeic Invertebrates individuals between morning, afternoon and evening hours were statistically significant (Kruskal-Wallis H = 14.66, p < 0.001).

Figure 5: Overall mean abundances of Epigaeic Invertebrates individuals between period of the day, during the dry and wet seasons, at the Urban Forest Remnant, Dar es Salaam, Tanzania.



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Species Diversity of Epigaeic Invertebrates

A total of 10,363 Epigaeic Invertebrates individuals were collected from which 133 morpho species, 87 families, and 18 orders were recorded (*Table 1*). Out of the 18 orders, Hymenoptera dominated by 71.4% of the individuals followed by Blattodea (7.4%), Araneae (5.4%), Orthoptera (4.1%), Coleoptera (3.3%), Diptera (3%), Hemiptera (1.9%), Julidae (1.2%), and the rest were less than 1%. At the family level Formicidae had 71.1% of the individuals followed by Blattidae (5.9%), Gryllidae (3.6%), Corinnidae (2.9%), Drosophillidae (2.4%), Agelenidae (1.3%), Julidae (1.2%) and the rest were less than 1%. At the morpho species level *Formicid sp.2* dominated by 54.2% of the individuals followed by *Formicid sp.1* (7.1%), *Messor capensis* (5.8%), *Corinnid sp.* (2.9%), *Periplaneta americana* (2.8%), *Cophogryllus sp.1* (2.4%), *Blatta sp.* (2.2%) and the rest had less than 2% of all the individuals collected.

Table 1: The Epigaeic Invertebrates caught during the dry and wet seasons, at the Urban Forest Remnant, Dar es Salaam, Tanzania.

Taxonomy			Data		
Order	**Family**	**Morpho Species**	**Dry Season**	**Wet Season**	**Total**
Araneae	Agelenidae	*Agelenopsis sp.*	49	87	136
	Lycosidae	*Lycosid sp.*	6	13	19
	Salticidae	*Salticid sp.*	24	41	65
	Thomicidae	*Thomicid sp.*	4	23	27
	Sparassidae	*Sparassid sp.*	1	4	5
	Corinnidae	*Corinnid sp.*	123	176	299
	Mimetidae	*Mimetid sp.*	1	4	5
	Pholcidae	*Pholcus sp.*	5	2	7
Blattodea	Blattidae	*Periplaneta americana*	151	139	290
		Periplaneta sp.	43	15	58
		Blattid sp.	23	6	29
		Blatta sp.	76	155	231
	Blaberidae	*Blaberid sp.1*	20	10	30
		Blaberid sp.2	31	2	33
		Blaberus sp.	22	2	24
	Blattellidae	*Blattellid sp.*	20	14	34
		Blattella sp.	19	22	41
Coleoptera	Trogidae	*Omorgus sp.*	2	0	2
	Passalidae	*Passalid sp.*	1	5	6
	Tenebrionidae	*Tenebrionid sp.1*	3	13	16
		Tenebrionid sp.2	3	7	10
		Tenebrio molitor	1	3	4
		Cossyphus sp.	1	2	3
	Coccinellidae	*Coccinellid sp.*	2	29	31
	Carabidae	*Carabid sp.1*	11	21	32
		Carabid sp.2	3	7	10
		Carabid sp.3	1	4	5
		Carabid sp.4	1	2	3
		Crepidogaster sp.	22	28	50
	Histeridae	*Histerid sp.*	1	0	1
	Chrysomelidae	*Chrysomelid sp.1*	1	22	23

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Taxonomy			Data		
Order	**Family**	**Morpho Species**	**Dry Season**	**Wet Season**	**Total**
		Chrysomelid sp.2	0	14	14
		Dicladispa sp.	1	3	4
	Scarabaeidae	*Scarabaeid sp.1*	8	2	10
		Scarabaeid sp.2	5	0	5
		Garreta azureus	0	6	6
		Garreta sp.	0	5	5
		Hypopholis sommeri.	0	3	3
		Serica brunnea	0	1	1
	Phalacridae	*Phalacrid sp.*	1	0	1
	Elateridae	*Elaterid sp.*	1	0	1
	Nitidulidae	*Nitidulid sp.*	0	72	72
	Curculionidae	*Curculionid sp.*	0	15	15
	Drilidae	*Drilid sp.*	0	1	1
	Staphylinidae	*Staphylinid sp.*	0	3	3
	Cerambycidae	*Cerambycid sp.*	0	1	1
Dermaptera	Forficulidae	*Forficulid sp.*	6	1	7
	Labiduridae	*Labidurid sp.*	0	8	8
Diptera	Muscidae	*Muscid sp.1*	6	5	11
		Muscid sp.2	0	11	11
	Calliphoridae	*Lucilia sericata*	1	6	7
	Phoridae	*Phorid sp.*	2	5	7
	Sciaridae	*Sciarid sp.*	2	1	3
	Drosophillidae	*Drosophila sp.*	20	229	249
	Platystomatidae	*Amphicnephes sp.*	0	13	13
	Pyrgotidae	*Pyrgotid sp.*	0	1	1
	Stratiomyiidae	*Stratiomyiid sp.*	0	1	1
	Sarcophagidae	*Sarcophagid sp.*	0	2	2
	Culicidae	*Aedes sp.*	0	1	1
Embiidina	Oligotomidae	*Oligotomid sp.*	7	1	8
Geophilomorpha	Geophildae	*Geophilus sp.*	11	12	23
Haplotaxida	Lumbricidae	*Lumbricid sp.*	0	13	13
Hemiptera	Reduviidae	*Reduviid sp.1*	3	7	10
		Reduviid sp.2	1	7	8
		Reduviid sp.3	1	1	2
		Reduviid sp.4	0	3	3
	Pseudococcidae	*Pseudococcid sp.*	41	61	102
	Coreidae	*Coreid sp.*	1	11	12
	Fulgoridae	*Fulgorid sp.*	3	0	3
	Lygaeidae	*Lygaeid sp.1*	4	8	12
		Lygaeid sp.2	1	4	5
	Pyrrhocoridae	*Dysdercus sp.1*	1	17	18
		Dysdercus sp.2	0	4	4
	Miridae	*Mirid sp.*	2	0	2
	Tingidae	*Tingid sp.*	0	1	1
	Cixiidae	*Cixiid sp.*	0	1	1
	Scutelleridae	*Scutellerid sp.*	0	2	2
	Pentatomidae	*Pentatomid sp.*	0	1	1

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Taxonomy			Data		
Order	**Family**	**Morpho Species**	**Dry Season**	**Wet Season**	**Total**
	Alydidae	*Alydid sp.*	0	1	1
	Cydnidae	*Pangaeus sp.*	0	7	7
	Aradidae	*Aradid sp.*	0	1	1
Hymenoptera	Formicidae	*Polyrhachis gagates*	85	7	92
		Pachycondyla sp.	41	17	58
		Messor capensis	503	102	605
		Lepisiota sp.1	7	48	55
		Tetraponera sp.	132	33	165
		Lepisiota sp.2	10	33	43
		Formicid sp.1	723	8	731
		Formicid sp.2	1341	4272	5613
		Formicid sp.3	1	1	2
	Eumenidae	*Eumenid sp.*	2	4	6
	Mutillidae	*Ronisia sp.*	2	0	2
		Mutillid sp.	2	1	3
	Sphecidae	*Chlorion maxillosum*	2	0	2
		Sphecid sp.	0	1	1
	Pompilidae	*Pompilid sp.*	1	4	5
	Masaridae	*Masarid sp.*	1	1	2
	Ichneumonidae	*Ichneumon sp.*	0	1	1
	Halictidae	*Halictid sp.*	0	1	1
	Pteromalidae	*Pteromalid sp.*	0	1	1
	Evaniidae	*Evaniid sp.*	0	2	2
	Braconidae	*Braconid sp.*	0	2	2
	Tiphiidae	*Tiphiid sp.*	0	2	2
Isoptera	Termitidae	*Macrotermes sp.*	58	10	68
Julida	Julidae	*Cylindroiulus sp.*	54	21	75
		Julid sp.	34	19	53
Lepidoptera	Psychidae	*Psychid sp.1*	4	10	14
		Psychid sp.2	0	5	5
	Hepialidae	*Hepialid sp.*	2	2	4
	Nymphalidae	*Nymphalid sp.1*	1	1	2
		Nymphalid sp.2	2	13	15
	Tineidae	*Tineid sp.*	0	2	2
	Noctuidae	*Noctuid sp.1*	0	3	3
		Noctuid sp.2	0	1	1
	Sphingidae	*Sphingid sp.*	0	1	1
	Tortricidae	*Tortricid sp.*	0	2	2
	Satyridae	*Satyrid sp.*	0	1	1
Mantodea	Thespidae	*Thespid sp.*	2	0	2
Mesogastropoda	Pomatiasidae	*Tropidophora sp.*	1	3	4
Orthoptera	Acrididae	*Acridid sp.*	13	20	33
		Acrotylus sp.	5	7	12
		Cannula grasilis	1	4	5
	Gryllidae	*Cophogryllus sp.1*	111	138	249
		Cophogryllus sp.2	54	68	122
		Brachytrupes sp.	1	0	1

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Taxonomy			Data		
Order	Family	Morpho Species	Dry Season	Wet Season	Total
		Gryllidae sp.	2	0	2
	Anostostomatidae	*Anostostomatid sp.*	3	1	4
	Tettigoniidae	*Tettigoniid sp.*	0	1	1
Solifugae	Solpugidae	*Solpugid sp.*	0	3	3
Stylommatophora	Subulinidae	*Pseudoglessula sp.*	0	10	10
	Streptaxidae	*Gullella sp.*	1	4	5
		Gonaxis sp.	0	3	3
	Urocyclidae	*Urocyclid sp.*	1	35	36
Number of Individuals (N)			4003	6360	10363
Number of Species (S)			88	121	133
Shannon Wiener Diversity Index (H’)			2.523	1.845	2.274

Species Diversity of Epigaeic Invertebrates Between Seasons

Epigaeic invertebrates during the wet season had an abundance of 6,360 and morpho species of 121; these were higher than those of the dry season (4,003 and 88 respectively), out of which 45 species were collected during the wet season only; 12 species were collected during dry season only and 76 species were collected in both seasons. However, the Shannon Wiener Index (H’) of the diversity of epigaeic invertebrates was higher during the dry season (H’ = 2.523) than during wet season (H’ = 1.845). A t-test on the Shannon Wiener Index values revealed the differences of species diversities between the two seasons to be statistically significant ($t = 17.995$, $df = 10127$, $p < 0.0001$).

Species Diversity of Epigaeic Invertebrates Between Period of a Day

Overall, for both dry and wet seasons and in both periods of the day (morning, afternoon, and evening), a total of 122 morpho species were collected out of which 99 were collected during morning, 76 during afternoon and 69 during evening. Shannon Wiener Index (H’) depicted morning hours to have higher diversity (H’ = 1.991) followed by evening hours (H’ = 1.816) and lastly afternoon hours (H’ = 1.771) (*Table 2*).

Table 2: The Epigaeic Invertebrates caught in different periods of a day, at the Urban Forest Remnant, Dar es Salaam, Tanzania. MOR = Morning, AFT = Afternoon, EVE = Evening.

Taxonomy			Data			
			Periods of the Day			Total
Order	Family	Morpho Species	MOR	AFT	EVE	
Araneae	Agelenidae	*Agelenopsis sp.*	46	41	15	102
	Lycosidae	*Lycosid sp.*	9	2	2	13
	Salticidae	*Salticid sp.*	21	23	4	48
	Thomicidae	*Thomicid sp.*	11	5	8	24
	Sparassidae	*Sparassid sp.*	2	0	2	4
	Corinnidae	*Corinnid sp.*	111	74	42	227
	Mimetidae	*Mimetid sp.*	3	0	1	4
	Pholcidae	*Pholcus sp.*	0	1	5	6
Blattodea	Blattidae	*Periplaneta americana*	142	44	43	229
		Periplaneta sp.	15	13	3	31
		Blattid sp.	10	7	6	23
		Blatta sp.	99	4	22	125

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Taxonomy			**Data**			
			Periods of the Day			**Total**
Order	**Family**	**Morpho Species**	**MOR**	**AFT**	**EVE**	
	Blaberidae	*Blaberid sp.1*	12	3	2	17
		Blaberid sp.2	14	4	0	18
		Blaberus sp.	0	0	2	2
	Blatellidae	*Blattellid sp.*	9	3	5	17
		Blattella sp.	7	4	2	13
Coleoptera	Passalidae	*Passalid sp.*	5	0	0	5
	Tenebrionidae	*Tenebrionid sp.1*	11	1	0	12
		Tenebrionid sp.2	2	0	3	5
		Tenebrio molitor	3	0	1	4
	Coccinellidae	*Coccinellid sp.*	1	3	0	4
	Carabidae	*Carabid sp.1*	20	0	2	22
		Carabid sp.2	5	0	1	6
		Carabid sp.3	2	2	0	4
		Carabid sp.4	2	0	0	2
		Crepidogaster sp.	42	6	2	50
	Histeridae	*Histerid sp.*	0	0	1	1
	Chrysomelidae	*Chrysomelid sp.1*	0	1	0	1
		Dicladispa sp.	0	3	1	4
	Scarabaeidae	*Scarabaeid sp.1*	1	0	4	5
		Scarabaeid sp.2	3	0	0	3
		Garreta azureus	5	0	0	5
		Garreta sp.	3	2	0	5
		Hypopholis sommeri.	2	0	0	2
	Phalacridae	*Phalacrid sp.*	1	0	0	1
	Elateridae	*Elaterid sp.*	1	0	0	1
	Nitidulidae	*Nitidulid sp.*	16	34	21	71
	Curculionidae	*Curculionid sp.*	5	6	2	13
	Drilidae	*Drilid sp.*	1	0	0	1
	Staphylinidae	*Staphylinid sp.*	0	2	1	3
	Cerambycidae	*Cerambycid sp.*	1	0	0	1
Dermaptera	Forficulidae	*Forficulid sp.*	1	2	4	7
	Labiduridae	*Labidurid sp.*	0	2	0	2
Diptera	Muscidae	*Muscid sp.1*	4	4	3	11
		Muscid sp.2	3	3	5	11
	Calliphoridae	*Lucilia sericata*	2	5	0	7
	Phoridae	*Phorid sp.*	3	1	3	7
	Sciaridae	*Sciarid sp.*	0	3	0	3
	Drosophillidae	*Drosophila sp.*	100	58	91	249
	Platystomatidae	*Amphicnephes sp.*	9	1	3	13
	Pyrgotidae	*Pyrgotid sp.*	1	0	0	1
	Stratiomyiidae	*Stratiomyiid sp.*	0	1	0	1
	Sarcophagidae	*Sarcophagid sp.*	1	1	0	2
	Culicidae	*Aedes sp.*	0	0	1	1
Embiidina	Oligotomidae	*Oligotomid sp.*	2	5	1	8
Geophilomorpha	Geophildae	*Geophilus sp.*	4	1	2	7
Haplotaxida	Lumbricidae	*Lumbricid sp.*	6	1	0	7

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Taxonomy			Data			
			Periods of the Day			Total
Order	**Family**	**Morpho Species**	**MOR**	**AFT**	**EVE**	
Hemiptera	Reduviidae	*Reduviid sp.1*	3	1	2	6
		Reduviid sp.2	4	0	1	5
		Reduviid sp.3	0	0	1	1
		Reduviid sp.4	0	3	0	3
	Pseudococcidae	*Pseudococcid sp.*	5	2	0	7
	Lygaeidae	*Lygaeid sp.1*	4	1	0	5
		Lygaeid sp.2	0	1	0	1
	Pyrrhocoridae	*Dysdercus sp.1*	5	3	5	13
		Dysdercus sp.2	0	1	0	1
	Miridae	*Mirid sp.*	0	1	0	1
	Tingidae	*Tingid sp.*	1	0	0	1
	Cixiidae	*Cixiid sp.*	1	0	0	1
	Scutelleridae	*Scutellerid sp.*	0	0	2	2
	Pentatomidae	*Pentatomid sp.*	1	0	0	1
	Alydidae	*Alydid sp.*	0	0	1	1
	Cydnidae	*Pangaeus sp.*	2	2	1	5
Hymenoptera	Formicidae	*Polyrhachis gagates*	42	15	24	81
		Pachycondyla sp.	17	14	15	46
		Messor capensis	243	207	116	566
		Lepisiota sp.1	15	20	11	46
		Tetraponera sp.	101	51	10	162
		Lepisiota sp.2	36	6	1	43
		Formicid sp.1	539	97	95	731
		Formicid sp.2	2804	1615	1191	5610
		Formicid sp.3	1	0	1	2
	Eumenidae	*Eumenid sp.*	3	2	1	6
	Mutillidae	*Ronisia sp.*	0	2	0	2
		Mutillid sp.	1	1	1	3
	Sphecidae	*Chlorion maxillosum*	1	0	1	2
		Sphecid sp.	1	0	0	1
	Pompilidae	*Pompilid sp.*	3	1	0	4
	Masaridae	*Masarid sp.*	2	0	0	2
	Ichneumonidae	*Ichneumon sp.*	1	0	0	1
	Halictidae	*Halictid sp.*	0	1	0	1
	Pteromalidae	*Pteromalid sp.*	0	0	1	1
	Evaniidae	*Evaniid sp.*	0	1	1	2
	Braconidae	*Braconid sp.*	1	1	0	2
	Tiphiidae	*Tiphiid sp.*	1	0	1	2
Isoptera	Termitidae	*Macrotermes sp.*	3	2	0	5
Julida	Julidae	*Cylindroiulus sp.*	16	0	3	19
		Julid sp.	11	0	0	11
Lepidoptera	Psychidae	*Psychid sp.1*	6	2	4	12
		Psychid sp.2	2	2	0	4
	Hepialidae	*Hepialid sp.*	3	1	0	4
	Nymphalidae	*Nymphalid sp.1*	0	1	1	2
		Nymphalid sp.2	8	1	1	10

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Taxonomy			Data			
			Periods of the Day			Total
Order	Family	Morpho Species	MOR	AFT	EVE	
	Tineidae	*Tineid sp.*	2	0	0	2
	Noctuidae	*Noctuid sp.1*	2	1	0	3
		Noctuid sp.2	1	0	0	1
	Sphingidae	*Sphingid sp.*	1	0	0	1
Mantodea	Thespidae	*Thespid sp.*	0	0	2	2
Mesogastropoda	Pomatiasidae	*Tropidophora sp.*	1	0	1	2
Orthoptera	Acrididae	*Acridid sp.*	16	9	6	31
		Acrotylus sp.	5	0	3	8
		Cannula grasilis	1	4	0	5
	Gryllidae	*Cophogryllus sp.1*	107	48	54	209
		Cophogryllus sp.2	46	27	30	103
		Gryllidae sp.	1	0	0	1
	Anostostomatidae	*Anostostomatid sp.*	3	1	0	4
	Tettigoniidae	*Tettigoniid sp.*	1	0	0	1
Solifugae	Solpugidae	*Solpugid sp.*	1	2	0	3
Stylommatophora	Subulinidae	*Pseudoglessula sp.*	4	0	0	4
	Streptaxidae	*Gullella sp.*	4	0	0	4
	Urocyclidae	*Urocyclid sp.*	25	7	3	35
Number of Individuals (N)			4887	2533	1907	9327
Number of Species (S)			99	76	69	122
Shannon Wiener Diversity Index (H')			1.991	1.771	1.816	1.939

Epigaeic Invertebrates individuals were statistically significantly different between morning and afternoon hours (p = 0.0007), as well as between morning and evening hours (p = 0.00002); they were not significantly different between afternoon and evening hours (p = 0.3607). The overall variations of Epigaeic Invertebrates individuals between morning, afternoon and evening hours were statistically significant (Kruskal-Wallis H = 19.49, p = 0.000036).

DISCUSSION

Abundance of Epigaeic Invertebrates

The higher abundance of epigaeic invertebrates during the wet season in comparison to the dry season agrees with the findings of many other studies around the world. In the East Usambara Mountains, Tanzania, Ndunguru (2006) reported higher abundance of dung beetles during the wet seasons; in the Brazilian forests Montine *et al.* (2014) obtained higher abundance of epigaeic ants during the wet season than in the dry season, while Cajaiba *et al.* (2017) got significantly higher differences in abundance of *Histerid* beetles between the averages of the rainy and dry seasons, and Thompson & Thompson (2007) obtained higher dry biomass of ground-dwelling invertebrates during the summer than in the winter season.

The higher abundance of other epigaeic invertebrates during the wet season could have resulted from increased food resources such as fruits, extra floral nectar, and honeydew that are more available in rainy times with better temperature and humidity conditions. In temperate regions, winter periods are often a major inhibitor of invertebrate activities owing the low temperatures that occur in the winters.

It was also shown, in the present study, that there was a low abundance of epigaeic invertebrates in the evenings compared to morning and afternoon hours. This deviation could not be readily explained as otherwise it would be expected that there is higher

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abundance of epigaeic invertebrates in the evening because of presumably favourable temperatures and humidity usually occurring in the evenings. Perhaps this could be attributed to the lack of termites, earthworms, and few ant individuals of which are all known as the three major ecosystems engineers (Cerdá & Dejean, 2011) with the major role of ensuring other ground dwelling invertebrates utilize a variety of ecological resources and hence the low abundances of the epigaeic invertebrates.

Overall, the abundance of epigaeic invertebrates was significantly higher during morning compared to the afternoon and evening hours. This suggests that epigaeic invertebrates were active at different times of the day but being more attracted to the warm temperatures after the land had been heated by the morning sunshine and only decreased as the land became hotter.

Species Diversity of Epigaeic Invertebrates

Species diversity of epigaeic invertebrates was found to be higher during the dry season than in the wet season despite their lower abundance then. This is different from what was expected due to the higher dominance of the abundance of very aggressive ants (Formicidae) species, *Formicid. sp.2* (little ant) by more than 67% of total collected individuals in the wet season. These ant species are known for being ground or litter dwelling predators for a variety of invertebrates such as earthworms, acarids, isopods, chilopods, collembolans, termites, beetles, bark lice, and lepidopterans (Cerdá & Dejean, 2011) and hence could have contributed to the lower diversity of epigaeic invertebrates in wet season instead of dry season as stated by Mora-Rubio & Parejo-Pulido (2021) that predators have effects on the diversity and abundance of preyed communities and ecosystem functions at large.

But also, in exclusion of *Formicid sp2.* the total number of ants (Formicidae) species and their diversity were significantly higher in dry season and since they are well known as among the three main soil ecosystem engineers, have made resources available for many other organisms (Cerdá & Dejean, 2011) and hence the higher diversity of the overall epigaeic invertebrates in dry seasons instead of wet season.

For both dry and wet seasons, species diversity of the epigaeic invertebrates was significantly higher during morning hours than afternoon and evening hours. This could have been contributed by the collection efforts from which morning hours collected both nocturnal ground dwelling invertebrates and the early morning active invertebrates, while the afternoon and evening hours had five hours each. Evening hours had insignificantly higher diversity of epigaeic invertebrates in comparison to afternoon hours and this could be due to the cooled and heated soil at the evening and afternoon hours respectively as stated by Mohamed (2016) that litter dwelling ants are negatively affected by high temperatures and positively to warm temperature of the morning and evening hours (Davis & Gorsuch, 2011). The overall variations of epigaeic invertebrate individuals between morning, afternoon and evening hours were statistically significant. This implies that, epigaeic invertebrates were very active during both mornings, afternoon, and evening hours of the day. At the same time morning hours depicted presence of many ground dwelling invertebrates active both at night and early warm hours.

CONCLUSION AND RECOMMENDATIONS

The present study is the first of its kind as far as urban forests litter dwelling invertebrates are concerned. The results depict urban forests being home for varieties of epigaeic invertebrates, a group of ground foraging fauna with many ecological roles from herbivory, predations, detritivores, and pollinators. Urban forests endure to have higher abundance and diversity of the epigaeic invertebrates despite their high anthropogenic disturbances and human encroachments which yet gives possibility for some native species to have been displaced.

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If further non-environmentally friendly human activities are entertained around many cities, the existing urban forests will highly be deteriorated, suggesting that with time there is a possibility that more native species will be evacuated. Thus, preserving the native habitat types, in urban forests would be highly needed in order to sustain the rich invertebrate diversity there.

This studied urban forest is extremely important to biodiversity conservation globally, regionally, nationally, and at the local level, mainly because it is located within a highly populated urban matrix with heavy industries such as the Wazo Hill Cement Factory found only a few kilometres from it. UF may help in balancing carbon dioxide and other toxic gases even if in a relatively small way.

In short, the present study contributes to knowledge about the abundance and diversity of epigaeic invertebrates in urban forest with their respective seasonal and periodic times of preferences.

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