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Tanko D
Department of Biological Sciences, Federal University Lokoja, Kogi State Nigeria

Shitta KB
Department of Biological Sciences, Federal University Lokoja, Kogi State, Nigeria

Correspondence
Tanko D
Department of Biological Sciences, Federal University Lokoja, Kogi State Nigeria

Community structure and composition of terrestrial macro-invertebrates in relation to bird and flora abundance at inselberg's ecosystem in Zaria, Nigeria

Tanko D and Shitta KB

Abstract
Species composition and abundance of terrestrial macro-invertebrates associated with Dumbi inselberg and its surrounding woodland was studied for 24 months. Inselbergs's ecosystems if not tampered with, could play important role in biodiversity preservation. The value of diversity of an ecosystem is viewed in terms of numbers of species interacting among themselves and the abiotic environment. Primary and secondary instruments were used for data collection. Primary data was done through field visits using pitfall traps, sweep net and direct search techniques for collection of the invertebrates. The secondary instrument was data adapted from existing data on vegetation and avifauna of the site. A total of 78 species of invertebrates belonging 43 families were collected. The woodland surrounding the inselberg had more species diversity (75) compared to the inselberg. Families Formicidae, Pieridae, gryllidae and pentatonidae had the highest number of species of 5 each. *Zonocerus variegatu*s with 204 individuals had the highest population. Shannon-Wiener diversity and equitability indices of woodland macro-invertebrates were higher than those of the inselberg. Highly significant negative correlation was observed between the macro-invertebrates abundance and the bird's abundance on the woodland. However, this relationship was not significant in the inselberg's plot. The tree density of the woodland correlated positively with the invertebrates. Similarity index (60%) showed the woodland and the inselberg's invertebrates to be similar. The higher density and diversity of invertebrates at the woodland may be due to high density of vegetation in the woodland than the inselberg. Significant negative correlation between birds and invertebrates is expected because a greater number of bird species encountered at the site were insectivorous. It is recommended that a complete inselberg ecosystem should be set aside for in-situ conservation of their biodiversity.

Keywords: Inselberg, Macro-invertebrates, abundance, woodland, avifauna

Introduction
Inselbergs in an arid environment if not tampered with, could play an important role in preserving biodiversity and forming refuges for species no longer able to grow in the surrounding plains [1, 2] where some species have become extirpated. The loss of species from the plains could either be due to human impacts such as overgrazing and subsequent degradation, or changes in key environmental factors such as climate. Inselbergs could therefore serve as species pools which, under favourable conditions, allow species to re-colonise the surrounding plains and thus contribute to the restoration of degraded lands.
The value of diversity of an ecosystem is viewed in terms of numbers of species interacting among themselves and with the physical environment. Tropical ecosystems are under much pressure globally. Such pressure on the forest and the woodland is likely to escalate to the inselbergs which in recent times are considered "forgotten granites habitat". Terrestrial macro-invertebrates serves as good ecological indicators [3]. The class insecta (the most predominant invertebrates) are usually considered as the most surrogate representatives of environmental quality changes, especially Lepidoptera [4]. They perform essential ecosystem services in the pollination of plants [5], recycling of soil nutrients and degradation of organic matter. Macro-invertebrates also serve as food to birds and other predators such as reptiles and some mammals (e.g. foxes). Higher density of birds was observed by Tanko *et al.* [2] at locations with thickets and dense vegetation than areas with sparse vegetation at the study site. They attributed this to high leaf litter from the vegetation which harbours invertebrates that are food to the birds.

Birds are sensitive to disturbances hence the reason why habitat fragmentation, degradation and destruction of natural landscape have been listed as the major factors responsible for decline in birds assemblages. Their sensitivity to environmental changes, responsiveness to bio-diversity patterns of other taxa and the fact that they are relatively easy to observe make the taxon convenient for use in the monitoring of forest disturbance. Birds and macro-invertebrates abundance are known to depend on vegetation structure and composition [2] which make the three suitable indicators taxon for ecological studies.

It is a well-known fact that there is a symbiotic association between invertebrates and birds and invertebrates and flora of an area. The extent to which the presence of one influences the composition and distribution of the other in the inselberg ecosystem has not been investigated. Suggestions were made by Holling *et al.* [6] on how removal of certain species could have minimal effect on the ecosystem functioning while the removal of others induces a serious transformation from one ecosystem type to another. It was Tanko *et al.* [7] who observed a shift in the phytogeography of the site from forest outlier to woodland, which in turn affected the bird species distribution and abundance. Studies conducted by Tanko *et al.* [2] on the avifauna and other vertebrate of the site recommended the protection of the site for in-situ conservation of their biodiversity using native flora. This they claimed, will provide leaf litter that will attract invertebrates, birds and other wildlife species. It is therefore, pertinent to investigate the correlation between the avifauna and the invertebrates and between the flora and the invertebrates of the site. This will further support their recommendations.

The estimation of biodiversity within a given habitat or community is necessary as this gives a baseline data that forms the basis for any conservation actions. The only information on the invertebrates associated with the inselberg is the works of Adebote *et al.* [8] on mosquitos breeding on the rock pools. The invertebrate's fauna of the Dumbi inselberg with its peak of over 756.82 m above sea level[9] has not been well studied. However, such information are very important for the inselberg ecosystem services and conservation. The inselberg is constantly exposed to human disturbance. Therefore, in the near future the habitat may not be able to support the diversity of birds and other vertebrates reported at the site [2]. The inselberg was chosen because of its altitude, situated within the northern guinea Savanna, it assumed infrequent nature or exclusion of fire and herbivory by domestic livestock. It is also regarded as an 'island' which could serve as a refugium for high altitude endemic species. Invertebrate diversity has been reported to be lower in grassland under communal grazing in comparison to grassland under nature conservation [10]. This study therefore aimed at documenting the terrestrial macro-invertebrates of the Dumbi inselberg and its surrounding woodland and to determine the influence of the invertebrates on the avifaunal abundance and distribution of the site and also determine if flora diversity and abundance influences the invertebrate's abundance.

Materials and Methods

Study Site

This study was conducted at Dumbi inselberg located near Dumbi village (Longitude 07º39.21′ E - 07º 39.23′ E and Latitude 10º 32 ′54′N - 10º56.98′N) about 19 kilometres away from Zaria along the Zaria-Kaduna highway. The weather and climatic conditions of Dumbi have been reported to be similar to that of Zaria [9]. The area has two major seasons, the dry season which usually starts in October and lasts till early April and the rainy season which commences from late April and ends in October.

For the purpose of comparison, the site was classified into two habitat types; the inselberg and its surrounding woodland. Figure 1 is the map of Kaduna state showing the study site, while Plate 1 is the Dumi inselberg and its surrounding woodland.

Data Collection

Data collection was by primary source as well as secondary source. The primary source were data collected through field visits for 24 months while the secondary source was data adapted from other researchers on other variables to test for possible relationships.

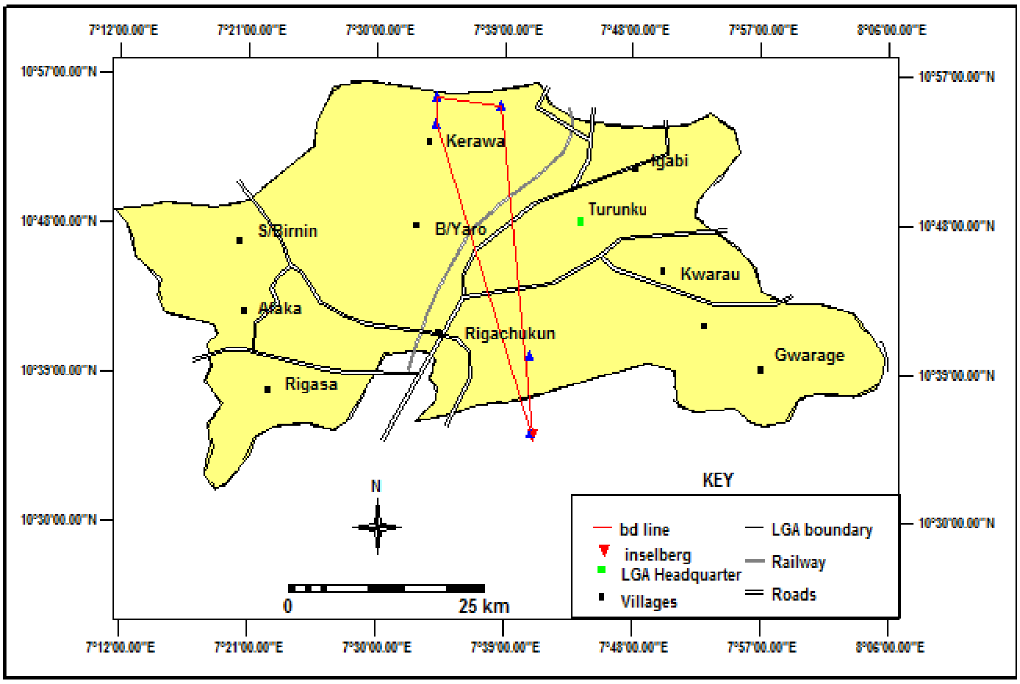

Fig 1: Map of Igabi Local Government with the Dumbi inselberg, the study site

Plate 1: Dumbi Inselberg and its surrounding woodland

Determination of Abundance and Diversity of Terrestrial Macro-Invertebrates

i. ***Setting of the Traps:*** A total of fifty plastic containers of equal diameter (9 cm) and depth (19 cm) were used as the traps. Twenty five were set at predetermined points on the inselbergs while the other twenty-five were set at the plain woodland. The plastic traps were buried in the soil so that the top was flush with the ground level. Five (5) mililitres of 5% formalin was poured into each of these buried containers and covered with cotton wool and filter paper of equal size with the diameter of the container. The set-ups were covered with polytelene, to exclude water during the rains and to short out light/heat penetration. The cover also kept trapped invertebrates out of the view of predators such as lizards.

ii. ***Observation of the Traps:*** The traps were visited once weekly for 24 months and trapped invertebrates were collected and separated into two categories; the smaller and larger invertebrates. This is to prevent damage of smaller specimens by the larger. The specimens were placed in specimen bottles or Killer jars and labelled

iii. ***Direct Searching and the sweep net methods:*** Invertebrates were also sampled by direct searching of suspected areas of invertebrate haunts such as, sheltered moist microhabitats, under stones, logs and barks, in crevices of rocks, under leaf litter, dungs and carrions[11]. Sighted or exposed invertebrates were picked with the aid of a forceps, and stored in sampling containers. Moths and butterflies on flight were intercepted and trapped with a sweep net. Moths and butterflies trapped were preserved in separate specimens bottles. This was to prevent contamination of other specimens by powdery bodies of the moths and butterflies.

iv. Identification and preservation. Identification of macro-invertebrates was done with the aid of identification guides by Youndeowei [12], Boorman [13] and Lawsen [14].

v. ***Preservation of the Collected Specimens:*** Representatives specimens of each group of invertebrates collected were preserved for reference purpose. Two methods of preservation were employed. These were:

a. ***Pinning Preservation Method:*** This method was used for the preservation of insect specimens. Insect specimens were mounted on entomological stainless pin of continental size. Pins were passed through the hard part (thorax) of the body of most of the insect taxa as described by Smithers [15]. After pinning the specimens were arranged according to their taxonomic groups in a specimen box.

b. Liquid Preservation*:* The soft bodied invertebrates were preserved in specimen bottles containing 5% alcohol.

vi. Secondary data: Data on the density of avifauna and woody vegetation of the site were adapted from the works of Tanko [2] and Tanko [16] respectively. This was to determine if the avifauna and the vegetation density influences the abundance and distribution of the macro-invertebrates. These aspects were conducted simultaneously with this study at the site

Data Analysis

Data collected were analysed using Paleontological Statistics Version 1.81 software to determined Shannon-wiener diversity indices, species richness, equitability and similarity index which is a measure of similarity in community composition of invertebrates between the inselberg and woodland.

Correlation coefficient was used to test relationship between the plant density and invertebrate abundance and between the invertebrates' abundance and the avifaunal abundance.

T-test was also used to ascertain if there are significant differences in the macro-invertebrate densities between the inselberg and the plain woodland, the wet and the dry seasons and the first and the second year.

Results

Abundance and Diversity of the Macro-invertebrates of the Inselberg and the Woodland Surrounding the Inselberg

A total of 78 species of macro-invertebrates were collected from both the inselbergs and the surrounding woodland. Out of this number, 75 species were from the woodland while the inselberg had 51 species. The woodland had a total number of 2,092 individuals as opposed to the inselberg that had only 468 individuals. Table 1 is a checklist of the macro-invertebrates recorded during this study. There were 43 families out of which, the families Formicidae, Pieridae**,** Gryllidae and Pentatonidae had the highest number of species of five each at the surrounding woodland while Formicidae was the only family with five species at the inselberg.

Considering the species encountered, *Zonocerus variegatus* (204) and *Pheidole liengme* (58) had the highest density from the woodland and the inselberg respectively. *Pheidole liengme* had the second highest in abundance of 109 in the woodland, while *Messor* sp (45) was second highest in terms of abundance from the inselberg. Shannon-Wiener index (H) and equitability values for the woodland were higher than those of the inselberg (Table 2). Shannon-Wiener diversity indices for the woodland and theinselberg were 3.90 and 3.41 respectively, while equitablity was higher in the woodland (0.9034) compared to the inselberg with 0.8674.

Table 1: Species Composition and Abundance of Macro-Invertebrate Fauna of Dumbi Inselbergs and the Surrounding Woodland

Family	Species	Total No. in the woodland	Total No. in the inselbergs	Total No on the woodland	Total No on the inselbergs
Acreadae	*Acrea eponina*	32	12	45	12
Acrididae	*Zonocerus variegates*	204	15		
Acrididae	*Paracomacris stenoptera*	9	0		
Alydidae	*Mirperus jaculus*	34	15		
Anophelidae	*Anopheles ardensis*	8	3		
Anophelidae	*Anopheles distinctus*	42	13		
Anophelidae	*Anopheles wilsoni*	13	2		
Aphrophoridae	*Poophilus costalis*	28	0		
Apidae	*Apis mellifera*	25	6		
Archatinidae	*Archachatina marginata*	35	0		
Argasidae	*Ornithodorous moubata*	76	0		
Carabidae	*Aulacoryssus aciculatus*	12	0		
Carabidae	*Craspedopharus tropicus*	26	14		
Carabidae	*Aulacoryssus* sp.	13	1		
Carabidae	*Orthogonius* sp.	12	5		
Caraebycidae	*Macrotoma serripes*	11	0		
Chrysomelidae	*Apophylia angustata*	17	1		
Culicidae	*Aedes vittatus*	12	2		
Culicidae	*Culex ingrami*	9	2		
Danidae	*Danaus chrysippus*	7	3		
Danidae	*Danaus liminace*	7	2		
Derceptidae	*Amphiboles venator*	22	0		
Dytyscidae	*Hydrovatus* sp.	8	0		
Forficulidae	*Forficular auricularia*	48	0		
Formicidae	*Componotus vestitus*	0	2		
Formicidae	*Pheidole liengme*	109	58		
Formicidae	*Odontomachus haematodos*	58	0		
Formicidae	*Dorylus affinis*	3	1		
Formicidae	*Messor* sp.	89	45		
Formicidae	*Componotus sericeus*	56	12		
Gryllidae	*Gryllopsis scenicus*	39	11		
Gryllidae	*Scaesipedus marginatus*	9	6		
Gryllidae	*Pteronemobius massaicus*	56	0		
Gryllidae	*Gymnogryllus lucens*	23	3		
Gryllidae	*Acanthoplistus acutus*	28	4		
Libellulidae	*Tritermis annulata*	57	10		
Lithobiidae	*Lithobius* sp.	11	0		
Lumbricidae	*Lumbricus terrestris*	48	0		
Lycidae	*Lycus trabeatus*	25	0		
Lycidae	*Lycus cornigera*	32	2		
Lygaeidae	*Distadieches* sp.	75	17		
Lygaeidae	*Oxycaremus* sp.	35	17		
Lyncaenidae	*Zizina* sp.	40	19		
Lyncaenidae	*Virachola* sp.	15	7		
Lyncaenidae	*Azanus moriqua*	10	3		
Meloidae	*Mylabris holosericea*	13	6		
Muscidae	*Dimorphia* sp.	32	1		
Mutillidae	*Smicromyrme* sp.	57	32		
Noctidae	*Polydesma* sp.	67	19		
Notonectidae	*Notonecta* sp.	13	0		
Nymphalidae	*Vanessa cadui*	15	5		
Nymphalidae	*Precis chorimene*	2	1		
Nymphalidae	*Precis orithya*	2	0		
Papilionidae	*Graphium pylades*	0	2		
Pentatomidae	*Agonoscelis versicolor*	18	3		
Pentatomidae	*Nezara viridula*	1	0		
Pentatomidae	*Sphaerocoris testudogrisea*	12	3		
Pentatomidae	*Glypsus conspicus*	2	0		
Pentatomidae	*Scotinophara* sp.	18	0		
Phasmidae	*Ramulus gracilipes*	17	7		
Pieridae	*Catopsidia florella*	8	13		
Pieridae	*Eurema hecabe*	5	0		
Pieridae	*Mylothris chloris*	16	2		
Pieridae	*Anaphaeis aurata*	16	0		
Pieridae	*Eurema dejardensi*	3	2		
Pieridae	*Eurema brigitta*	0	3		
Reduviidae	*Pirates spinipes*	5	0		
Reduviidae	*Ectomocoris* sp.	14	0		
Total	79	2,092	468		

Table 2: The Diversity Indices of the Terrestrial Macro Invertebrate Fauna at the inselberg and its surrounding woodland

S/No	Diversity Indices	Woodland	Inselbergs
1	Species richness	74	51
2	Individuals	2,092	468
3	Shannon-Wiener	3.9	3.41
5	Equitability	0.9034	0.8674

The Relationship between the Flora and Fauna of the Study Site

Table 3 is the tree, shrubs, herbs and bird density adapted from Tanko *et al.* (2013 and 2014).

To test for any relationship between plant density and invertebrate abundance and between bird abundance and macro-invertebrate abundance, Pearson's Correlation coefficient was used. The result in Table 4 showed a highly significant negative correlation between bird abundance and woodland macro-invertebrate abundance ($P<0.05$). Bird abundance showed a non-significant ($P>0.05$) but negative correlation with inselberg Macro-invertebrate abundance.

The woodland macro-invertebrate showed a non-significant positive correlation with shrub density ($P>0.05$) but, there was a significant positive correlation with tree density ($P<0.05$). The inselberg macro-invertebrates showed positive correlation with the both the trees and shrub density, however, the relationship was statistically not significant ($P>0.05$). Invertebrates' abundance in both the woodland and inselberg correlated negatively with the herbs, forbs and grass density, though not significant. The details of the correlation are shown in Table 4. The bird abundance correlated negatively with both the inselberg invertebrates and the woodland invertebrates. However, the correlation was only significant with the woodland invertebrates. Similarity index showed that the invertebrate on the woodland and inselberg were 60.26% similar. Test for differences in density between the wet and dry seasons and between the first and second year of sampling showed no significant difference. ($P>0.05$)

Table 3: trees, shrubs herbs and birds density of the Dumbi Inselberg and the woodland surrounding it

	Number at the Woodland	Number at the Inselberg
Bird abundance	107	107
Tree Density	24	06
Shrub Density	1152	321
Herb Density	7366172	5471

Adapted from Tanko *et al*. 2013 and 2014

Table 4: Correlation Matrix of the Relationships between the Terrestrial Flora and Fauna of the Study Site (ns = not-significant at 0.05% level, * = significant at 0.05% level)

	Woodland macro –invertebrate	Inselbergs macro –invertebrates
Bird abundance	-0.193^{*}	-0.093^{ns}
Tree Density	0.246^{*}	0.167^{ns}
Shrub Density	0.140^{ns}	0.093^{ns}
Herb Density	-0.077^{ns}	-0.042^{ns}

Discussions

The higher species diversity and abundance at the woodland than the rock outcrop might be due to higher density of plants at the surrounding woodland compared to the inselberg as reported by Tanko *et al.* [2] at the site. Invertebrates feed on the plants or decaying parts of the plant especially leaf-litter. It was Tanko[9] who observed high density of birds at the surrounding woodland than the inselberg and attributed his observation to the high density of lieaf-litter harbouring invertebrates that serves as food to the birds. More butterflies population were observed by Amusan *et al.* [4] at parks and Gardens and Teaching and Research Farms than in oxidation ponds and attributed this to large water sources, tree plantations and grasslands areas which serve as breeding sites. These features were also common in the woodland than the insellberg.

The abundance of *Zonocerus variegatus* could be attributed to the vegetation of the surrounding woodland which was relatively undisturbed and so, provided a better opportunity for the species as food and protection from predators. Since the species is polyphagous in habit. *Pheidole leigme* were more at the inselberg than the woodland. The preference to the inselberg might be for concealment from predators, since the colour of the species blend with the rocky background, thus making it difficult to be sighted by predators. The low diversity of birds recorded at the inselberg compared to the woodland by Tanko *et al.* [2] is an indicative of low pressure on this species of ants and hence their high number.

The correlation showed that increase bird abundance led to decrease in invertebrate's abundance. This relationship was statistically significant as stemmed from the fact that a good number of the birds recorded by Tanko *et al.* [2] at the site were insectivorous and fed on the macro-invertebrates thereby depleting their number. Food (macro-invertebrates) is a major factor that determines habitat utilization by an organism. It was Tanko [9] in his studies who opined that bird abundance depends mainly on habitat quality which in turn correlated with food availability. Furthermore, Tanko [11] suggested that the knowledge of food availability is very important in developing any conservation plans for animals in any given ecosystem. In the Northern Guinea Savanna, any conservation plans which aim to increase and conserve bird diversity and abundance must include actions that will increase diversity and abundance of macro-invertebrates and other avian food resources in the habitat.

The positive correlation between macro-invertebrates and tree population was probably due to factors and niche or micro-habitat provision such as tree holes, etc. which serve as shelter to the invertebrates. From this result, it may be inferred that re-afforestation programs will have a positive effect of increasing macro-invertebrates abundance in the habitat; this will in turn increase bird abundance. Portions of a study site with high density of trees had correspondently high leaf-litter density which haboured macro-invertebrates that were potential foods of birds as observed by Tanko [11].

Conclusion

With these it can be concluded that the objectives of the study were successfully achieved, seeing that what was not known of inslebergs in the savanna is now known. This study will form a baseline for further studies on inselbergs. With these, it is recommended that completely protected inselbergs should be set aside for in-situ conservation of their biodiversity. Conservation intervention actions should involve the participation of the local communities, to ensure grassroots ownership.

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