Impact of habitat degradation on the assemblage of riparian ground beetles (Coleoptera: Carabidae) in the Morogoro Municipality, Tanzania

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Abstract

This study assessed the impact of habitat degradation on the assemblage of riparian ground beetles in the Morogoro Municipality, Tanzania. The beetles were collected from three degraded (Ngerengere, Morogoro and Kikundi) and three relatively pristine streams (Bigwa, Vituli and Lukuyu) during the rainy season between January and April 2013. The beetles were collected by active searching on the ground, in leaf litters, under logs and stones. The abundance, species richness and diversity of the beetles were analyzed using Diversity and Richness ver. 2.65, PRIMER ver. 6.1 and SYSTAT ver. 10. The abundance of beetles was significantly high in relatively pristine streams (n=143) compared to the degraded streams (n=75; 34.4%) (Mann-Whitney U=4396.500; p<0.05). Metagonum sp.2, Peryphus sp.3, Boeomimetes ephippium, Abacetus sp.2 were the most abundant in relatively pristine streams while Diatypus uluguruanus, Metagonum mboko, Peryphus sp.3 were the most abundant in degraded streams. The highest species richness (S=21) was recorded in relatively pristine streams (s=21) while the lowest species richness (S=13) was recorded in the degraded streams. Furthermore, relatively pristine streams showed the highest average diversity (H' = 2.5359) compared to the degraded streams (H' = 2.0662). Based on the findings, ground beetles are good indicators of habitat quality. These results call for strengthened measures to control degradation of the riparian areas in the Morogoro municipality.

Key words: Ground beetles, Carabidae, habitat degradation, Tanzania

1.0 Introduction

Morogoro Municipality is located in Morogoro region on the eastern side of Tanzania at latitude 5 ^{o} - 6^{o}S and longitude 36 ^{o} - 37^{o}E. It is found on the lower slopes of the Uluguru Mountains at an altitude of about 500 m a.s.l and 190 Km west of Dar es Salaam. Morogoro Municipality receives several streams from the mountains, which supply water to Morogoro Municipality and other nearby regions such as the Coast and Dar es Salaam. The streams also create riparian habitats, which play a key role in water and biodiversity conservation. The riparian habitat often has high species diversity and is critical for wildlife. The habitat is important for insects, birds and other groups of organisms (Hafeez, Khan, & Inayatullah, 2000). Despite the benefits riparian habitat provide, they face an increasing pressure from both natural and anthropogenic activities.

The knowledge of biodiversity changes as a result of natural or anthropogenic mediated activities requires a baseline record (Maveety, Browne, & Erwin, 2011). Biodiversity inventories are important and can serve as studies of climate change and other expected environmental transformations (Chen *et al*., 2009; Maveety *et al*., 2011). This is useful particularly in planning to protect habitats in order to yield the greatest gains for wildlife (Knutson & Naef, 1997). As in other parts of the world, a wide range of anthropogenic activities such as domestic and industrial waste discharge, quarry mining, tree clear-cutting, farming activities and settlement establishment threaten riparian habitats in Morogoro Municipality.

Ground beetles have been widely used as bioindicators of environmental change and health of habitats because they are diverse and highly sensitive to habitat changes (Alexander et al., 2011; Rainio & Niemelä, 2003). Whereas ground beetle fauna of the Uluguru Mountains has been documented in a few surveys made by Basilewsky (1962; 1976) and Maganira and Nyundo (2015), there has been no any survey in the lowlands next to the mountains. It is feared that many species including some ground beetle species may be lost before they are described, as riparian forest clearing and other forms of habitat degradation continue to rise. The objective of the present study was to investigate the assemblage of riparian ground beetles in relation to anthropogenic activities taking place along stream banks in Morogoro Municipality, Tanzania.

3.0 Material and methods

3.1 *Sampling*

Baseline data of riparian ground beetles were collected from riparian habitat (stream banks) in Morogoro Municipality, Tanzania in the wet season between January and April, 2013 using active searching method. Six study sites were set at the riparian habitat of streams with two different habitat conditions (Figure 1). The sampled area for all the study sites measured 4 m wide and 10 m long. The relatively pristine streams (Vituli, Bigwa and Lukuyu) were located in the least urbanized zone (Bigwa area) with many large trees, ferns, herbs and received minimum domestic effluents. On the other hand, the degraded streams (Kikundi, Morogoro, and Ngerengere) were located in the highly urbanized zone (Morogoro Town area) with few large trees, ferns, herbs and received more effluents from homes, markets, and small industries than the relatively pristine streams and had pronounced tree clear-cutting, farming activities, and quarry mining. Generally, the vegetation cover was much more pronounced in relatively pristine streams compared to degraded streams.

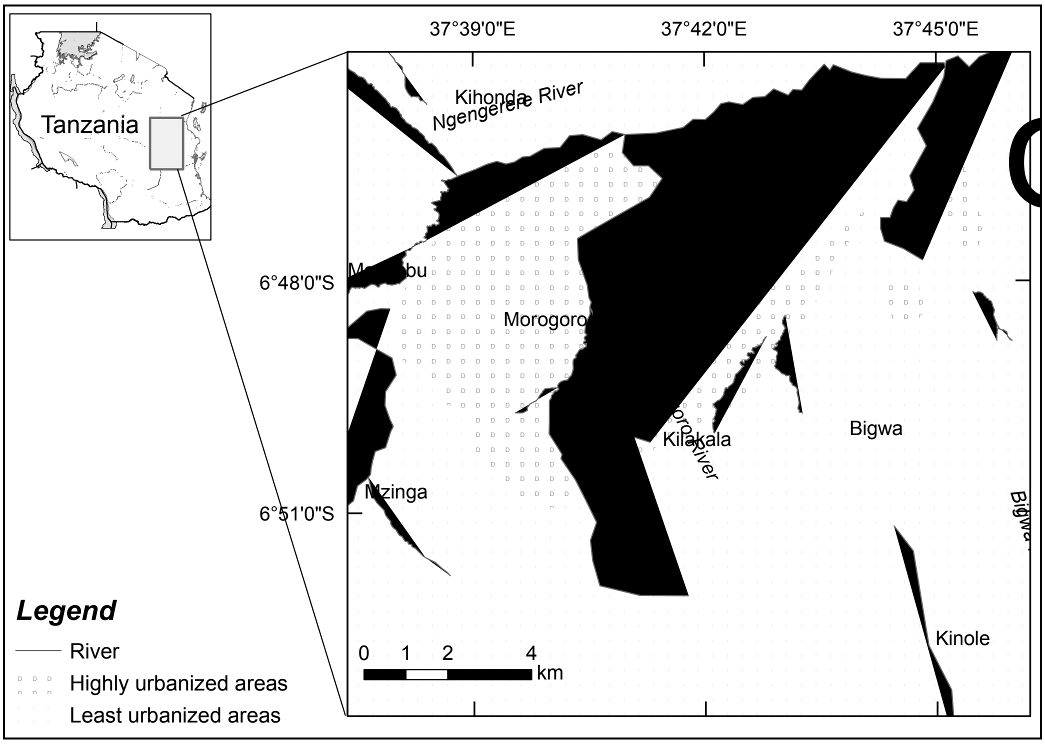

Figure 1: Map of the Morogoro municipality showing the studied streams

Active searching was done by searching for riparian ground beetles, at each site during the day, on the ground, in leaf litters, under logs and stones. The ground beetles collected by each of the collectors involved for a period of one hour constituted one “sample”. A total of 216 samples were collected. Each sample was placed into one plastic bag containing 75% ethanol and then placed into plastic buckets before they were transferred to the laboratory for analysis.

3.2 Identification of the sampled beetles

In the laboratory, all the collected riparian ground beetles in each sample were counted and identified according to Basilewsky (1953), CSIRO-DE (1991), White (1983) and Picker, Griffiths, & Weaving (2004). In case where it was impossible to identify the specimens to species level, numbers were used for every mophospecies and were left to be identified later when experts and resources are available. Morphospecies is here used for Recognizable Taxonomic Unit (RTU) (CSIRO-DE, 1991), meaning a morphologically recognizable entity, to which all morphologically similar specimens are assigned. Some of the identified species were mounted and pinned (for relatively larger specimens) and carding was done for smaller specimens. The rest of the specimens were deposited in the Zoology laboratory in the Department of Biosciences of the Sokoine University of Agriculture for reference.

3.4 Data analysis

The diversity of the riparian ground beetles was calculated using Shannon-Wiener index (Shannon, 1948).The species diversity between the two stream habitats was compared using Student's t-test(Barnett, Shapley, Benjamin, Henry, & McGarrell, 2002; Zar, 1984).Mann-Whitney test was used to compare the abundance of riparian ground beetles among sites. Species Diversity and Richness ver. 2.65 (Henderson & Seaby, 2001) and SYSTAT ver. 10 (Kroeger *et al*., 2000) were used for univariate analysis. Multivariate analysis of the assemblage of ground beetles was performed using PRIMERver. 6.1 (Clarke and Warwick, 2001). Constrained ordination analysis of the community structure of ground beetles was performed based on non-metric multidimensional scaling (n-MDS). Prior to this, abundance data were square root transformed to reduce the contribution of most abundant species. The Bray-Curtis similarity matrix was then generated. To test for differences in the assemblage of beetles between degraded and relatively pristine streams, one way analysis of similarities (ANOSIM) was performed. Furthermore, one way similarity percentage (SIMPER) routine was performed to identify beetles accounting for most of the dissimilarity between degraded and relatively pristine streams.

4.0 Results

4.1*Univariate analysis of community structure*

A total of 218 specimens of riparian ground beetles belonging to 25 species were recorded. The relatively pristine streams had the highest abundance of ground beetles (average density=0.033) while the degraded streams gave the lowest abundance (average density=0.017). The difference in abundance between these streams was statistically significant (Mann-Whitney U=4396.500; $p<0.05$). *Metagonum sp.2, Peryphus sp.3, Boeomimetes ephippium*, *Abacetus sp.2* were the most abundant species in relatively pristine streams while *Diatypus uluguruanus*, *Metagonum mboko*, *Peryphus sp.3* were the most abundant species in degraded streams (Table 1). The total number of species collected varied significantly with habitat type, with the highest species richness (S=21) found at the relatively pristine streams while the lowest species richness (S=13) were recorded at the degraded streams. There was a high level of site specificity for species in which among the 25 collected species, 12 species (*Metagonum* sp.1, *Acanthoscelis ruficornis, Peryphus meruanus, Trechodes* sp.1, *Tachys* sp.1, *Peryphus* sp.1, *Trechodes babaulti, Peryphus* sp.2, *Craspedophorus* sp.1, *Cymindis* sp.1, *Caminara* sp.1 and *Chlaenius cambodiensis*) occurred only in relatively pristine streams while only 4 species (*Odacantha* sp.1, *Tefflus* sp.1, *Abacetus* sp.1 and *Abacetus straneoi*) occurred in degraded streams only. The number of rare species was estimated using a taxonomic index (Coddington *et al*., 1991). Among the 25 collected species, 8 species were singletons and 3 species were doubletons. The number of rare species was higher in relatively pristine streams than in degraded streams (Table 1). Furthermore, relatively pristine streams showed the highest average diversity of beetles (H' =2.5359) compared to the degraded streams (H' = 2.0662). The difference in diversity was significant ($p<0.05$).

Table 1: List of riparian ground beetle species collected in the Morogoro municipality

Species	Relatively pristine streams	Degraded streams
Metagonum sp.1	1	0
Crepidogaster pauliani	2	4
Odacantha sp.1	0	1
Clivina fossor	9	1
Tefflus sp.1	0	6
Acanthoscelis ruficornis	1	0
Abacetus sp.1	0	1
Abacetus sp.2	12	2
Peryphus meruanus	4	0
Trechodes sp.1	1	0
Peryphus sp.1	14	0
Tachys sp.1	10	0
Trechodes babaulti	5	0
Peryphus sp.2	6	0
Diatypus uluguruanus	4	22
Scarites linearis	1	1
Craspedophorus sp.1	2	0
Metagonum mboko	4	14
Peryphus sp.3	25	12
Abacetus straneoi	0	2
Metagonum sp.2	27	7
Boeomimetes ephippium	12	2
Cymindis sp.1	1	0
Chlaenius cambodiensis	1	0
Caminara sp.1	1	0
Total	**143**	**75**

4.2 Multivariate analysis of the community structure

Results of multidimensional scaling (MDS) are shown in Figure 2. The analysis separated samples from degraded and relatively pristine streams though the separation was not very clear. At 17% similarity level, MDS formed four clusters. Cluster I contained samples from Site 1 (Bingwa stream), while cluster III contained most samples from the streams of Vituli and Lukuyu (Sites 2 and 3) and few samples from the degraded streams (5b, 5c and 6C). Clusters II and IV were largely composed of samples from the degraded streams of Ngerengere, Kikundi, and Morogoro (4, 5, and 6 respectively).

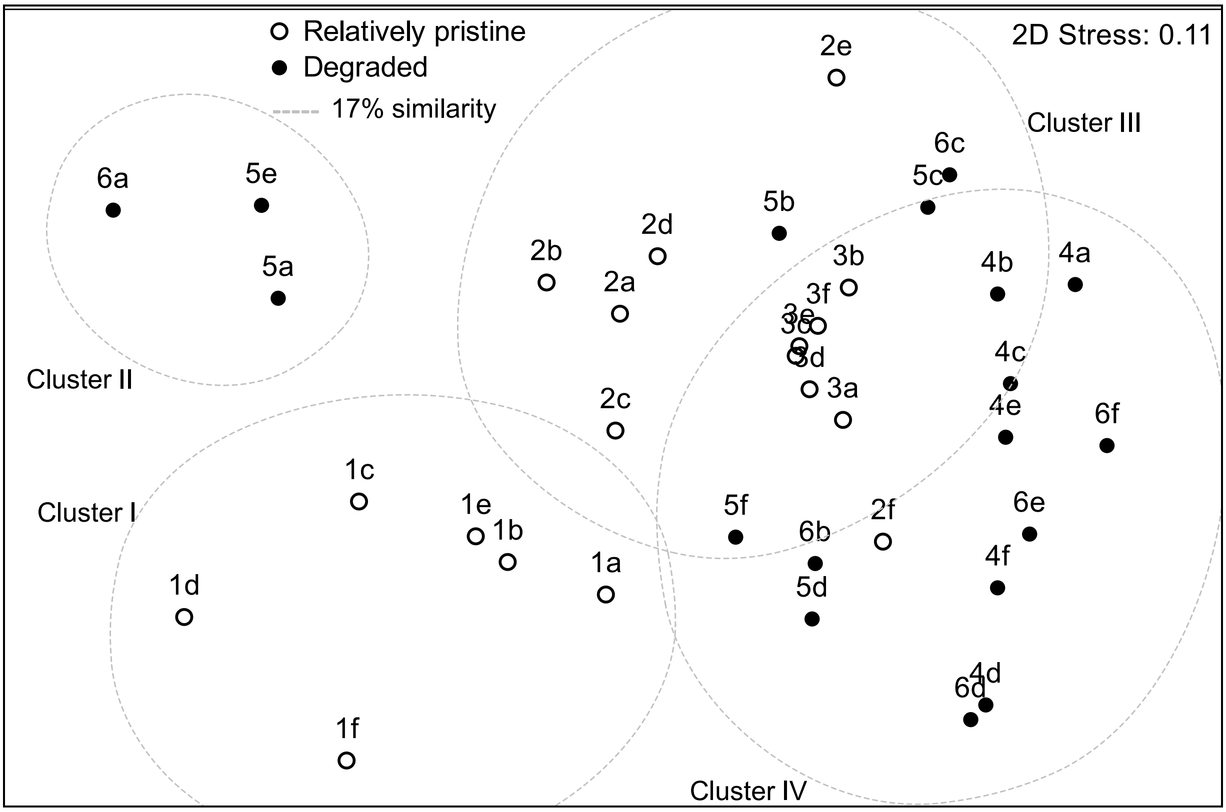

Figure 2: Two dimensional n-MDS of carabid beetle samples from riparian areas in Morogoro, Tanzania in 2015. Numeric values represent site number and letters represent sample number.

Although some clusters contained a mixture of samples from degraded and relatively pristine streams, ANOSIM indicated significant differences in assemblages between degraded and relatively pristine streams (Global R = 0.151, p = 0.3%). SIMPER indicated an average dissimilarity of 87.21% between degraded and relatively pristine streams (Table 2).*Peryphus sp.3, Metagonum sp.2,* and *Diatypus uluguruanus* contributed most of the dissimilarity, each contributing 13.49, 12.72 and 10.70% of the dissimilarity respectively. Other species which contributed at least 5% of the dissimilarity included *Metagonum mboko, Tachys sp.1, Abacetus sp.2, Clivina fossor* and *Boeomimetes ephippium*. SIMPER also identified an average similarity of 19.16 and 21.96 between degraded and relatively pristine streams respectively. *Diatypus uluguruanus, Peryphus sp.3* and *Metagonum mboko* contributed at least 20% of the similarity among degraded streams while *Metagonum sp.2, Peryphus sp.3, Clivina fossor, Abacetus sp.2* and *Tachys sp.1* contributed at least 10% of the similarity among relatively pristine streams.

Table 2. Average dissimilarity of carabid beetles from degraded and relatively pristine streams. Av.Abund = average abundance.

Species	Relatively pristine	Degraded				
	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%

Peryphus sp.3	0.74	0.5	11.76	0.94	13.49	13.49
Metagonum sp.2	0.84	0.25	11.1	0.93	12.72	26.21
Diatypus uluguruanus	0.19	0.7	9.33	0.79	10.7	36.92
Metagonum mboko	0.19	0.53	7.26	0.8	8.32	45.24
Tachys sp.1	0.41	0	6.16	0.59	7.06	52.3
Abacetus sp.2	0.49	0.08	6.12	0.75	7.01	59.32
Clivina fossor	0.43	0.06	5.55	0.77	6.36	65.68
Boeomimetes ephippium	0.33	0.11	4.77	0.55	5.47	71.15
Peryphus sp.1	0.38	0	3.94	0.46	4.52	75.67
Crepidogaster pauliani	0.08	0.19	3.42	0.47	3.92	79.59
Peryphus sp.2	0.27	0	3.39	0.49	3.88	83.47
Tefflus sp.1	0	0.23	2.47	0.42	2.83	86.3
Peryphus meruanus	0.19	0	1.95	0.42	2.24	88.53
Trechodes babaulti	0.17	0	1.82	0.34	2.08	90.62

5.0 Discussion

Degradation of natural riparian habitat through different land use systems have negative effect on ground beetle abundance, species richness and diversity in streams occurring in the Morogoro Municipality. The decline in ground beetle species richness and diversity due to habitat degradation have also been reported previously (Koivula, Kukkonen, & Niemelä, 2002; Niemelä *et al*., 2002; Niemelä, Langor, & Spence, 1993). A decrease in the abundance, richness and diversity following habitat degradation has also been recorded for other groups of insects (Beck, Schulze, Linsenmair, & Fiedler, 2002; Boonrotpong, Sotthibandhu, & Pholpunthin, 2004; Holloway, Kick-Spriggs, & Khen, 1992; Kwon, Lee, & Sung, 2014; Shahabuddin, Schulze, & Tscharntke, 2005). Ngerengere, Kikundi, and Morogoro streams are subjected to human activities including urbanization, pollution, and reduction of vegetation cover that might have contributed to alteration of habitats for the ground beetles. Degradation and loss of habitats may be among the prime factors for the observed decrease in abundance, richness and diversity of the ground beetle in this study.

We recorded species of beetles which showed high level of site specificity as many of them were found to reside only in relatively pristine streams. Some studies have also indicated species site specificity in ground beetles (Maganira & Nyundo, 2015; Niemelä, 2001). It has been reported that some beetles preferred to colonize less suitable habitats when density increases in the preferred sites otherwise they prefer to select suitable habitats (Binckley & Jr, 2005). The preference of relatively pristine streams by many species of beetle in this study can be demonstrated by suitability of the microhabitats in these streams which may favour their survival and reproduction. The beetles in relatively pristine streams may be benefiting from the soil moisture, microclimate stability and the vegetation cover. Pristine sites offer greater diversity of food, more stable microclimate, higher humidity and greater quantity of refuges against predators while in degraded habitats there is low availability of food resources and decreased soil moisture content (Fagundes, 2011).

The impact of degradation of the streams were observed to have less influence on *Peryphus sp.3*, *Metagonum sp.2*, and *Diatypus uluguruanus* as they were the most species observed to exist in both relative pristine and degraded streams and therefore contributed to most of the average abundance dissimilarities observed between relative pristine and degraded streams. The reason for this observation may be due to the fact that some species of beetles including *Trechodes babaulti* have ability to tolerate the disturbance (Maganira & Nyundo, 2015; Skłodowski & Garbalińska, 2011) and therefore can attain high abundance in both degraded and relatively pristine habitats.

In general the difference in riparian ground beetle assemblage recorded in degraded and relatively pristine streams is an indication of the significance of habitat quality on the preference or assemblage of riparian ground beetles. The reasons to the observed difference in riparian ground beetle assemblage may be due to differences in disturbance levels since the level differed significantly between degraded and relatively pristine streams.

In conclusion, riparian ground beetle communities of the Uluguru Mountains lowlands appear to be relatively susceptible to anthropogenic degradation activities. High abundance, richness and diversity were recorded in relatively pristine than degraded streams explaining the influence of riparian habitat quality on the assemblage preference of ground beetle species. The majority of riparian ground beetles preferred relatively pristine streams while only four species occurred exclusively in the degraded streams indicating adaptation to degraded environment. Based on the findings, ground beetles are good indicators of habitat quality. These results call for strengthened measures to control degradation of the riparian areas in the Morogoro municipality. For effective stream and riparian habitat management, further studies may focus on seasonal riparian ground beetle assemblage and quantification of the extent of pollutants in the streams in Morogoro Municipality.

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