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Assessment of the Diversity of Dung Beetles (Coleoptera, Scarabaeidae) Along a Disturbance Gradient in Udzungwa Mountain National Park, Tanzania.

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Abstract

The diversity of dung beetles was assessed along a disturbance gradient in the Uzdungwa Mountains National Park in Tanzania. The form of disturbance involved human activities such as excessive deadwood collection, cutting grasses for thatching and collection of medicinal plants. Disturbance gradients were primary forest (low level / no human activities), moderately disturbed sites and highly disturbed sites. Pitfall traps baited with fresh cow dung were used, nine transect were established along with three transects at each disturbance gradient. Dung beetles abundance, species richness and diversity were analyzed statistically using Diversity and Richness–2.65, SYSTAT Version 10 software. A total of 12,894 dung beetles comprised of 55 species were collected. Species richness was high in highly disturbed sites (48 species) compared with moderately and primary forest sites (41 species each). Kruskal–Wallis showed statistically significant difference among the three levels of disturbance ($H=80.920$, $p<0.05$), with abundance being highest in primary forest. The Shannon-Wiener index showed higher species diversity in the moderately disturbed sites ($H' = 2.5678$) and lowest at primary forest (1.7248) and the difference was statistically significance, $p>0.05$.

Key words: Diversity, disturbance gradient, dung beetles, Uzdungwa Mountains National Park.

1. Introduction

The Udzungwa Mountains are the largest of the Eastern Arc Mountains (EAM), an ancient chain of mountains estimated to be approximately 30 million years old. The EAM stretch in an arc from the Taita Hills in southern Kenya down to south-central Tanzania (respective 3025′S, 380 20′E to 8051′S, 34049′E), (Lovett & Wasser, 1993). The Udzungwa Mountains are particularly important because they have the greatest amount of forest cover, greatest altitudinal range in the entire EAM (300-2,576 m above sea level), and provides essential catchment areas for major rivers of southern Tanzania (UNESCO & MNRT, 2010). They are the source of perennial water for agriculture (small and large scale), domestic use, the water serves two hydroelectric installation that provide approximately 70% of Tanzania's hydroelectricity and 52.6% of country's energy (year 2000-2005, GoT 2006). In addition, they provide habitat to Plants and animals, some of which are endemic to these mountains. The Udzungwa Mountains National Park (UMNP) occupies the northern sector of the Udzungwas.

Despite its biodiversity importance, the Park was facing threats such as illegal logging, excessive firewood collection, uncontrolled fires, medicinal plant collection, hunting (Bakarr 2000; Nyundo *et al*. 2006; Rovero *et al*. 2008). These threats are associated with an increase in human population which is highly pronounced along the eastern side of the mountain range (Harison 2006).

At the gazettement of the UMNP in 1992 there was a verbal agreement between Tanzania National Parks Authority (TANAPA) and local District Council to allow some human activities (collection of dead wood, cutting of grass for thatching, extraction of medicinal plants and traditional worshiping) to take place inside the UMNP. These activities were banned in mid 2011. The present study aimed at using dung beetle diversity to assess the health of the park following the banning of human activities. It was a follow-up study after two previous ones (Nyundo *et al*. 2006, Rovero *et al*. 2008)

Dung beetles are among the species which were affected especially in species composition (Nyundo *et al*. 2006), it was worried that they may have experienced extinction and possibility of irreversible change in this tropical forest. Therefore it necessitates assessing dung beetles to ascertain the effects of human pressure in the Park.

There has been numerous studies that have been conducted as far as dung beetles and disturbance are concerned, but most of the studies that have been conducted on the impact of forest clearing on dung beetle assemblages and have put much attention on disturbance of intact tropical rainforest such as fragmentation, logging, clearing, conversion into pasture land, annual culture of maize or into plantation (Howden &Nealis 1975; Holloway *et al*. 1992; Halffter *et al*. 1992; Davis 2000; Davis *et al*. 2001; Medina *et al*. 2002; Andresen 2002; Larsen *et al*. 2005; Scheffler 2005; Shahabuddin *et al*. 2005). All these studies reported important negative effects such as fewer species and lower population densities.

Dung beetles have been chosen because they are known to be highly habitat specific and sensitive to habitat change (Mico *et al*., 1998), species rich, well known taxonomy, simple method of sampling (Hanski and Cambefort, 1991), ecological importance Vaughan 2006; Bornemissza 1970; Mittal 1993; Wilson 1998 Grønvold *et al*. 1992; Estrada & Coates-Estrada 1991; Andresen 2002).

2. Materials and methods

2.1 Study areas

The study areas were located within Udzungwa Mountains National Park (30° 41´ E and 70° 48´ S). The study sites and method were the same as those employed during the baseline survey in 2005 (see Nyundo *et al*. 2006), except that one of the primary forest sites (Lumemo) was replaced by another site (Kidatu Hydropower Plant), which was closer to the rest of the sampling sites. The original site was very far from the remaining site. The sampling points are described in Table 1and Figure 1.

Table 1: Description of the study site (P, M and D represent the three level of disturbance: P = primary/intact forest, M = moderately disturbed forest, and D = highly disturbed forest).

S/N	site	Levels of disturbance	Location(GPS points)	Description
1	P1	Low	271671 9155083	Primary Forest near Kidatu HEP project
2	P2	Low	274069 9153188	Intact primary forest near Kidatu HEP project
3	P3	Low	268874 9154977	Intact woodland/forest near Kidatu HEP project
4	M1	Moderate	272415 9147004	Moderately used Forest near sugar plantation
5	M2	Moderate	268799 9139246	Moderately used forest near Sanje Post
6	M3	Moderate	267904 9136673	Moderately used Forest near Mwanihawa Trail
7	D1	High	275221 9150502	Highly disturbed forest near Mkamba Village
8	D2	High	266253 9132665	Disturbed forest near TANAPA Man'gula Head quarter
9	D3	High	266508 9131045	Highly disturbed Forest/woodland adjacent Mwaya's town

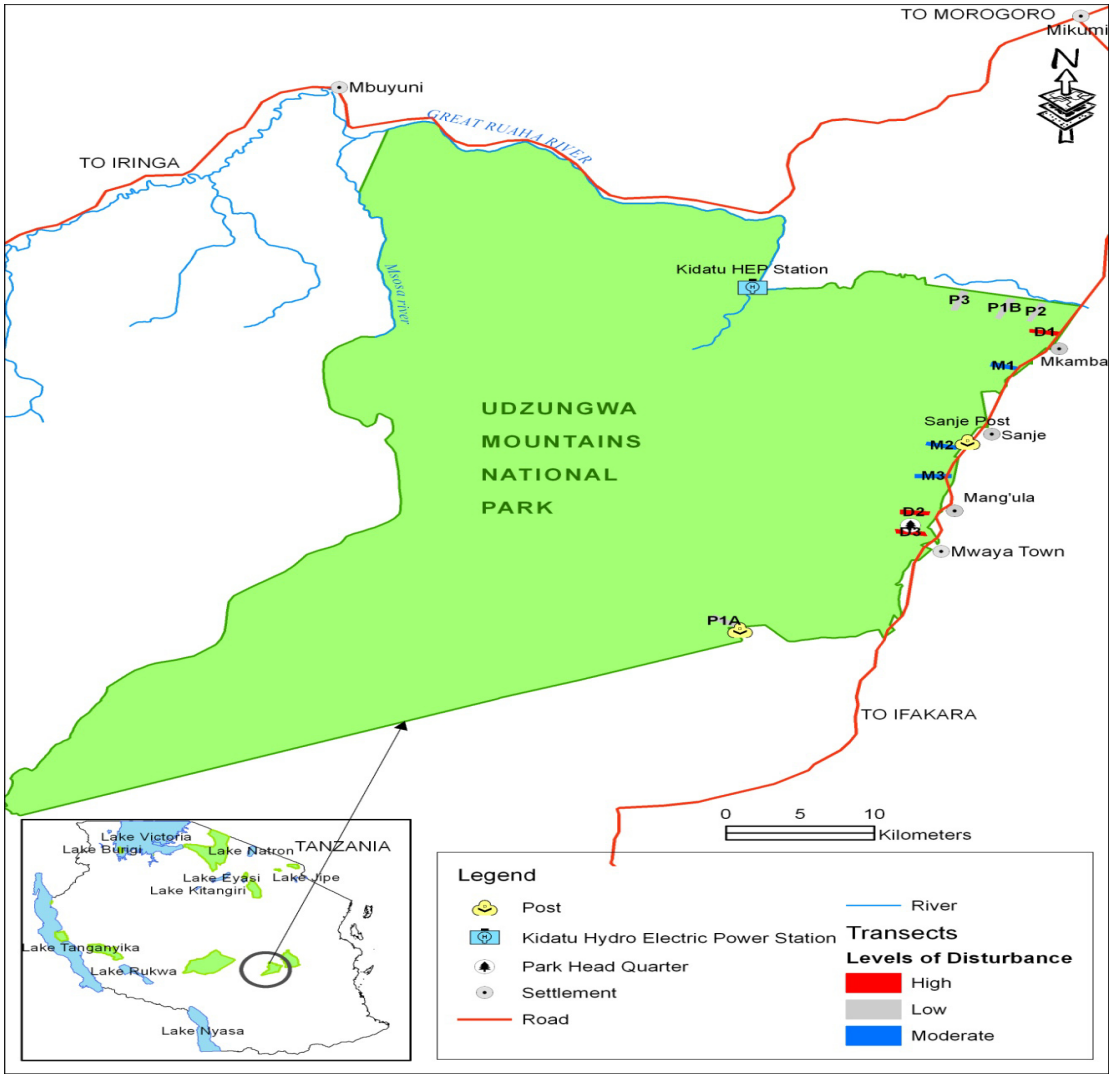

Fig 1; Map of the Udzungwa Mountains National Park showing the nine transect in which dung beetles were collected.

2.2 Beetle sampling

Sample collection was conducted in March and April 2012. Baited pitfall traps method with fresh cow dung was employed. Dung beetles were sampled along the disturbance gradient, from near the edge of the forest to the interior. The criterion for determining the level of disturbance was the number of people living adjacent to the particular sampling point. This was assumed to be proportional to the disturbance in the particular area (in terms of deadwood collection, cutting grasses for thatching and collection of medicinal plants), as supported by previous findings by a social-economic team (Nyundo *et al*. 2006).

Sampling involved three visits per transect before shifting to another transect. A total of nine transects (of size 80m by 250m) were established. At each transect, 20 pitfall traps were set at distances of 0m, 40m, 100m and 250m from the forest edge, with 5 pitfall traps at each distance. The distance between the five traps was 20m. The traps were made of 1-litre plastic cups. They were set in the morning and emptied after 24 hours, each trap constituting one "sample". The cups were half-filled with water with a few drops of a detergent to break the surface tension. Traps were baited with fresh cow dung tied in a piece of light clothing material and placed at the top of the pitfall trap on 2 wooden sticks. Dung beetles were sieved from the traps and immediately transferred into specimen bottles containing 80% alcohol. Geographical position of each site was recorded using GPS. Specimens were transported to the University of Dar es Salaam for sorting and identification. A total of 540 samples were collected, amounting to 12,960 trapping hours.

In the laboratory, the collected dung beetles were identified to species level wherever possible (9 species); otherwise they were assigned a morpho-species code (46 species). Voucher specimens are kept in the Zoology Department of the University of Dar es Salaam.

2.3 Data analysis

Descriptive statistics were used to summarize and present the data. Data collected did not meet the assumptions of parametric tests; therefore non parametric tests were used. Kruskal-Wallis test was used for abundance, Shannon-Wiener index for species diversity, and diversity indices between different levels of disturbance were compared by using a special t-test. Evenness was computed using the formula e=H/S (where H= Shannon and S= species richness). Statistical packages used were SYSTAT (SPSS 2000) for abundance and SDR-IV (Seaby & Henderson 2006) for diversity.

3. Results

3.1 General Results

In total 55 species were identified from 12,894 individuals that were collected. These were distributed as follows: 6,224 (48.27%) dung beetles from Primary forest sites, 1,588 (12.32%) from moderately disturbed sites, and 5,082 (39.41%) from highly disturbed sites. The average abundance was 24 dung beetles per trap with standard deviation of 38.98. The minimum number of dung beetles in the traps was 0 while the highest abundance obtained was 338. Relative abundance was about 35 dung beetles per trap in primary forest, 9 for moderately disturbed sites, and 28 in highly disturbed sites.

3.2 Effect of disturbance on abundance of dung beetles

Primary forest contribution to the number of individual was the highest, followed by highly disturbed and the lowest abundance being at moderately disturbed sites (6,224, 5,083 and 1,588 beetles respectively) (Figure 2). The difference was statistically significant (Kruskal-Wallis $H = 80.920$, $p<0.05$). Comparison between pairs of levels of disturbance using the Mann-Whitney test showed a significant statistical difference between the primary and moderately disturbed sites, and between moderate and highly disturbed sites (Mann-Whitney $U=10205.500$, 24893.500 and $p<0.05$), while the primary and highly disturbed sites showed no significant difference in abundance of dung beetles (Mann-Whitney $U=17949.500$, $p>0.05$).

3.3 Effect of disturbance on diversity of dung beetles and their distribution

A total of 55 species were collected from the nine study sites. Overall, the most dominant species was DB species 27 which consisted of 4,547 dung beetles accounting for 35.26% of the total. This species was most abundant at primary forest sites where it contributed about 76% (3446 individuals). The second most abundant species overall was DB species 2 (3643 individuals accounting 28.25%). This was followed by *Sysiphus* species 1 which contributed 7% of the total (930 individuals). The later were commonly collected in highly disturbed sites. The rest of species contributed less than 5%. Eighteen species were rare, accounting for less than 10 individuals. Among the rare specie 6 were represented by a single specimen (singletons), one species had 2 specimens (doubleton) and two species by three specimens (tripletons). Some species were exclusively found in disturbed sites while others were found in primary forest sites and others in moderately disturbed sites only.

Species richness was found to be higher in the disturbed sites (48 species), compared to 41 species each in moderately disturbed and primary forest sites.

Shannon-Wiener index of species diversity (H′) was used to compare diversity between levels of disturbance. The indexes (H′) at three levels of disturbance were as follows: 2.196 for highly disturbed site, 2.5678 for moderately disturbed site and 1.7248 for primary forest site (Figure3). Special t-test showed statistically significant difference between all three sets, that is D with M, P with D and M with P (respective $t=0.3717$, 0.4713, 0.0841, $p<0.05$).

Species evenness was found to be higher in moderately disturbed site ($e= 0.318$) and low in disturbed and primary forest sites (0.1873 and 0.1369 respectively).

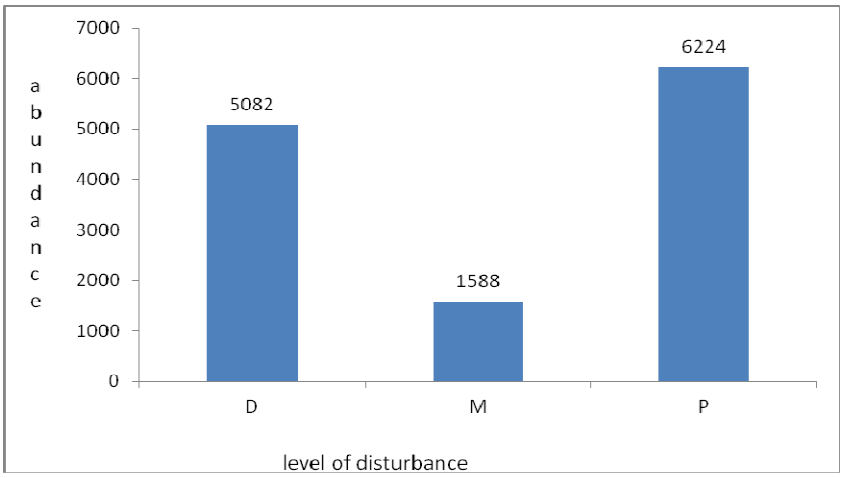

Figure 2: The abundance of dung beetles at three levels of disturbance. P = primary forest (with no or minimal utilization) , M = moderately ultilized sites and D = sites with highest intensity of utilization.

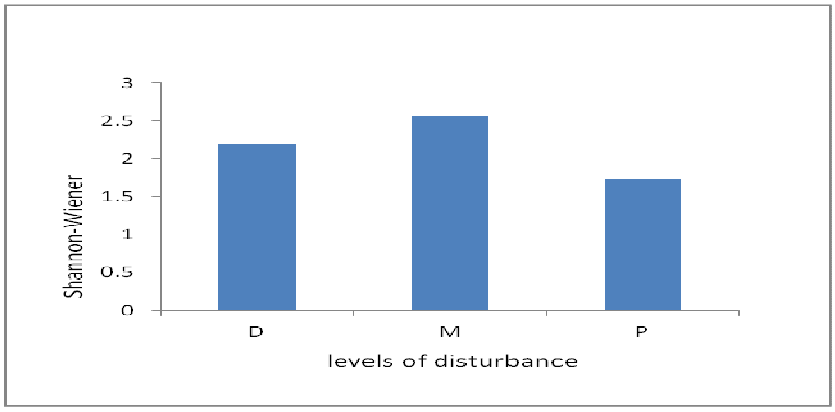

Figure 3: Diversity (Shannon-Wiener index H′) at three levels of disturbance (P=Primary forest (with no dead wood collection), M= Moderately utilized areas, D=Highly utilized areas)

4. Discussion

The present study has shown that the four human activities that were allowed to take place in the UMNP (collection of dead wood, cutting of grass for thatching, extraction of medicinal plants and traditional worshiping) had an impact on the dung beetle fauna. This impact did not show a consistent trend from primary forest to highly disturbed forest. Moderately disturbed sites had the lowest abundance of dung beetles and a low species richness, but high diversity. This can be explained by the fact that the moderately disturbed sites had lower dominance, compared to the primary forest, where two species of dung beetles (DB species 27 and DB species 2) were over-represented. Although the same species were also the most abundant at the moderately disturbed sites, they were relatively less dominant. The high diversity at the disturbed sites was probably due to creation of additional microhabitats, which would attract generalist species from the surrounding non-forested areas outside the national Park.

Our results have shown that primary forest and highly disturbed sites had a higher abundance of dung beetles relative to intermediate sites. This may be attributed to the fact that, several species of mammals were encountered/ detected directly or through signs of presence in both disturbed and primary forest such as duikers, buffalo, yellow baboons black and white colobus monkeys, velvet monkeys and small mammals. In addition elephants were encountered in highly disturbed sites, and were reported to cross the boundaries of the park and enter adjacent villages (pers. observ.). These mammals are an important source of food for dung beetles. It is clearly known that the composition and structure of dung beetle communities is highly correlated with the availability of fresh dung (Halffter & Methews 1966; Hanski & Cambefort 1991; Lumeret & Kirk 1991).

Several studies have reported similar changes in dung beetle abundance in relation to disturbance. In the Amazon, Howden & Nealis (1975) reported that some community attributes such as abundance of dung beetles were negatively affected by anthropogenic forest disturbance. In another study carried out in Missouri Ozarks Masis & Marquis (2007) reported a reduction in dung beetle abundance caused by timber harvesting activities. Several other studies such as (Davis *et al*. 2001; Boonrotpong *et al.* 2004; Shahabuddin *et al.* 2005; Lee *et al.* 2009), showed that dung beetles abundance in disturbed forests is lower than that of undisturbed forests.

Species richness was higher in the disturbed sites compared to that of primary and moderate disturbed sites, the reason for this may be due to the fact that highly disturbed areas where in close proximity to either human habitats or field farms, therefore dung beetles from human habitat and field farms might migrate in the park. Similarly, for the same site, Nyundo *et al.* (2006) found higher species richness in highly disturbed sites but low equitability. In Brazil, Liberal *et al.* (2011) found higher species richness in intense land use areas compared to undisturbed areas, suggesting that the higher species richness could be due to availability of resources as the area was near cattle raising sites.

On the other hand, other studies show the opposite trend. Boonrotpong *et al.* (2004), for example, found higher species richness in primary forest, when compared to secondary forest in Ton Nga Chang Wildlife Sanctuary. In South Asia Shahabuddin (2011), found higher species richness in primary forest than land use types. In comparing clear cut and primary forest, Scheffler, (2005) found high species richness in primary forest.

From this study, species diversity was maximum at the moderately disturbed sites and minimum at primary forest sites. Despite the maximum abundance in dung beetles at the primary forest sites species diversity was highest at the moderately disturbed sites. At primary forest sites, abundance was high due to presence of many rare species and domination by one species (DB27), this might have reduced species diversity (Scheffler 2005).

Species diversity at the moderately disturbed sites was high and low species diversity at the primary forest. It is known that, moderately disturbed sites create more niches for more species to survive and reduce competition, high disturbance reduce diversity and low disturbance allow competition especially when resources are limited. This is commonly known as the intermediate disturbance hypothesis (Connell 1978). Similar to the present study, there are several previous studies which seem to confirm the intermediate disturbance hypothesis; for example, Scheffler (2005) found high diversity of dung beetles at selectively logged areas than in intact forest. Selectively logged areas were considered as moderately disturbed sites. Other studies that came out with a similar pattern include (Nyundo *et al.* 2006; Rovero *et. al.* 2008; Hayes *et al.* 2009).

On the other hand, there are other studies which are opposed to the present study. These found higher species diversity in the least disturbed habitats. Examples include Boonrotpong *et al*. (2004) obtained higher species diversity in primary forest compared to secondary forest habitats. Moreover, there are several studies that report negative effects of anthropogenic disturbances on dung beetle diversity. Davis *et al.* (2001) reported a significant decrease of dung beetle diversity in Northern Borneo across a forest disturbance gradient, ranging from primary to logged and plantation forest. Other studies such as Nichols *et al*. (2007) and Shahabuddin (2010) do not support the intermediate disturbance hypothesis as well. However it should be stressed that, studies that show high species diversity at the lowest disturbed sites and low species diversity at highly disturbed sites are not exclusively against the intermediate disturbance hypothesis. The theory itself stresses that at moderately level of disturbance diversity increases but when the intensity of disturbance is high diversity is affected negatively. Therefore intensity of disturbance is an important aspect (Hill 1995; Davis 2000: Davis 2001).

The total number of species collected in this study (55 species), provide evidence that the area has outstanding species richness than other eastern Arc mountain forest such as Usambara with 23 species. In Sokhulu Forest reserve in South Africa the number of species ranges between 18-23 (Davis, 2001). The present findings (Udzungwa Mountains) are similar to others reported for tropical rain forests, where species richness can often reach over 50 species (Escobar, 2000; Feer, 2000; Davis *et al*., 2001; Andresen, 2002). The higher number of species in UMNP might be a reflection of the diversity of dung (type of animals) is very high in UMNP, habitat diversity such as Miombo woodland, mountain forest and grassland patches. Also high number of species might be the result of habitat patchiness due to disturbance, which might have resulted in more niches for different animal species.

5. Conclusions and Recomendations

A total of 55 species collected from nine study sites, three from each disturbance gradient helps us to have a clear concept that UMNP is rich in dung beetle fauna. Considering the short time lapse between the present study and the banning of human activities, it is evident that, over sufficient time lapses, vegetation and animal species recovery will take place, and this may enhance the recovery of dung beetle fauna. Monitoring activities in areas that have been impacted as a result of human activities are highly encouraged as it is an important component in conservation issues. For this reason monitoring activities should be carried out in the park on yearly basis to have more knowledge on recovery of dung beetle fauna and other aspects as far as biodiversity is concern. Future studies on monitoring activities should address the feeding guilds in dung beetles, and differences in biomass of dung beetles among the three study sites. This will help to have a clear understanding on the functional diversity of dung beetles.

REFERENCES

Andresen, E. (2002). Effect of forest fragmentation on dung beetle communities and functional consequences for plant regeneration, *Journal of Ecography*, 26, 87-97

Bakarr, M. (ed.) (2000). Biodiversity conservation and forest resource management in the Udzungwa Mountains, Tanzania. Technical report of Workshop held on October 23-24, 2000,UMNP Headquarters, Mang'ula, Tanzania

Boonrotpong, S., Sotthibandhu, S., & Pholpunthin, C. (2004). Species Composition of Dung Beetles in the Primary and Secondary Forests at Ton Nga Chang Wildlife Sanctuary, *Journal of Science Asia,* 30**,** 59-65

Bornemissza, F. (1970). Insectary studies on the control of dung breeding flies by the activity of dung beetle, *Onthophagus gazella* F. (Coleoptera: Scarabaeinae). *Journal of Australian Entomological Society,* 9, 31-41

Connell, H. (1978). Diversity of tropical rain forests and coral reefs. *Journal of Science,* 199, 1302– 1310

Davis, J. (2000). Does reduced-impact logging help preserve biodiversity in tropical rainforests? A case study from Borneo using dung beetles (Coleoptera: Scarabaeoidea) as indicators. *Journal of Environmental Entomology,* 29, 467–475

Davis, J., Holloway, D., Huijbregts, H., Krikken, J., Kirk-Spriggs, H. & Sutton, L. (2001). Dung beetles as indicators of change in the forests of northern Borneo. *Journal of Applied Ecology,* 38, 593–616

Estrada, A., & Coates-Estrada, R. (1991). Howler monkeys (*Alouatta palliata*), dung beetles (Scarabaeidae) and seed dispersal - ecological interactions in the tropical rain forest of Los Tuxtlas, Mexico. *Journal of Tropical Ecology, 7*, 459-474.

Escobar, F. (2000). Diversidad de coleópteros coprófagos (Scarabaeidae: Scarabaeinae) en un mosaico de hábitats en la Reserva Natural Nukak, Guiviare, Colombia. *Journal of Acta Zoologica Mexicana* 79, 103-121

Feer, F. (2000). Dung and carrion beetles of the rain forest of French Guiana: composition and structure of the guild. *Annales De La Societe Entomologique De France,* 36, 29–43.

Government of Tanzania (2006). *A study to establishing mechanism for payments for water environmental services for the Rufiji River Basin in Tanzania. Revised Report*. Ministry of Natural Resources and Tourism, Forest and Beekeeping Division. Economic Research Bureau, University of Dar es Salaam.

Grønvold, J., Sommer, C., Holter, P., & Nansen, P. (1992). Reduced splash dispersal of bovine parasitic nematodes from cow pats by the dung beetle *Diastellopalpus quinquedens*. *Journal of Parasitology,* 78, 845–848

Halffter, G., Favila, E., & Halffter, V. (1992). A comparative study on the structure of the scarab guild in Mexican tropical rain forests and derived ecosystems. *Folia Entomolo'gica Mexicana,* 84, 134–156

Halffter, G., & Matthews, G. (1966). The natural history on dung beetles of subfamily Scarabaeinae (Coleoptera: Scarabaeidae). *Folia Entomolo´gica Mexicana,* 12, 1– 312

Hanski, I., & Cambefort, Y. (eds) (1991). *Dung beetle ecology*. Princeton University Press, Princeton, New Jersey

Harrison, P., Burgess, N.D., Butynski, T.M., Cordeiro. N.J., Doggart, N.H., Fjeldsa, J., Howell, K.M., Kilahma, F.B., Loader, S.P., Lovett, J.C., Mbilinyi, B., Menegon, M., Moyer, D.C., Nashanda, E., & Perkin, A. (2006). *Socio-Economic study of the Udzungwa Scarp area: a potential wildlife corridor. Incorporating livelihood assessments and options for future management of Udzungwa Forests.* Unpublished report for Critical Ecosystem Partnership Fund and WWF-Tanzania.

Hayes, L., Mann, D.J., Monastyrskii, A.L. and Lewis, O.T. (2009). Rapid assessments of tropical dung beetle and butterfly assemblages: contrasting trends along a forest disturbance gradient. *Journal of Insect Conservation and Diversity*, 2, 194–203

Hill, C.J. (1995). Linear strips of rain forest vegetation as potential dispersal corridors for rain forest insects. *Journal of Conservation, Biology*, 9, 1559–1566

Holloway, J.D., Kirk-Spriggs, A.H., & Vun, K.C. (1992). The response of some rain forest insect groups to logging and conversion to plantation. Phil T Royal Soc London. *Journal of Biological Science,* 335, 425–436

Howden, A.T., & Nealis, V.G. (1975). Effects of clearing in a tropical rain forest on composition of the coprophagous scarab beetle fauna (Coleoptera). *Journal of Biotropica,* **7**, 77–83

Larsen, T.H., Williams, N.M., & Kremen, C. (2005). Extinction order and altered community structure rapidly disrupt ecosystem functioning. *Ecological Letter,* 8, 538–547

Lee, J.S.L., Lee, I.Q.W., Lim, S.L., Huijbregts, J., & Sodhi, N. S. (2009). Changes in dung beetle communities along a gradient of tropical forest disturbance in South-East Asia *Journal of Tropical Ecology*, 25, 677–680.

Liberal, CN., de Farias, I.Â.M., Meiado, M.V., Filgueiras, B.K.C., & Iannuzzi, L. (2011). How habitat change and rainfall affect dung beetle diversity in Caatinga, a Brazilian semi-arid ecosystem. *Journal of Insect Science,* 11, 114

Lumaret, P. & Kirk, A. (1991). South temperate dung beetles. In *Dung Beetle Ecology* Hanski, I., & Cambefort Y, (eds) pp. 97–115. Princeton, NJ: Princeton University Press.

Lovett, J.C., and Wasser, S.K. (1993). Biogeography and Ecology of the Rain Forests of Eastern Africa. *New York: Cambridge University Press*, 341 pp.

Masis, A., & Marquis, J. (2007). Dung Beetle (Coleoptera: Scarabaeoidea) Community Response to Clear-cutting in the Missouri Ozarks. *Journal of the Kansas Entomological Society,* 80, 146-155

Medina, C.A., Escobar, F., & Kattan, G.H. (2002). Diversity and habitat use of dung beetles in a restored Andean landscape. *Journal of Biotropica,* 34, 181–187

Mico,´ E., Verdu,´ R., & Galante, E. (1998). Diversity of dung beetles in Mediterranean wetlands and bordering bushwood. *Annals of Entomological Society of America,* 91, 298–302

Mittal, I.C. (1993). Natural manuring and soil conditioning by dung beetles. *Journal of Tropical Ecology,* 34, 150-159.

Nichols, E., Larsen, T., Spector, S., Davis, A., Escobar, F., Favila, M. and Vulinec, K. (2007). Dung beetle response to tropical forest modification and fragmentation: a quantitative review and meta-analysis. *Journal of Biological Conservation,* **137**: 1-19

Nyundo, B.A., Mtui, A., & Kissaka, H. (2006). Assessment of ecological and social impacts caused by collection of deadwood and medicinal plants and cutting of grass for thatching in Udzungwa Mountains National Park. Unpublished report to TANAPA/WWF-TPO

Rovero, F., Nyundo, B.A., &Kitegile, A.S. (2008). The impact of human disturbance (especially deadwood collection) on the biodiversity of Mwanihana forest, Udzungwa Mountains National Park: a re-assessment following the 2005 study. Report by World Wide Fund for Nature Tanzania Programme Office, Tanzania

Seaby, R.M., & Henderson, P.A. (2006). *Species Diversity and Richness version* 4. Pisces Conservation Ltd., Lymington, England

Scheffler, Y. (2005). Dung beetle (Coleoptera: Scarabaeidae) diversity and community structure across three disturbance regimes in eastern Amazonia. *Journal of Tropical Ecol*ogy, 21, 9–19

Shahabuddin, Schulze, H., & Tscharntke, T. (2005). Changes of dung beetle communities from rainforests towards agroforestry systems and annual cultures in Sulawesi (Indonesia). *Journal of Biodiversity Conservation,* 14, 863– 877

Shahabuddin, (2011). Effect of land use change on ecosystem function of dung beetles: experimental evidence from Wallacea Region in Sulawesi, Indonesia. *Journal of Biodiversitas* 12, 177-181

Shahabuddin, (2010). Diversity and community structure of dung beetles (Coleoptera: Scarabaeidae) across habitat disturbance gradient in Lore Lindu National Park, Central Sulawesi. *Journal of Biodiversitas* 11, 29-33.

UNESCO & MNRT. (2010). Nomination of properties for inclusion in the world heritage list. Serial nomination Eastern Arc Mountain Forest of Tanzania

Wilson, E.O. (1998). The current state of biological diversity.In Wilson EO (ed) *Biodiversity. National Academy press*, Washngton DC., pp. 3-18