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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

A report by
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Executive Summary

This study conducted an assessment of the dung beetle community at the edge of Mwanihana forest, in the eastern part of the Udzungwa Mountains National Park, repeating a baseline study done in July 2005. Like other invertebrates, dung beetles are excellent indicators of the status of the biodiversity of the forest floor. They were therefore used to assess the impact on the park's biodiversity of dead wood removal, a practice allowed in this area of the park since its establishment in 1992. Dung beetles were collected through pitfall traps set along 8 sites (12 traps in each site), and kept for 24 hours. Sampling was repeated 3 times at each site within a month. Of the 8 sites, 2 were in undisturbed areas (control = L1), 3 in moderately disturbed areas (L2) and 3 in heavily disturbed areas (L3). The level of disturbance (amount of deadwood removal) was inferred from the abundance of human population in settlements adjacent to the forest. The baseline assessment in 2005 found decreased abundance from control to moderately disturbed sites of dung beetles collected, but highest abundance at most disturbed sites. Dung beetle species' diversity was impoverished in areas of the forest that were more intensively utilized (L3 versus L2), thus clearly revealing the negative impact on biodiversity of firewood collection. The present study found similar trends in dung beetles abundance and species diversity as revealed in 2005, except that diversity was lowest at control sites (L1) and not intermediate, probably because one control site at Lumemo, in a different forest, was not repeated given the potential bias of sampling different dung beetle communities. The increased abundance and diversity at disturbed versus control sites is considered an effect of vegetation and forest floor alteration creating a greater number of ecological niches for dung beetles.

In general, the results indicate that there has not been significant changes in the negative effects on dung beetles of dead wood removal for firewood, contrary to expectations following the halving in the number of days that communities are allowed to enter the park (from two days to one day per week). Complementary data were also reviewed and helped putting results in a broader context. Results of disturbance transects conducted in 2006 (counts of timber tree, pole cuts, snares and other signs of encroachment), albeit not providing any information on forest floor biodiversity, indicate that the park is well protected from illegal encroachment, especially when compared to southern forests in the Udzungwa. However, data on monitoring of primates and duikers seem to indicate a possible decrease in the relative abundance of baboons and Harvey's red duikers, two species that occurs in the lower zone utilized for firewood collection and two ground-dwelling species that might be more sensitive than others to forest floor disturbance.

The most important recommendations from this study is that more efforts should be put into helping communities to become self-sufficient for energy sources if the negative effects of collecting firewood in the National Park are to be decreased and eventually stopped. In particular, the "once-per-week" firewood collection policy should be seriously reviewed, and alternatives explored, such as access restricted to selected zones or establishment of a system (e.g. provision of individual entry permits) to control the amount of firewood collected.

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This report is intended to inform the wider stakeholders interested in the Udzungwa Mountains Ecosystem and is available at WWF's website http://www.pand.org

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Photographs by F. Rovero

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Background

The outstanding importance for biodiversity and ecosystem services of the Udzungwa Mountains has been widely recognized. Despite this, the area is still very vulnerable to human disturbance, especially along the eastern side of the mountain slopes that face the densely populated Kilombero valley. Disturbance is higher along the southern forests (Kilombero Nature Reserve and Uzungwa Scarp Forest Reserve), than along the eastern side of the Udzungwa Mountains National Park-UMNP (Museo Tridentino di Scienze Naturali 2007), despite human density being actually higher along the eastern side of UMNP. However, firewood collection is allowed inside the UMNP by the communities inhabiting the several villages along the eastern edge, and unfortunately the negative impact of this practice on the park's biodiversity has been largely overlooked.

For protected areas facing high human pressure, such as the Udzungwa Mountains, quantitative assessment of human disturbance on biodiversity is obviously critical for interpreting biodiversity trends and thus evaluating protection strategies. Yet, only recently this concept is beginning to be conceptualized into a framework whereby a "Zone of Interaction" between parks and human influence is defined, and systematic monitoring of human influence inside this area is recommended [see DeFries et al. (in press) for more details including a case study on the Udzungwa Mountains].

In the Udzungwa Mountains National Park, a study funded by WWF-Tanzania titled "An assessment of ecological and socio-economic impacts caused by collection of deadwood, medicinal plants and cutting of grass for thatching in Udzungwa Mountains National Park" was conducted in 2005 by Nyundo et al. (2006). This study was the first to quantitatively assess the impact of human disturbance, especially firewood collection, on the park's biodiversity. The study focussed on Mwanihana forest, which is the eastern-facing forested slope on the eastern side of the park.

The study used dung beetles as indicator group of forest floor disturbance, and results clearly revealed a negative trend in the ecological diversity in areas where deadwood collection was supposed to be most intense based on higher population density, especially in proximity of the two main population centres near the Park (Mkamba town in the north and Mwaya/Mang'ula towns near the Park Headquarters). This pattern was predicted by a disturbance hypothesis, and it was reported that "<u>although at present the situation has not yet reached a critical stage, if allowed to continue a stage will be reached when local species extinction will take place</u>".

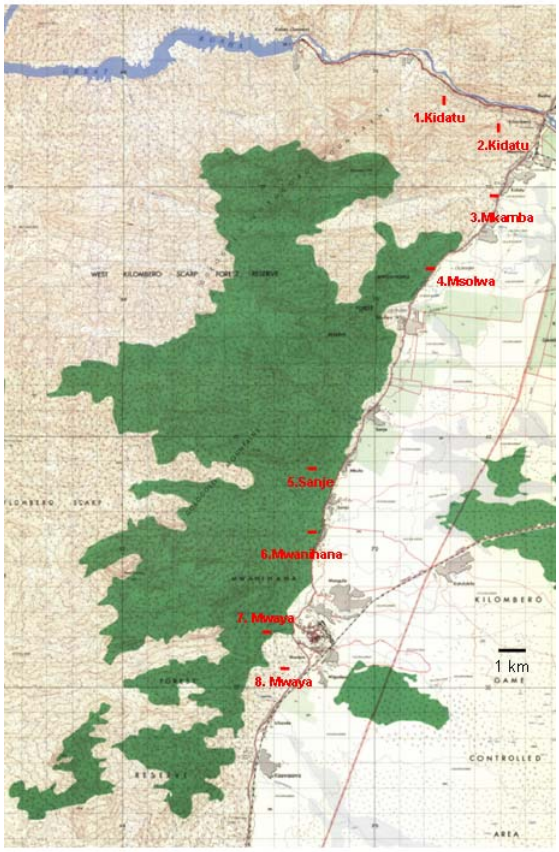
In a follow-up meeting between various stakeholders, it was agreed that firewood collection should be progressively phased out by 2011. Specifically, since 2006, it was decided that firewood collection should take place only once a week instead of twice, and exclusively by women. A second resolution was that the Park authorities should carry out regular monitoring to assess the impact of the new arrangement. The present study aims at repeating the study conducted in 2005 to assess whether changes occurred in the effect of human disturbance on biodiversity (as indicated by the species' diversity of the dung beetle community).

The key **objective** of the research study proposed was therefore to re-assess the impact of human disturbance on the biodiversity of UMNP as evaluated through dung beetles sampling in 2005, thus providing the first temporal trend on the impact of firewood collection that will help management strategies.

The study also reviews complementary data on human disturbance that may help interpreting the results from the dung beetle assessment.

METHODS

During July 2008, dung beetles were sampled along a disturbance/intensity of utilization gradient placed from forest edge to forest interior all along Mwanihana forest. The study sites and methods were the same as those employed during the baseline survey in 2005 (see Nyundo et al. 2006, map and table below). These included 3 sites adjacent to densely-populated areas (Mkamba, Mang'ula and Mwaya), three intermediate sites (Sonjo, Sanje and Mkula) and control sites in areas where human activity was absent or minimal (two sites near the Tanesco hydropower plant at Kidatu). A third site in Lumemo was not visited due the greater distance and related logistic problems. Detailed locations and descriptions of the study sites are provided in the Table 2 at page 14 of Nyundo et al. (2006). Shannon-Wiener Index of diversity was computed from sub-samples of the original samples (using a Computer Software by Henderson and Seaby, 2001), and t-test used for test of significance.



Topographic map (scale 1:10,000) of Mwanihana forest with locations of the 8 transects along which dung beetle were collected

Dung-burying beetles have been sampled using pitfall traps baited with fresh cow-dung (see photo below). At each transect, 12 pitfall traps were set at distances of 0m, 40m, 100m and 250m from the forest edge, i.e. 3 pitfall traps at each distance, with distance between traps of 10m. The traps were made of 1-litre plastic cups. The traps were set in the morning and emptied after 24 hours. Cups were half-filled with water with a few drops of a detergent added to break the surface tension. Cups were baited with fresh cow dung tied into a piece of light clothing material and placed at the top of the pitfall trap on 2 wood sticks. Collected dung beetles were

sieved from the traps and immediately transferred into specimen bottles containing 80% alcohol. Specimens were carried to the University of Dar es Salaam for identification.

Table with locations and description of the study sites (from Nyundo et al. 2006)

No.	SITE	LEVEL OF DISTURBANCE	LOCATION (UTM coordinates)	DESCRIPTION
1	P1	Low (control)	271738 9154749	Primary forest near Kidatu HEP project.
2	P2	Low (control)	274085 9153161	Intact primary forest near Kidatu HEP project.
3	P3	Low (control)*	243198 9114309	Intact woodland/forest near Lumemo Post
4	M1	Intermediate	272511 9146700	Moderately used forest near a teak plantation
5	M2	Intermediate	268909 9138948	Moderately used forest near Sanje Post
6	M3	Intermediate	268909 9136366	Moderately used forest near Mwanihana trail
7	D1	High	275300 9150205	Highly disturbed forest near Mkamba Village
8	D2	High	266350 9132356	Disturbed forest near TANAPA Mang'ula HQ
9	D3	High	2666609 9131744	Highly disturbed forest/woodland adjacent Mwaya Town

*Not re-sampled in 2008

Photo of a baited pit-fall trap used in the study

In addition to repeating the dung beetle study, we reviewed available data on human disturbance. "Disturbance transects" have been conducted in late 2006 throughout Mwanihana forest and the southern, less protected forests (Nyanganje, Matundu, Iyondo and Uzungwa Scarp) for a study conducted by the Museo Tridentino di Scienze Naturali (2007) aimed at assessing protection status and connectivity options. We refer to that report for methodological details. Disturbance transects are used to count evidence of poles and timber trees being cut, as well as other encroachment signs (snares, human trails, pitsowing sites, fires, etc.).

We also present here updated results of primate and forest antelope monitoring conducted by the Udzungwa Ecological Monitoring Centre (UEMC) in Mwanihana forest. Data have been collected since 1998 and represent the only long-term data-set currently available against which the effect of forest management strategies can be evaluated. Data have been collected along three transects, 4 km in length, for over 90 repetitions for each transect conducted thus far (data for Harvye's duiker are from a subset of 53 repetitions).

RESULTS and DISCUSSION

Dung beetle study

A total of 9,344 dung beetles were sampled from the eight study sites, compared to 10,243 during the earlier study in 2005. The mean abundance at each level was 30.23 individuals per sample at control sites (level 1, Undisturbed), 24.07 at medium utilization sites (level 2) and 55.74 at highly utilized/disturbed sites. Kruskal-Wallis test showed that the difference was significant ($H=22.139$, $p<0.001$). All species collected during the baseline study are represented in the present study, except for two rare species (see table in Appendix for full list of species).

The Table below shows the Shannon-Wiener H' diversity indexes for both studies, and results of statistical comparison of results for the two studies. There was no significant change in the diversity of dung beetles at moderately and heavily utilized sites. At the control sites, diversity was significantly lower compared to 2005.

Table showing Shannon-Wiener index of species diversity (H') for dung beetles collected in Mwanihana forest in the UMNP in 2005 and 2008

LEVEL OF DISTURBANCE	2005 (Baseline)[1]	2008 (Present study)	Results of statistical comparison
L1 (Control)	2.4330	2.0763	Significant ($p<0.001$)
L2 (Moderate)	2.5584	2.6256	Not significant ($p=0.1378$)
L3 (Disturbed)	2.2356	2.2143	Not significant ($p=0.2770$)

The trend of variation in dung beetles abundance across sites is consistent with results from the previous study, with abundance decreasing from L1 to L2, but increasing to highest levels at the most disturbed sites (L3). On the contrary, the pattern in species' diversity is slightly different than in 2005, with lowest diversity recorded at Level 1 of disturbance (control sites). This is probably because one of the 3 original study sites (Lumemo) was omitted during the present study. This latter site was located at a different forest from the remaining cluster of 8 sites, thus probably inflating the diversity of this level through different species composition. As a result of this lower diversity found at control level, the variation of diversity across the 3 levels of disturbance does not support the "intermediate disturbance hypothesis" suggested to explain the trend obtained in 2005. The pattern of increased diversity from control to disturbed sites may be an effect of higher heterogeneity - thus greater number and variety of microhabitats – allowing for a more diverse community of beetles to occur. Most importantly, however, that the difference in species diversity recorded between low and high disturbance sites (L2 versus L3) are even more pronounced than in the 2005 study indicates that dung beetles are good indicators of disturbance, with species diversity decreasing in the more densely populated areas.

The results overall indicate clearly that diversity of dung beetles at both sites where firewood collection occurs (L2 and L3) has not changed significantly over the 3-year period considered.

[1] Data collected in 2005 were re-analysed to compare them with present data, using a computer package, and as a result it was realized that due to computational mistakes the values of diversity index H' reported earlier were not correct.

Because of the correlation found by many studies between invertebrate diversity and dead wood removal (see Nyundo et al. 2006 for a review), results in turn indicate that the measure of reducing the number of days for firewood collection from twice to once a week may not have actually led to any decrease in dead wood removal. Otherwise we would have expected an increase in species' diversity at least at the most disturbed sites. Additional repetitions of the study in the future will be critical to confirm the validity of the trends revealed.

In the original report, it was emphasized that the success of the new policy was dependent on local communities increasingly adopting alternative sources of energy than firewood, primarily through fuel-efficient stoves and plantations of wood plots for firewood on a large scale. The importance of such recommendation is re-enforced by our findings, since dependence of firewood from the park has remained unaltered and no decrease has probably occurred.

Photos showing various phases of the fieldwork for the dung beetle assessment: Dr. Nyundo training students and field assistants (left), sorting specimen at the Udzungwa Ecological Monitoring Centre (top right) and emptying pitfall traps in the field (bottom right).

Review of other data

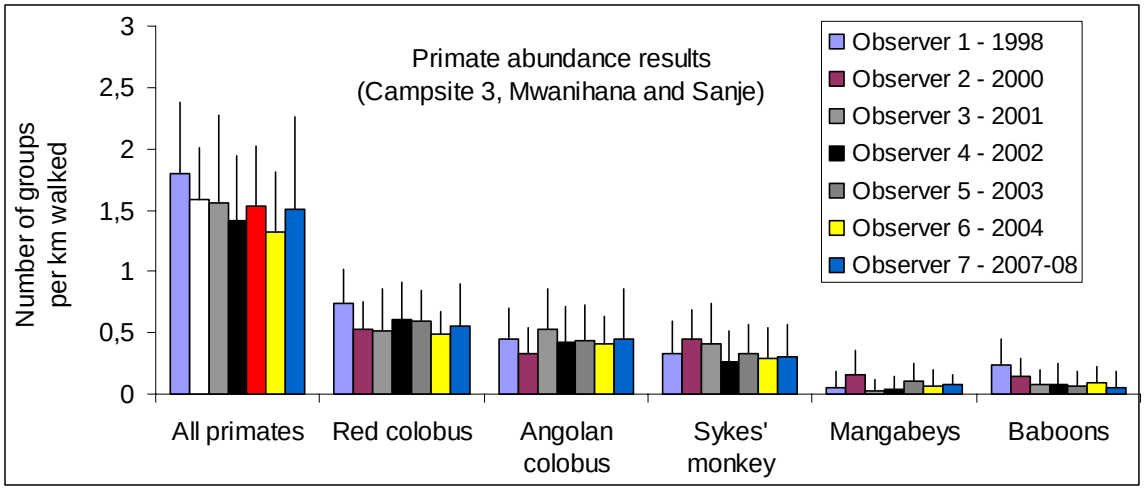
A review of other indicators of disturbance might help putting our results in a broader context. The disturbance transects conducted in Mwanihana forest in 2006 (Museo Tridentino Scienze Naturali 2007) showed that Mwanihana seems very well protected in comparison to southern forests, as shown by the following table: there resulted almost absence of disturbance with the exception of some pole cutting and very minimum timber tree cutting. It should be noted, however, that transects were only measuring disturbance at the lower 0.5 km zone of forest from the edge to forest interior, whilst timber tree cutting especially in the northern area above Msolwa sporadically occur in the more interior part of the forest (F. Rovero personal observation).

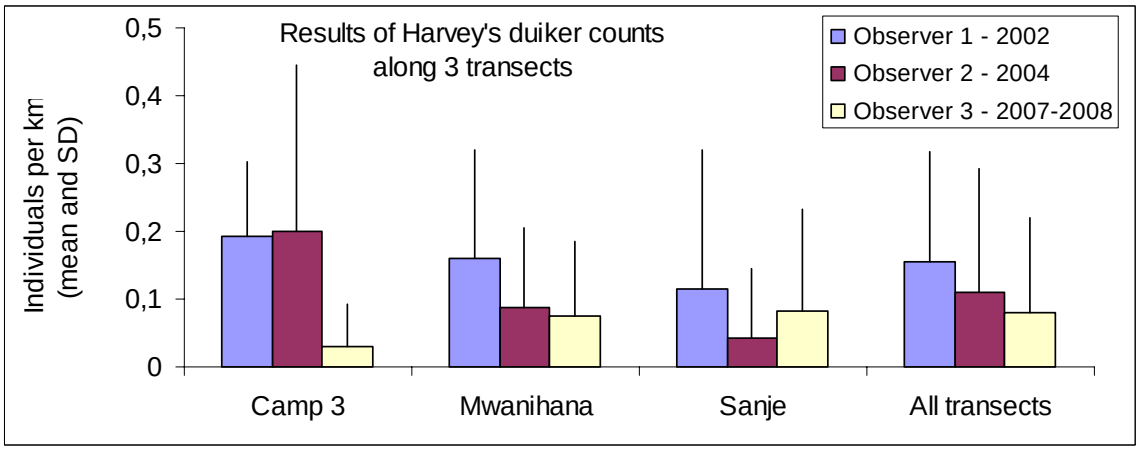
Table showing the results of disturbance transects conducted by Museo Tridentino di Scienze Naturali (2007) in Mwanihana and south-eastern Udzungwa forests.

	Mwanihana (National Park)	**Nyanganje**	**Matundu**	**Iyondo**	**USFR**
Number of 0.5 km transects	20	24	40	23	25
Total km walked	10	12	20	11,5	12,5
Freshly-cut poles (n/km)	1,0	1,5	2,1	22,5	33,7
Mean freshly-cut pole index*	0	0,01	0,01	0,07	0,15
SD of pole index	0	0,01	0,02	0,07	0,12
Freshly-cut timber trees (n/km)	0,3	2,6	0,3	11,2	27,3
Mean freshly-cut timber index*	0	0,01	0,00	0,03	0,07
SD of timber index	0	0,02	0,00	0,03	0,07
Recent and active pitsawing sites (n/km)	0	0,3	0,1	0,4	0,2
Snares (n/km)	0	0	0,4	1,5	0,1
Charcoal-making sites (n/km)	0	0	0	0,3	0,2
Snares+charcoal+recent pitsawing (n/km)	0	0,3	0,5	2,2	0,6
Old cut poles (n/km)	26,4	22,4	11,0	15,3	32,6
Old cut timber trees (n/km)	10,3	14,0	6,4	10,6	19,4
Old pitsawing sites (n/km)	1,8	0,4	0,5	1,6	1,0

* Index computed as: number of poles cut / (total number of poles counted + poles cut). It is the proportion of poles cut on the total number of stems counted in the transect strip (see Methods for details).

The results of primates and duiker counts conducted since 1998 (sources: Rovero et al. 2006, UEMC unpublished data) are reported in the two following charts. As discussed in details for a subset of data (Rovero et al. 2006, Rovero and Mtui 2006, UEMC 2008), the updated comparison continues to support the overall stability in the relative abundance of species counted, with variations not revealing any temporal trends and attributed to the expected differences in census ability by the different observers that have been involved in the monitoring over the years. However, a suspected decline in the abundance of baboons and red duikers indicated in the UEMC first technical report (UEMC 2008) seems supported by the more recent data. Baboons and red duikers are two species that are likely to be most impacted by firewood collection, as baboons almost exclusively occur in the lower miombo zone of the forest, and red duikers, albeit not exclusively, are also often seen in this habitat. Both species forages on the forest floor. The possible decline in red duiker from the 3 transects is, however, only due to a statistically significant decline at Campsite 3 transect (and to a less extent the Mwanihana transect), which are closer to Mwaya and Mang'ula, i.e. adjacent to the some of the most intensively settled areas. These results should be interpreted with caution, however, as longer-term data with confidence on the inter-observer consistency will be required to assess how realistic is the trend obtained.





Results of counts of primates (above) and Harvey's red duiker (below) made along 3 transects in Mwanihana forest, Udzungwa Mountains National Park by several observers. Data are mean (and standard deviation) number of groups (for primates) and individual duikers seen per km of transect walked. Data are from: Rovero et al. 2006, Rovero and Mtui 2006, UEMC 2008, UEMC and F. Rovero unpublished data.

CONCLUSIONS and RECOMMENDATIONS

By repeating the dung beetle assessment conducted in 2005, the present study laid a framework for a monitoring project that we highly recommend for continuation, preferably on a yearly basis. Like for any monitoring study, much care should be ensured that field and analytical methodology are standardized. Whilst disturbance transects are not aimed at assessing impact of firewood collection, they do provide important, complementary information and should therefore be considered in the future for a systematic monitoring protocol to measure other forms of encroachment such as hunting, pole and tree cutting. For the purpose of directly assessing the mass of dead wood collected, and restoration of dead wood mass following any change in protection measure), future work should consider sampling the "Coarse Wood Debris" (CWD, e.g. Woldendorp et al. 2004). Ideally, the study design should include (1) control, (2) artificially fenced, and (3) utilization areas. The primate and duiker monitoring programme has also proved critical to provide indications of possible negative effects caused by human disturbance. The apparent decline emerging for red duikers and baboons – which may well be a direct or indirect effect of firewood collection - is a matter of concern and should be more finely assessed in future work.

The most important recommendation from the study results is that much effort still needs to be put in place to help communities becoming self-sufficient for energy sources if the negative effects of firewood collection in the National Park are to be decreased and eventually stopped. In particular, the "once-per-week" firewood collection policy should be seriously reviewed, and alternatives explored, such as a revised and strict control of zones allowed for dead wood collection, and the establishment of a system that controls the amount of firewood taken (perhaps by granting individual entry permits).

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APPENDIX: Table with the list of dung beetles (data are number of individuals) collected from the three levels of disturbance in Mwanihana forest, July 2008

Species	L1	L2	L3	Total
DB1	93	121	829	1043
Sisy1	132	61	359	552
DB3	118	82	249	449
ScaptSeg	24	44	275	343
DB2	17	87	185	289
DB9	4	25	107	136
OnthLac	2	31	94	127
Sisy3	20	62	39	121
DB5	12	22	81	115
AnaProc	9	64	29	102
DB6	18	11	39	68
Sisy2	10	26	28	64
DB7	2	15	8	25
CoprisSp	0	2	16	18
OnthAreo	8	6	4	18
DB23	0	0	18	18
DB8	1	8	6	15
DB24	0	0	13	13
OnthMisc	0	11	0	11
OnthPugi	0	0	11	11
DB10	3	4	3	10
DiastThom	1	6	1	8
Cathar2	0	1	6	7
CatharSp	0	2	4	6
CoprisGil	6	0	0	6
GareAzur	0	0	4	4
DB19	0	0	3	3
Copris1	0	1	1	2
DB12	0	0	2	2
DB20	1	0	0	1
DB25	1	0	0	1
No. Species	**20**	**22**	**27**	**36**