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Impact of habitat disturbance in the wetland forests of East Usambara, Tanzania

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Abstract

We evaluated habitat characteristics of East Usambara wetland forests. The abundance and species composition in the tree, shrub and herbaceous layers were enumerated in two sets of nested plots, one set in a natural wetland forest and the second in a wetland forest that had been disturbed by small-scale gold mining activities. Each set had thirty-six 1 m × 1 m plots for herbs, inside nine 5 m × 5 m plots for shrubs, in three 20 m × 20 m plots for trees. The habitat profile of herbaceous – shrub – tree layers was found to be sharply different from one obtained in previous studies at the surrounding nonwetland forests as were species composition and abundance. Unlike in the non-wetland forests, the herbaceous layer was thick, the shrub layer very thin and the woody species density and richness much lower. Disturbance significantly reduced woody cover and changed species composition in the herbaceous layer. Recovery of the woody vegetation was low. Wetland forests in the East Usambaras form a small fraction of the total area, but they are a unique biodiversity repository, they appear to be an important carbon dioxide sink and to reserve and purify water. They are sensitive to disturbance and need protection.

Key words: Disturbance effects, East Usambara, wetland plants

Résumé

Nous avons évalué les caractéristiques de l'habitat des forêts humides d'*East Usambara.* L'abondance et la composition des espèces dans les étages d'arbres, d'arbustes et d'herbes furent dénombrées dans deux ensembles de parcelles emboitées, un situé dans une forêt humide naturelle, l'autre dans une forêt humide qui avait été perturbée par les activités d'orpaillage à petite échelle. Chaque ensemble se composait de 36 carrés de 1 m^2 pour les herbes, situés dans neuf carrés de 5 m × 5 m pour les buissons, eux-mêmes situés à l'intérieur de trois carrés de 20 m × 20 m pour les arbres. Le profil des habitats pour les trois couches d'herbes – d'arbustes – d'arbres s'est révélé très différent de celui qui avait été obtenu lors d'études précédentes réalisées dans des forêts environnantes non humides; il en était de même pour la composition et l'abondance des espèces. Contrairement aux forêts non humides, la couche herbeuse était épaisse, la couche des arbustes très claire et la densité et la richesse des espèces ligneuses étaient beaucoup plus faibles. La perturbation avait significativement réduit le couvert ligneux et changé la composition des espèces de l'étage herbacé. La restauration de la végétation ligneuse était faible. Les forêts humides des East Usambara ne constituent qu'une petite fraction de la superficie totale, mais elles sont un sanctuaire unique pour sa biodiversité, elles semblent être un puits de carbone important et aussi retenir et purifier l'eau. Elles sont sensibles à toute perturbation et doivent être protégées.

Introduction

The East Usambara Highlands are part of the range of ancient mountain blocks, collectively known as the Eastern Arc that starts at Taita Hills in Kenya and ends with the Udzungwa Mountains in South East Tanzania. Largely owing to their old age, the forests on the mountains harbour very high diversity and level of endemism of flora and fauna (Rodgers & Homewood, 1982; Hamilton & Bensted-Smith, 1989; Lovett, 1998). Together with the Ethiopian Highlands, the Albertine Rift and the neogene volcanics (e.g. Mts Kilimanjaro and Kenya), they constitute the Eastern Afromontane Hotspot, which is known to be high on biodiversity and to contain a 31% level of plant

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endemism globally (Kuper *et al.*, 2004; Mittermeier *et al.*, 2004; http://www.biodiversityhotspots.org/xp/hotspots/afromontane/Pagesbiodiversity.aspx). In between the mostly steep forested hills are often swampy flat lands of varying sizes. The swamps are often covered with herbs (mostly Cyperaceae) and woody plants (trees and shrubs) and are here referred to as wetland forests.

Substantial research and field expeditions have studied aspects of the biology of East Usambara highland forests (Hamilton & Bensted-Smith, 1989; Newmark, 1994, 2004a,b; Newmark & Senzota, 2003; ANON, 2007a; Hanson, Newmark & Stanley, 2007; John & Kabigumila, 2007). However, to date, there is no detailed study that has examined the wetland forests of the area. The wetlands have a tendency to accumulate huge piles of dead organic matter that mineralizes very slowly (Kweyunga & Senzota, 2006). They are usually water saturated even during very dry periods and they might be playing an important role in water reservation and purification as well as carbon dioxide sequestration (*sensu* Mitsch & Gosselink, 2000; Finlayson, 2005). Furthermore, in October 2003, there occurred an influx of small-scale gold miners attracted by a discovery of alluvial gold deposits there. The ensuing mining activities took place largely in the wetland forests and altered the ecological set-up and functioning of the affected forests (Senzota, 2004; Kweyunga & Senzota, 2006). This article details results of a study that evaluated species composition of plants in the wetland forests and makes a comparison between the wetland and the surrounding hills forests, a forest impacted by gold mining and a natural (un-impacted) forest, and a 1.5 year trend on the succession of the impacted forest.

Materials and methods

The present study was conducted at the natural (Monga) and disturbed (Jangili) forests in the East Usambara Mountains, Tanzania. The natural forest site (Monga), is situated at 05°05.92′S, 38°35.14′E and 990 masl; the disturbed site (Jangili) is at 05°05.17′S, 38°35.32′E and 1082 masl. The sites are surrounded by hills of varying gradients that were mostly covered by patches of forest, tea estates and cultivated crops. At each site, the relief was almost level and the parent material sandstone (Kweyunga & Senzota, 2006). Following the disturbance from gold mining activities, an assessment was made, in February 2004, of ecological impact at the wetland forest (Jangili) as detailed in Senzota (2004). Trees and shrubs were enumerated inside a 1 ha plot. The distinction between life forms (trees, shrubs and herbs) largely followed Pratt & Gwynne (1977), although shrubs also included tree saplings and herbs included woody plant seedlings. Subsequently, between November 2005 and February 2006, two sets of three 20 m × 20 m sample plots were established, one set at the disturbed forest (Jangili) site and the other at the natural forest (Monga) site. Inside each plot, all trees were named, enumerated and tagged and standard measurements were taken including DBH, canopy cover and heights. The states of trees were also recorded, namely fallen, leaning, standing, dead and alive (*sensu* Senzota, 2004). Plots were 50 m apart; the first plot at Jangili was about 20 m from the base of the main water ilet hill, while that at Monga started at about 40 m from the respective hill base. Inside each plot nested were three 5 m × 5 m plots for description of shrubs and twelve 1 m × 1 m plots for description of herbs (Fig. 1). The canopy cover of each shrub was determined using a tape measure; shrub heights were visually estimated. In the 1 m^2 plots, records were made of number of herbaceous (grass, sedges, forbs) stems and number of flowering and/or fruiting heads. The height and percent cover of the herbaceous layer were visually estimated per plot and subsequently average for all plots.

In the nonwetland forests on the hillsides, Lyaruu & Mbago (2000, 2004) have set 36 permanent nested plots

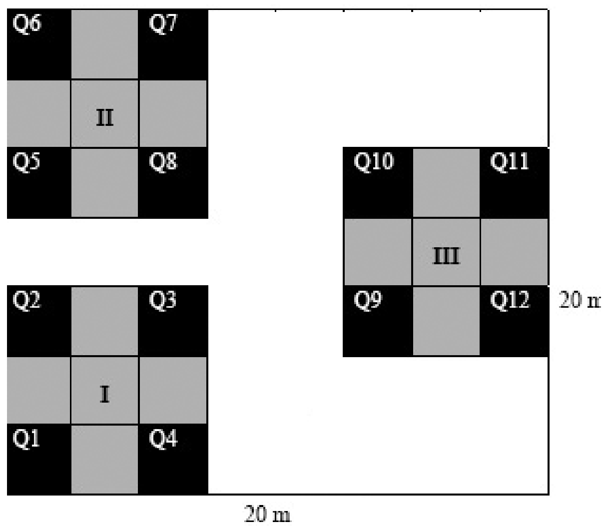

Fig 1 Sketch (not drawn to scale) of nested design for 1 m × 1 m quadrats (Q1 – Q12) inside 5 m × 5 m quadrats (I – III) inside the 20 m × 20 m plots set at the disturbed and natural wetland forests. East Usambara, Tanzania. November 2005 – February 2006

for regular monitoring of trees (20 m × 20 m plots), shrubs and juvenile trees (5 m × 5 m plots) and herbs and tree seedlings (1 m × 1 m plots). In each of their plots, tree DBH and number of plants have been recorded. They categorized the regular, nonwetland forests as primary, slightly disturbed and moderately (most) disturbed largely on the basis of the presence of *Maesopsis eminii* which is considered to be invasive in the East Usambaras. The present study makes a comparison of the wetland forest data with that from the surrounding hillsides forests according to Lyaruu & Mbago (2000, 2004). Statistical analyses followed Kent & Coker (1996) and Zar (1999). Cut off point for significance in the Jaccards Similarity Index followed Price (1975).

Results

Overall, 21 woody and 64 herbaceous plant species were recorded from the wetland forests in East Usambara (Table 1). The mining activities impacted over eight wetland forests in which there were heavy soil disturbance, tree felling and change in the water drainage system. At the Jangili site, in February 2004, over 40% of the trees were felled and over 80% of the area was devoid of vegetative cover. There was much variation in the similarity of trees and species richness between the disturbed and natural wetland sites and between the wetland sites and the regular hillside (nonwetland) forests (Table 1; Fig. 2). Considering the 50% cut off for significance, the disturbed Jangili site (in 2004) and natural Monga site (in 2006) had a significant species Jaccards Similarity Index (*S*j) at 50%; similarities between Jangili (2005) and Monga (in 2006) and wetland (present study) and nonwetland forests were insignificant at *S*j = 22.2% and *S*j = 27.8% respectively.

Considering the eight most common wetland trees, there was a significant change in the density of trees (including trees killed by mining activities) at the disturbed Jangili site between February 2004 and November 2005 ($P < 0.05$, two-tailed Wilcoxon Signed Rank Test); however, the more abundant species in 2004 were still the more abundant ones in 2005 (Spearman $r = 0.7918$, $P < 0.05$; Table 2; Fig. 2). *Voacanga africana* remained the predominant tree at the site (Jangili); there was, however, much reduction in abundance and species richness between 2004, the time when the site was freshly mined, and 2005, a period of about 1.5 years (Table 2). The percentage reductions were 45.2, 79.5 and 100 for *Voacanga, Bridelia* and *Syzygium* respectively. In the natural wetland forests, the roots of *V. africana* were found to have pneumatophores and to be mostly alive deep in the soil, those of *Bridelia* were mostly dead (Fig. 3).

The plot of DBH size classes depicted a near J-shaped trend for *V. africana* and all the three common species were dominated by lower DBH classes suggesting that the natural forests were healthy and in a positive growth trend (Fig. 4). The DBH size classes at the disturbed forest (Jangili) shifted from being dominated by <50 cm in February 2004 (86.3%) to being dominated by the >50 cm classes in November 2005 (69.7%); the DBH classes for the two periods were uncorrelated (Spearman *r* (two-tailed) = 0.3727; $P > 0.05$). However, the DBH classes obtained at the disturbed (Jangili) site in February 2004 were strongly positively correlated with those obtained from the natural (Monga) site in February 2006 (Spearman $r = 0.8000$; $P < 0.05$), suggesting existence of similar age structures for the two forests in the natural state. Tree canopy cover for the disturbed (Jangili) site in November 2005 was significantly lower than that at the natural (Monga) forest in February 2006 ($t = 3.182$; $P < 0.05$).

In the disturbed forest in February 2004, there was a profusion of coppicing from fallen live trees of all the dominant species, *Voacanga, Bridelia* and *Rauvolfia*. However, by November 2005, most of those trees were dead and no coppice had survived. Also, the shrubs recorded in November 2005 included *Lantana camara* which was also recorded in the natural wetland forest. As of November 2005, there was not a single sapling of *Voacanga africana.* Lyaruu & Mbago (2000) recorded a total of 48, 50 and 43 species of shrubs (including tree saplings) respectively in the 'primary' forests, slightly disturbed forests and 'moderately' disturbed forests at the nonwetland adjacent hills. The respective shrub densities were 15,367, 13,600 and 12,600 stems ha^{-1}. This is in sharp contrast with the situation at the natural wetland forest where, in the present study, only nine shrub species were recorded at a density of 4500 stems ha^{-1}; over 40% of the plots did not have a single shrub stem. Also, considering woody plants overall (trees and shrubs), *Bridelia* and *Voacanga* were not recorded in any of the 36 permanent research plots outside the wetlands; *Syzygium* was rare (two stems only) in the 'primary' forest plots and fairly common (four stems) in the slightly disturbed forest plots. *Lantana camara* was completely absent from all the 36 plots in the nonwetland forests; although it is common in the cultivated areas and along the road sides.

Table 1 Woody plants (trees and shrubs) and herbs (grass, sedges, forbs, tree seedling) recorded at the wetland forests in East Usambara, Tanzania

WOODY PLANTS
Alchornea hirtella[b] Benth.
Anthocleista zambesiaca[b] Baker
Bersama abyssinica[b] Fresen.
Bridelia micrantha[a,b] (Hochst.) Baill.
Combretum pentagonum[b] M.A.Lawson
Synsepalum cerasiferum[b] (Welw.) T. Pennington
Ficus sur[b] Forrsk.
Ficus thonningii[b] Blume
Galiniera saxifraga[b] (Hochst.)Bridson
Harungana madagascariensis[b] Poir.
Lantana camara[a,b] L.
Macaranga capensis[b] (Baill.)Sim
Newtonia buchananii[b] (Baker)G.C.C. Gilbert & Boutique
Parinari excelsa[a,b] Sabine
Rauvolfia caffra[b] Sond.
Sapium ellipticum[b] (Krauss)Pax
Solanecio mannii[b] (Hook.f.)C.Jeffrey
Syzygium guineense[a,b] (Willd.)DC.
Triumfetta rhomboidea[b] Jacq.
Voacanga africana[a,b] Stapf
Xymalos monospora[b] (Harv.)Warb.
HERBS
Acalypha neptunica[b] Muell.Arg.
Adenia rumicifolia[b] Engl.
Aframomum mala[a] (K.Schum.)K.Schum.
Ageratum conyzoides[b] L.
Aneilema aequinoctiale[b] Kunth
Aspilia mossambicensis[b] (Oliv.)Wild
Asplenium nidus[a] L.
Asystasia gangetica[a,b] (L.)T.Anders
Basella alba[b] L.
Bidens pilosa[b] L.
Blumea aurita[b] DC.
Centella asiatica[b] (L.)Urb.
Cissus rotundifolia[a] (Forssk.)Vahl
Clidemia hirta[a,b] (L.)D.Don
Chloris gayana[b] Kunth
Commelina beghalensis[b] Wall.
Conyza aegyptiaca[b] Dryand.
Cyperus digitatus[b] Roxb.
Cyperus exaltatus[a,b] Retz.
Cyperus undulatus[b] Kuk.
Desmodium repandum[a,b](Vahl)DC.
Dissotis rotundifolia[a,b](Sm.)Triana
Emilia coccinea[b] (Sim.)Sweet
Fuirena umbellata[b] Rottb.
Hewittia sublobata[b] (L.f.)Kuntze
Hibiscus surattensis[b] L.
Impatiens walleriana[b] Hook.f.
Impatiens nana[a] Engl.
Ipomoea acuminata[b] (Vahl)Roem.& Shult.
Ipomoea ficifolia[a,b] Lindl.
Justicia betonica[a,b] L.
Justicia nyassana[b] Lindau
Lantana camara[b] L.
Leersia hexandra[a] Sw.
Lobelia anceps[b] L.f.
Jussiaea abyssinica[a,b] (A.Rich.)Dandy&Brenan
Jussiaea jussiaeoides[a] (Desr.)Brenan
Macrotyloma axillare[b] (E.Mey.)Verdc.
Melanthera angustifolia[a] Gilli
Melanthera scandens[b] (Schumach. &Thonn.)Brenan
Mikania cordata[a,b] (Bum.f.)B.L. Rob.
Nephrolepis biserrata[a] (Sw.)Schott *Newtonia buchananii*[b] (Baker f..)G.C.C. Gilbert & Boutique
Oldenlandia capensis[b] L.
Oleandra distenta[a] Kunze
Panicum maximum[a,b] Jacq.
Panicum pleianthum[b] Peter
Panicum trichocladum[a,b] K.Schum.
Pellaea viridis[a] (Forssk.)Prantl
Plectranthus flaccidus[a] Gurke
Polygonum setosulum[a] A.Rich.
Pteris atrovirens[a] Willd.
Rubia cordifolia[a] L.
Rubus niveus[b] Thunb.
Rubus pinnatus[b] Willd.
Sabicea orientalis[a] Wernham
Scleria distans[b] Poir.
Scleria foliosa[a] Hochst.ex A.Rich.
Solanum incanum[b] L.
Solanum nigrum[b] L.
Acmelia caulirhiza De.
Tectaria gemmifera[a] (Fee)Alston
Typha capensis[a,b] (Rohrb.)N.E.Br. *Urochloa mosambicensis*[a] (Hack.)Dandy

[a]Present in natural forest (Monga).
[b]Present in disturbed forest (Jangili).

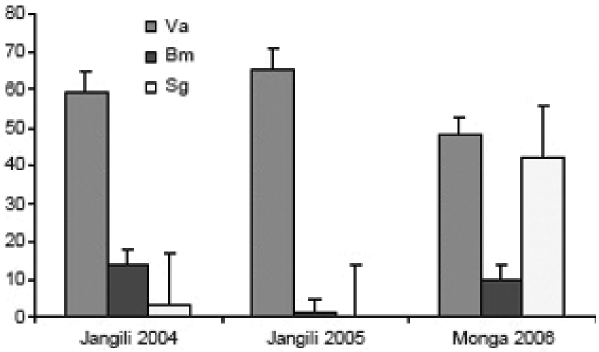

Fig 2 Percent composition (y-axis) of the three most abundant trees [*Voacanga africana* (Va), *Bridelia micrantha* (Bm) and *Syzygium guineense* (Sg)] at the Jangili (in February 2004 and November 2005) and Monga (in February 2006) sites with standard error bars. East Usambara, Tanzania

The profusion of the ground herbaceous layer, rich in both abundance and species richness (Table 1; Fig. 5) is in sharp contrast with the situation in the nonwetland forests, where the ground layer is often dominated by leaf litter. During the present study, 46 and 30 herbaceous species were recorded in the Jangili and Monga plots respectively.

Species Diversity (and Equitability) were 1.0482 (0.6964) and 1.1730 (0.4453) for Jangili and Monga plots respectively. Thus the disturbed Jangili site had slightly higher species richness and evenness, but was slightly lower on overall diversity. The difference in the diversities of the two sites was, however, insignificant ($t = 1.2494$; $P > 0.05$; df = 859). The two sites exhibited a high level of dissimilarity in their herbaceous species composition (*S*j = 13.2%. The predominant species (those with at least ten records from all plots) in the natural wetland plots were also mostly the least common in the disturbed wetland plots (Fig. 5).

Mean herbaceous cover was 70% at the disturbed (Jangili) wetland forest and 75% at the natural (Monga) wetland forest; the difference for the two sites was statistically insignificant (Mann–Whitney *U*-statistic = 589.00; $P > 0.05$). However, herbaceous layer in the natural wetland forest had a significantly higher stature (mean height = 97.8 cm) than in the disturbed wetland site (mean height = 38.5 cm) ($t = 6.695$; $P < 0.05$). Over 60% of herbaceous species recorded at the disturbed wetland forest had flowers and/or fruits, while at the natural wetland forest the figure was only 31%; the difference was statistically significant (Mann–Whitney *U*-statistic = 317.5; $P < 0.05$).

Discussion

The present study shows that species composition in the wetland forests differ significantly from that of the surrounding nonwetland forests suggesting that the wetlands contribute to the high biodiversity in the East Usambaras. The wetland predominant tree, *Voacanga africana*, is absent

Table 2 Density of typical wetland trees and shrubs (no/ha) at the various sites and times in East Usambara, Tanzania

Species	Jangili/Disturbed (Feb 2004)	Jangili/Disturbed (Nov 2005)	Monga/Natural (Feb 2006)	Hillside forests[c]
Voacanga africana	168	91.7	366.7	0
Anthocleista zambesiaca[a,b]	13	8.3	0	16.7
Rauvolfia caffra	14	8.3	0	0
Newtonia buchananii[a]	8	8.3	0	275
Sapium ellipticum[b]	25	16.7	0	3
Bridelia micrantha	39	8.3	75	0
Syzygium guineense	9	0	325	58.3
Parinari excelsa[a]	7	0	1	191.7
Ficus sur[a]	14	0	0	0
Bersama abyssinica[a,b]	5	0	0	0
Harungana madagascariensis[a,b]	6	0	0	8.3
Macaranga capensis[a]	11	0	0	8.3
SPECIES RICHNESS	12	6	4	–

[a]At periphery of wetland.
[b]Shrub.
[c]Derived from Lyaruu & Mbago (2004).
–, not applicable.

Fig 3 Left photo: knee rooting and air roots of *Voacanga africana.* Right photo: live roots of *V. africana* (L) and dead roots of *Bridelia micrantha* (R) from similar soil depths in the natural wetland forests of East Usambara, Tanzania. February 2006

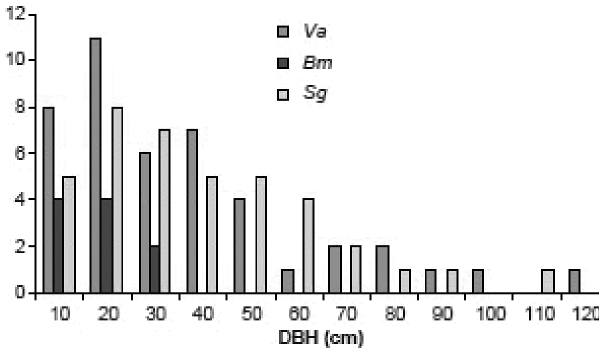

Fig 4 Frequency (total stem counts; y-axis) of DBH size classes for the three dominant tree species [*Voacanga africana* (Va), *Bridelia micrantha* (Bm), *Syzygium guineense* (Sg)] at the natural wetland forest (Monga). East Usambara, Tanzania; February 2006

in the surrounding hillside forests. It is well adapted to the wetland environment largely through its capability to form air roots that project above the water level (Palgrave, 1983). *Syzygium* is reported to be the most variable woody genus in Africa; it grows well in swampy areas wherein it has the tendency to produce elbow-angled roots. In a study where a species of *Syzygium* received a continuous flooding treatment, the plants did not show signs of physiological disorder (Lin & Lin, 1992). The range of DBH size classes is similar to that obtained from the surrounding nonwetland forests (Lyaruu & Mbago, 2004); both habitats were dominated by the young age class, suggesting good potential for recruitment. After 1.5 years postdisturbance, only *Voacanga* retained notable presence at the disturbed (Jangili) site where only half of the stems had completely disappeared. On the other hand, the disappearance rates of *Bridelia* and *Syzygium* were about 80% and 100% respectively. Even for *Voacanga* the DBH shifted from being dominated by the smaller classes to being dominated by the larger ones. In addition to the regular decay, a number of local residents collected fuel wood and building poles from the many woody stems and branches that had been felled through the mining activity. Both decay and collection would preferentially affect the smaller size classes because they are softer, lighter and easier to cut and carry. In addition, both *Bridelia* and *Syzygium* are much better fuel and building quality woods than *Voacanga,* hence a possibility for their preferential collection (Mbuya *et al.*, 1994; Senzota, 2004).

Unlike the nonwetland forests, the wetland forests had very little abundance and cover of shrubs, but a much higher abundance, diversity and cover of the herbaceous ground layer (Lyaruu & Mbago, 2004). In the hill forests of the Eastern Arc Mountains, the ground layer is usually devoid of herbaceous cover and is instead dominated by tree leaf litter (Nikundiwe *et al.*, 1998; Lyaruu & Mbago, 2000; Kalumanga, 2007). The special wetland conditions entail that only species adapted to such environment could

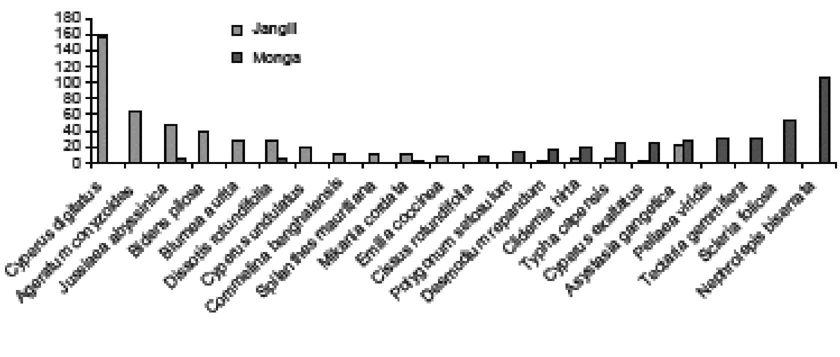

Fig 5 Relative abundance (total stem counts; y-axis) of herbaceous species that had a score of at least ten in natural (Monga) or disturbed (Jangili) wetland forest plots. East Usambara, Tanzania; November 2005 and February 2006

grow there (such as *Voacanga*). The paucity of shrubs entailed that more light could reach the ground layer thus stimulating growth of the herbaceous plants. Although herbaceous cover and diversity were of similar magnitude in the disturbed (Jangili) and natural (Monga) plots, growth at the latter site attained a significantly higher stature, but lower level of flowering and fruiting, possibly because of the paucity of woody canopy cover at the disturbed site. Woody cover increases shading and a corresponding high stature that would result from competition to access light.

Herbaceous species composition was found to differ significantly between the disturbed and natural forest sites. The natural forest was dominated by ferns and epiphytes while the disturbed habitat was dominated by rooted herbs. The dominant herb in the wetland forest was the giant swordfern (*Nephrolepis biserrata)* which often spreads rapidly using its long rhizomes (Croft, 1982). Disturbance improved water drainage thus promoting growth of rooted herbs. It also opened up the tree canopy thus allowing more light to be available to the herbaceous layer, which then became richer in species composition.

Wetlands are globally recognized as being important; they harbour unique biodiversity and associated values, they enable water preservation and purification and act as a major carbon dioxide sink. Some of the wetland forest plants are also of ethnobiological importance; they have a range of uses such as medicinal (*Voacanga africana, Syzygium guineense, Bridelia micrantha, Ageratum conyzoides)*, vegetables (*Nephrolepis biserrata, Asystasia gangetica)*, antivenin (*Bidens pilosa, Pellaea viridis, Solanum incanum)*, rituals (fronds of *N. biserrata*), timber and fuel wood (*B. micrantha, S. guineense)* and ornamental (*Jussiaea abyssinica, N. biserrata*) to mention only a few (Powell, 1976; Croft, 1982; Tona *et al.*, 1999; Jenks, 2002; ANON, 2004, 2007b; Ignacimuth, Ayyanar & Sankara Sivaram, 2006; Owour & Kisangau, 2006). Local people in the Usambaras traditionally exploit the forests for all of these uses.

Relatively much less effort has been put in understanding the basic functions and ecological processes that characterize the wetland habitats (Mitsch & Gosselink, 2000; Finlayson, 2005). Wetland forests in the East Usambaras might turn out to be significant in water preservation and purification for the inhabitants downstream. For reasons of their relatively small spatial coverage, any activities such as mining and farming that alter these rather delicate habitats should be avoided. Peterson & Heemskerk (2001) modelled forest recovery trends following small scale mining in the Amazon. They noted that forest recovery following mining tends to be slow and to end up being poor in vegetative cover and type of species. Quinn *et al.* (2005) found a marked change in vegetation following a reduction in water flow in the Kihansi Gorge, Tanzania.

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References

Anon. (2004) *Voacanga africana Seeds*. Available at: Psychoactiveherbs.com (and http://psychoactiveherbs.com/catalog/index.php?cPath=97-89) (accessed on 10 July 2008).

Anon. (2007a) *Building Expertise in Tropical Conservation: Annual Report*. Tropical Biology Association, Department of Zoology, University of Cambridge. Available at: http://www.tropical-biology.org (accessed on 10 July 2008).

Anon. (2007b) *Voacanga africana seeds from West Africa*. Trade Tie-up Promotion Program (TTPP). Available at: http://www3.jetro.go.ip/ttppoas/ankeen/0001092000/1092163-e.html. (accessed on 11 August 2009).

Croft, J. (1982) *Ferns and Man in New Guinea*. Paper presented at Papua New Guinea Botany Society (1982). Australian National Herbarium Centre for Plant Biodiversity Research, Canberra, Australia.

Finlayson, C.M. (2005) Plant Ecology of Australia's Tropical Flood Plain Wetlands: a review. *Ann. Bot.* **96,** 541–555.

Hamilton, A.C. & Bensted-Smith, R. (1989) (Eds). *Forest Conservation in the East Usambara Mountains*. IUCN, Gland.

Hanson, T.R., Newmark, W.D. & Stanley, W.T. (2007) Forest fragmentation and predation on artificial nests in the Usambara Mountains, Tanzania. *Afr. J. Ecol.* **45,** 499–507.

Ignacimuth, S., Ayyanar, M. & Sankara Sivaram, K. (2006) Ethnobotanical investigations among tribes in Madurai District of Tamil Nadu (India). *J. Ethnobiol. Ethnomed.* **2,** 25. (Open access article).

Jenks, C.W. (2002) Extraction studies of *Tabernanthe iboga* and *Voacanga africana*. *Nat. Prod. Lett.* **16,** 71–76.

John, J.R.M. & Kabigumila, J.D.L. (2007) Impact of *Eucalyptus* plantations on the avian breeding community in the East Usambaras, Tanzania. *Ostrich* **78,** 265–269.

Kalumanga, E. (2007) *Abundance and Diversity of Small Mammals in Disturbed and Undisturbed Forests at the Uluguru Mountains, Tanzania.* MSc dissertation, University of Dar es Salaam.

Kent, M. & Coker, P. (1996) *Vegetation Description and Analysis: A Practical Approach.* John Wiley & Sons, New York.

Kuper, W., Sommer, H., Lovett, J.C., Mutke, J., Linder, H.P., Beentje, H.J., Rompaey, R.A.S.R., Chatelain, C., Sosef, M. & Barthlott, W. (2004) Africa's hotspots of biodiversity redefined. *Ann. Mo. Bot. Gard.* **91,** 525–535.

Kweyunga, C. & Senzota, R.B.M. (2006) *Physical and Chemical Characteristics of Soils in Disturbed and Primary Wetland Forests of East Usambara, Tanzania.* Research Report; Departments of Botany/Zoology and Wildlife Conservation, University of Dar es Salaam, Tanzania.

Lin, C.H. & Lin, C.H. (1992) Physiological adaptation of waxapple to waterlogging. *Plant Cell Environ.* **15,** 321–328.

Lovett, J.C. (1998) Eastern Arc Mountain forests: past and present. In: *Trees of Amani Nature Reserve* (Eds L. Schulman, L. Junikka, A. Mndolwa and I. Rajabu). Ministry of Natural Resources and Tourism, Tanzania.

Lyaruu, H.V.M. & Mbago, F.M. (2000) Report on vegetation survey of East Usambara Mountains, Amani Nature Reserve. In: *Ecological Monitoring of the East Usambara Catchment Forests. Report 2* (Eds A.M. Nikundiwe, F.M. Urasa, F.M. Elia and R.B.M. Senzota (Compiler)). UDSM – MacArthur Project, University of Dar es Salaam, Tanzania.

Lyaruu, H.V.M. & Mbago, F.M. (2004) Vegetation survey of East Usambara Mountains, Amani Nature Reserve. In: *Ecological Monitoring in the East Usambara Mountains: Proceedings of the Second Workshop* (Eds A.M. Nikundiwe, J.D.L. Kabigumila, F.S.S. Magingo and R.B.M. Senzota). Departments of Botany/Zoology and Marine Biology, University of Dar es Salaam, Tanzania.

Mbuya, L.P., Msanga, H.P., Rufo, C.K., Birnie, A. & Tengnas, B. (1994) *Useful Trees and Shrubs for Tanzania.* Regional Soil Conservation Unit, SIDA, Nairobi.

Mitsch, W.M. & Gosselink, J.G. (2000) *Wetlands.* John Wiley & Sons, Inc, New York.

Mittermeier, R.A., Robles Gil, P., Hoffmann, M., Pilgrim, J., Brooks, T., Mittermeier, C.G., Lamoreux, J. & Da Fonseca, G.A.B. (2004) *Hotspots Revisited.* CEMEX, Mexico City.

Newmark, W.D. (1994) *Recommendations for Prioritizing Wildlife Corridors in the East Usambara Mountains.* East Usambara Catchment Forest Project. Tanga, Tanzania.

Newmark, W.D. (2004a) Highlights on forest birds in the East Usambaras. In: *Ecological Monitoring in the East Usambara Mountains: Proceedings of the second workshop* (Eds A.M. Nikundiwe, J.D.L. Kabigumila, F.S.S. Magingo and R.B.M. Senzota). Departments of Botany/Zoology and Marine Biology, University of Dar es Salaam, Tanzania.

Newmark, W.D. (2004b) Gold mining threatens biodiversity in the East Usambara Mountains, Tanzania. *Oryx* **38,** 254.

Newmark, W.D. & Senzota, R.B.M. (2003) Power to detect trends in ecological indicators in the East Usambara Mountains, Tanzania. *Afr. J. Ecol.* **41,** 294–298.

Nikundiwe, A.M., Urasa, F.M., Elia, F.M., Newmark, W. & Senzota, R.B.M. (1998) *Ecological Monitoring of the East Usambara Catchment Forest: Report 1.* UDSM – MacArthur Project, University of Dar es Salaam, Tanzania.

Owour, B.O. & Kisangau, A.P. (2006) Kenyan medicinal plants used as antivenin: a comparison of plant usage. *J. Ethnobiol. Ethnomed.* **2,** 7. Available at: http://www.ethnobiomed.com/content/2/1/7/abstract. (accessed on 10 July 2008).

Palgrave, K.C. (1983) *Trees of Southern Affrica.* Struik Publishers, Cape Town.

Peterson, G.D. & Heemskerk, M. (2001) Deforestation and forest regeneration following small-scale gold-mining in the Amazon: the case of Suriname. *Environ. Conserv.* **28,** 117–126.

Powell, J.M. (1976) Some useful wild and domesticated plants of the Huli of Papua. *Sci. New Guinea* **4,** 173–201.

Pratt, D.J. & Gwynne, M.D. (1977) *Rangeland Management and Ecology in East Africa.* Hodder and Stoughton, London.

Price, P.W. (1975) *Insect Ecology.* John Wiley and Sons, New York.

Quinn, C.H., Ndangalasi, H.J., Gerstle, J. & Lovett, J.C. (2005) Effect of the Lower Kihansi Hydropower Project and post-project mitigation measures on wetland vegetation in Kihansi Gorge, Tanzania. *Biodivers. Conserv.* **14,** 297–308.

Rodgers, J.A. & Homewood, K.M. (1982) Species richness and endemism in the Usambara Mountain Forests, Tanzania. *Biol. J. Linn. Soc.* **18,** 197–242.

Senzota, R.B.M. (2004) Ecological impact in Amani Nature Reserve following the rush for gold. In: *Ecological Monitoring in the East Usambara Mountains: Proceedings of the second workshop* (Eds A.M. Nikundiwe, J.D.L. Kabigumila, F.S.S. Magingo and R.B.M. Senzota). Departments of Botany/Zoology and Marine Biology, University of Dar es Salaam, Tanzania.

Tona, L., Kambu, K., Mesia, K., Cimanga, K., Apers, S., De Bruyne, T., Pieters, L., Totte, J. & Vlietinck, A.J. (1999) Biological screening of traditional preparations from some medicinal plants used as antidiarrhoeal in Kinshasa, Congo. *Phytomedicine* **6,** 59–66.

Zar, J.H. (1999) *Biostatistical Analysis.* Prentice Hall, New Jersey.

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