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ARTHROPOD DIVERSITY AND ABUNDANCE ALONG THE KIHANSI GORGE (KIHANSI RIVER) IN THE SOUTHERN UDZUNGWA MOUNTAINS, TANZANIA

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ABSTRACT

Arthropod diversity and abundance at the order level was investigated along the Kihansi Gorge in the southern Udzungwa Mountains between June and August 1997 by using sweep netting, timed Lepidoptera counts, malaise-traps, solar powered light-traps, baited pitfall-traps, sticky-traps and baited butterfly traps. The study was undertaken to predict the possible effects of damming the Kihansi River above the fierce waterfall in the gorge. The gorge was divided into four micro-habitats, two of which are affected by waterfall spray (open spray, forest spray), and two of which were not affected directly by the waterfall (forest and riverine sites). The highest arthropod diversity was found in the forest spray, whereas the open spray contained the least. The forest spray area harboured the rarest arthropod orders. Arthropods are most abundant in the riverine site where 31 % of all sampled arthropods were recorded. The forest spray channel, forest site and open spray channel follow with 28 %, 23 % and 18 % of the sample respectively. It is suggested that the Mhalala Stream should be diverted to the gorge to replace the dammed Kihansi River. This would maintain at least partially the extraordinary micro-climate of the gorge and possibly retain the specialised arthropod community.

INTRODUCTION

Tanzania is known to have exceptionally rich biodiversity (URT, 1997). The Eastern Arc Mountains belong to one of the world's 'hotspots' of endemism (Thomsen *et al.*, 1997). It has been estimated that 60 % of all Tanzanian endemic plant species occur only in the

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Eastern Arc Mountains (Lyaruu & Mwasumbi, 1997). However, the major part of the studies done so far are restricted to the north-eastern parts of the Eastern Arc Mountains leaving the south-western part (including Udzungwa) less researched. Although the biodiversity of the Udzungwa Mountains is still poorly studied, it is already known that there are single-mountain endemics as in other parts of the Eastern Arc Mountains (see *e.g.* Rodgers & Homewood, 1982; TANESCO, 1995). Despite the high biodiversity value, forests of the Udzungwa Mountains suffer from human disturbance and use that is often unsustainable (Zilihona *et al.*, this volume). Extensive logging in the area during the past few years, cultivation and other human activities have resulted in modification of the natural habitats, which has most probably already caused the extinction of some species. The construction of a hydropower dam above the Kihansi River gorge is a current threat to the fauna and flora that depends on the special environment created by the waterfall and associated spray zones in the gorge.

In order to predict the effect of the project operations an Environmental Impact Assessment (EIA) has already been done (TANESCO, 1995). The EIA report recommends, among other things, further studies with special emphasis on the spray zone, which was not covered in the EIA. The present study was conducted with two main objectives: First, to give a better understanding of the environmental effects of the Kihansi River dam construction along the gorge, and secondly to document in detail the arthropod biodiversity along the Kihansi River gorge before any dramatic environmental changes occur. The present study includes a wider time scale than earlier studies (TANESCO, 1995), since it is well documented that there might be great variation in arthropod abundance in African rainforests between both seasons and years (*e.g.* Nummelin & Fürsch, 1992; Nummelin, 1996).

MATERIALS AND METHODS

Description of Study Area

The Udzungwa Mountains cover about 10,000 km^2 (07°15'–08°45'S, 35°00'–37°00'E), rising from 300 m altitude at the valley of the Great Ruaha River in the north through a series of rolling hills and dissected plateaux up to an area of gently undulating upland (>1,200 m) with peaks reaching 2,800 m. They end as a steep south-east facing scarp. The Udzungwas were formed by fusion of the ancient Mozambique shield of Usagaran biotite gneiss to the south-east and Archaean granites to the north-west, followed by uplift and faulting (Rodgers & Homewood, 1982; Lovett *et al.,* 1997). The Kihansi Gorge cuts into the Udzungwa scarp in the southern part of the Udzungwa Mountains. The climate in the area is influenced by movements of the Inter-Tropical Convergence Zone (ITCZ) and the Indian Ocean monsoon, which brings rainfall with a peak in April and a smaller peak in January (TANESCO, 1995; Lovett *et al.,* 1997).

The Kihansi River catchment covers 607 km^2 (Minja, 1995). The Kihansi Gorge runs north-south for about 2 km and lies below an impressive, fierce, over 100 m high waterfall which generates a substantial amount of spray (TANESCO, 1995; Lovett *et al.,* 1997). Montane trees, such as *Aphloia theiformis* and *Olea capensis,* are found in the forest near the waterfall, well below their normal elevation range presumably due to the effect of windy, cool spray. The escarpment on either side of Kihansi Gorge is covered by deciduous woodland dominated by *Brachystegia* species (Lovett *et al.*, 1997). Forest occurs along the river and is bounded by present or past cultivation and rocky cliffs. The only substantial moist forest area in the gorge is on the eastern bank below the main waterfall where it reaches 1 km in width. In other parts of the gorge the moist forest is not more than 0.5 km wide and it extends 2 km below the gorge to the Chita-Mlimba road. In the valley the canopy height is about 20–30 m with emergents to up to 60 m tall. Canopy height falls to 5–15 m at the forest edge and on rocky ridges. The gorge terrain is mostly steep and broken with only a few level areas.

The Lower Kihansi Hydropower Project is constructing a dam in the Kihansi River, a tributary of the Kilombero and Rufiji rivers. The project will result in the diversion of the flow of the current river. This river flow provides a special micro-climate along the gorge as the spray from the two consecutive waterfalls, together over 700 m high, leads to the development of a thick vegetation (Lovett *et al.*, 1997). Diversion of the water flow will result in a decline in water spray along the gorge, hence jeopardising the species that depend on the special micro-climatic conditions. The dam will be mounted on the top of the ridge, and the river flow will be diverted from the dam, well above the present Kihansi falls. It is planned to maintain the water flow in the gorge by diverting Mhalala stream into the gorge to avoid major environmental changes.

For this study the Kihansi Gorge was divided into four main micro-habitats: 1) open spray channel, 2) forest spray channel, 3) forest site, and 4) riverine site. The spray channel is influenced by constant spray, humidity and wind from the waterfall. The vegetation is very dense, but no trees seem to succeed to grow there, probably due to competition by moisture-demanding fast-growing grassy species. The forest spray channel sampling site is further away from the river, but still affected by constant spray. The forested and riverine sampling sites are situated in the gorge, about one and two kilometres below the waterfall respectively. The forested site is situated on the gorge slope in a moist forest about 50 m from the river and the riverine site is in a moist forest next to the river. All these habitats were located 550–700 m altitude.

Collecting methods

Arthropod collecting methodologies are divided into two categories: 1) active pursuit and ambush methods, and 2) passive methods. Two active pursuit methods were used: a) sweep-netting, and b) timed Lepidoptera counts. Five passive methods were used: a) malaise-traps, b) solar-powered light-trap, c) baited pitfall-traps, d) sticky traps, and e) baited butterfly traps.

Sweep-netting was used to collect arthropods from the above-ground vegetation and foliage. The sweep-net was a standard 38 cm diameter muslin arthropod net with a 61 cm handle (see Janzen, 1973). Sweeps were made only in places where the net could hit the forest floor vegetation. Thus, open gaps in forest floor vegetation were avoided. Depending on the height of the vegetation, the minimum sweeping height varied from 20 to 80 cm. The net was brushed back and forth through the vegetation so that the dislodged arthropods fell into the net. Sweeping was done at all sites on the same day starting at 9 am. No sweeping was done during rainy or showery days. One sample comprised 800 sweeps (Nummelin, 1996). Sweeping was done for continuous bursts of 50 sweeps, then insecticide was sprayed into the net to kill the arthropods before pouring them into a plastic bag. The exercise was repeated until the 800 sweeps were scored. Sorting of arthropods from the swept plant material was done in the camp. All arthropods were put into 70 % alcohol, except Lepidoptera, which were stored as dry specimens.

Malaise-traps (BioQuip, 1997, 2875AG, 210 cm high, green netting) were used to collect mainly flying arthropods. In this method arthropods either fly or crawl upwards into a collection jar in an open sided tent-like net construction. At each study site a malaise-trap was left to catch insects for 48 hours. Emptying the trap's collecting jar was done after 24 hours by pouring water in the collecting jar or by removing each arthropod by forceps. Caught arthropods were stored in 70 % alcohol. Sorting them into their respective orders was done in the camp. The trap was set to catch insects at each site for an interval of two weeks.

As pitfall-traps we used 14 simple 0.3 litre aluminium cans. They were dug into the soil with the opening at the soil surface. Half of each container was filled with water, and human dung baits, tightened in a small piece of cloth, were placed just above the pitfall mouth. Two samples were collected in each study site every two weeks. After emptying the traps in the field the sorting of the specimens to their respective orders was done in the camp.

As sticky-strip traps we used yellow pieces of cardboard with a sticky surface where arthropods were trapped (BioQuip, 1997, Sticky Strips, 2872, 7.6 x 12.7 cm). They were randomly mounted on the top of stakes at a height of 20 cm above the ground. A total of 25 traps were placed at each site in two phases, the first phase with 10 traps, the second with 15.

For the solar-powered light-trap, a solar panel was used to charge a motor vehicle battery to give power for a 20 cm long UV-tube lamp. The trap was suspended at a height of approximately 1.5 m in front of a white polythene sheet (Nieminen, 1996). The light was switched on at about 20:00 for two hours. Arthropods were collected in a plastic container into which chloroform was placed as an anaesthetic. Fine leaves were also placed into the container to prevent the arthropods getting damaged and loosing essential structures for identification.

A timed Lepidoptera count was specifically used for Lepidoptera assessment. The same sweep-net as described above was used to trap the flying and perching Lepidoptera. The time unit for a sample was one hour. Two collectors worked simultaneously at one site. A total of four samples were collected per site.

Baited butterfly traps were built of a 2 m high cylinder-shaped tent made of white mosquito net with a bottom tray (radius 0.5 m). Between the tray and net tent there was a 10 cm space for butterflies to enter. Fermented bananas were put on the plywood tray as bait. This method was used for eight days and the trap was emptied every day.

RESULTS

There is a high diversity and abundance of arthropods along the Kihansi Gorge (table 1, figure 1), with a total of 24 arthropod orders recorded. The forest spray channel included the highest order-level arthropod diversity with 20 orders. In the number of recorded arthropod orders the forest zone and riverine zone were close to each other having 18 and 17 arthropod orders, respectively. The open spray channel was the least diverse micro-habitat in the gorge, with 13 orders.

The arthropods were most abundant in the riverine site, where 31 % of all sampled arthropods were recorded. The forest spray channel, forest site, and open spray channel follow with 28 %, 23 % and 18 % of all sampled arthropods respectively.

Diptera and Coleoptera specimens were the most abundant arthropod orders in all micro-habitats except in the open spray channel where Coleoptera were ranked third, after Diptera and caterpillars (Lepidoptera/Symphyta larvae). Homoptera were more abundant in the open spray channel than in the other three micro-habitats. Hymenoptera and Opiliones were most abundant in the riverine site and very few specimens were recorded in the open spray channel. The abundances of Lepidoptera, Heteroptera, Araneae, and Orthoptera were high in all sites, whereas Plecoptera, Zygoptera, Thysanura, Dermaptera, and Trichoptera were found at low abundances. Other infrequently recorded arthropod orders were Isoptera, Psocoptera, Neuroptera and Collembola. The results indicate that the forest spray harbours more than 80 % of the recorded low abundance-rank arthropod orders. However, the low abundance of Thysanura, Dermaptera, Isoptera, Psocoptera, Neuroptera and Collembola is most probably an artefact caused by the sampling methods used.

Table 1. Numbers of arthropod individuals recorded in the Kihansi Gorge from June to August 1997 with the same sampling effort (occasional observations of Acari, Thysanura, Psocoptera, Neuroptera and Isoptera not indicated).

ORDER	Open spray	Forest spray	Forest site	Riverine site
Diptera	2,711	5,823	2,316	4,879
Coleoptera	478	1,279	2,833	2,061
Hymenoptera	31	303	670	826
Aranea	66	191	224	221
Lepidoptera	83	147	332	277
Orthoptera	94	222	193	271
Heteroptera	26	35	161	263
Homoptera	27	127	131	21
Phasmida	0	2	23	74
Mantodea	2	40	6	1
Opiliones	2	32	3	240
Isopoda	11	118	3	220
Blattoidea	2	20	4	52
Diplopoda	0	21	52	14
Collembola	0	112	0	0
Zygoptera	0	0	1	0
Plecoptera	0	6	1	0
Lepidoptera caterpillar	875	5	0	0
Trichoptera	8	0	0	0
TOTAL	4,416	8,483	6,953	9,420

DISCUSSION

Based on the results of this study, it is clear that in order to obtain a comprehensive view of arthropod diversity, benefits are obtained from the simultaneous use of a variety of methods. The results also revealed the extreme importance of a long sampling period, as noted previously by *e.g.* Nummelin & Fürsch (1992). The low diversity (only 17 orders) and abundance (650 specimens) of arthropods recorded along the Kihansi Gorge during the original EIA study resulted from the short time spent at the site. The constantly favourable micro-climate, especially along the forest spray channel, possibly contributes to the high number of arthropod orders found there. Our observations of the highest occurrence of 'rare' arthropod orders in the forest spray zone suggest that these are specialist arthropods in the spray area. Water diversion as a result of damming by the hydropower project will change the micro-climatic conditions and habitats and thus affect the arthropod community in the Kihansi Gorge. According to this study, this will affect the rarest orders, but not necessarily the total abundance, since the riverine site (by the river, but without spray) had the highest number of arthropods. However, if the micro-climate dries so much that the riverine site resembles the present moist forest site, this will also lead to a decline in total arthropod numbers.

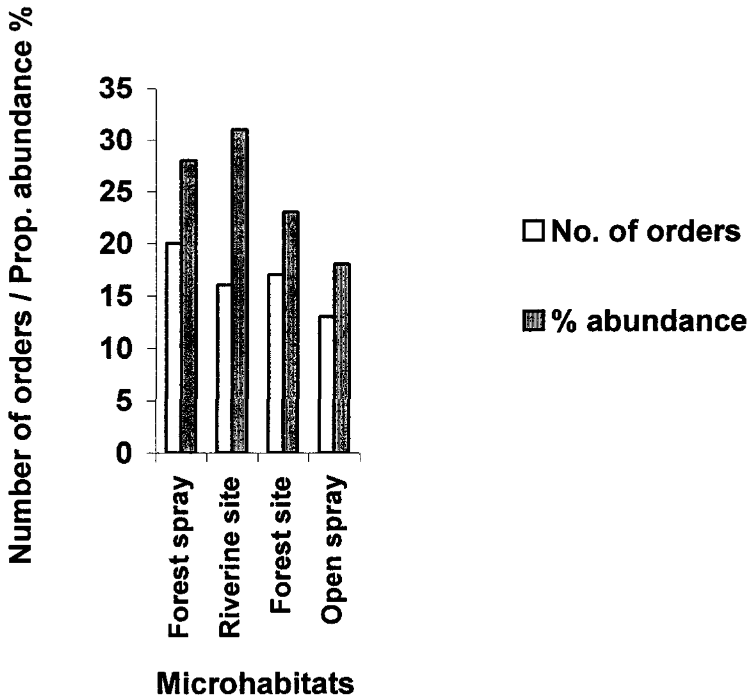

Figure 1. Arthropod order diversity and proportional abundance along the Kihansi Gorge in June–August 1997.

The habitats surrounding Kihansi Gorge have been destroyed through extensive logging, cultivation and other human activities (Zilihona *et al.*, this volume). Tilman *et al.* (1994) indicated that a slight increase in habitat destruction threatens many more species if a habitat has already been under pressure of disturbance. They noted that, if 90 % of the habitat in a region has already been destroyed, destroying an additional 1 % of the habitat causes extinction of eight times more species than in undisturbed habitats. This situation may exist along the Kihansi Gorge. Furthermore, it is known that damming results in a loss of biodiversity (Attwell, 1970; El Moghraby & El Sammani, 1985; Happold, 1995; Pimm, 1991; Sheppe, 1985).

Clark & Samways (1997) highlighted that in biodiversity conservation, it is very important to conserve pristine or near-pristine habitats, especially in areas of high endemism. The next best choice would be to conserve semi-natural habitats, with appropriate management. Since the Kihansi Gorge is going to loose its virginity due to damming, the next best management solution to total conservation is probably to try to keep the physiochemical conditions of the gorge as close to the original state as possible by mitigation measures. For example, the suggested manipulation of the Mhalala tributary flow to the gorge will, at least to some extent, help maintain the exceptional micro-climate, although its flow is only a few percent of the Kihansi River. This tributary should be modified so that it provides a water spray along the gorge.

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