TAITA HILLS BIODIVERSITY PROJECT REPORT

Compiled by

Benny Bytebier
Project Co-ordinator
National Museums of Kenya

January 2001

This report should be cited as
Bytebier, B. 2001. Taita Hills Biodiversity Project Report. National Museums of Kenya, Nairobi.

Cover Picture
Ronald Mulwa and Taita White-eye, *Zosterops (poliogaster) silvanus*
Photograph by Thierry Geenen

TABLE OF CONTENTS

1. THBP PROJECT FACT SHEET

Project Name
Biodiversity of the Taita Hills (Kenya): Zoogeography and impact of habitat fragmentation and degradation

Country
Kenya

Project Leader
Prof. Walter Verheyen, University of Antwerp, Belgium

Project Duration
1 November 1996 - 31 July 2000

Funding Agency
Directorate General for International Collaboration (DGIS), Belgium through the Flemish Interuniversity Council (VLIR)

Collaborating Institutions

University of Antwerp
Department of Biology
Research Group on Evolutionary Biology
Groenenborgerlaan 171 — Tel: 32 3 2180469
B-2020 Antwerp — Fax: 32 3 2180474
Belgium — nwouters@ruca.ua.ac.be

Kenyatta University
Zoology Department
P.O. Box 42844 — Tel: 254 2 810901/19 Ext. 305
Nairobi — Fax: 254 2 810759
Kenya — noguge@africaonline.co.ke

National Museums of Kenya
Centre for Biodiversity
P.O. Box 40658 — Tel: 254 2 742445
Nairobi — Fax: 254 2 741424
Kenya — nmk@africaonline.co.ke

Co-ordinator/Resident Scientist

Benny Bytebier
Centre for Biodiversity
National Museums of Kenya
P.O. Box 40658 — Tel: 254 2 742445
Nairobi — Fax: 254 2 744833
Kenya — bytebier@africaonline.co.ke

2. EXECUTIVE SUMMARY

2.1. Introduction

The Taita Hills Biodiversity Project (THBP) is a collaboration between the National Museums of Kenya (NMK), Kenyatta University (KU) and the University of Antwerp (UA). The Directorate General for International Co-operation (DGIS) (formerly known as the Belgian Administration for Development Co-operation, ABOS) funded the project, through the Flemish Interuniversity Council (VLIR), with input from the Kenyan counterparts.

The main objective of the project was to improve the human resources and infrastructure of the Department of Zoology of KU and of the collaborating departments of NMK. This was by done by training of scientific personnel, both in Kenya and in Belgium, and by improving existing scientific facilities of both institutions. Ultimately the goal was to improve the existing ability to conduct modern scientific research in the field of biodiversity, systematics, ecology and conservation. Furthermore, a thorough understanding of the deterioration of the environment, and the decline of biodiversity in Kenya and the world, will form the basis for preservation, protection and/or sustainable utilisation of the remaining biological resources through sound management plans.

The realisation of the main objective was through a study of the effects of forest fragmentation on the biodiversity of the Taita Hills in the Southeast of Kenya. The Taita Hills (03°20'S 38°15'E), together with Mount Sagala and Mount Kasigau, form the northernmost part of the Eastern Arc Mountains, and are the sole representatives of this geological formation within the Kenyan political boundaries. As many other Eastern Arc Mountains, this complex of hills harbours an unusually high proportion of rare and endemic fauna and flora. Because of recent and past population pressure, the remaining forest fragments are now small, scattered, and are becoming more and more fragmented and degraded.

2.2. Project history

The University of Antwerp has a well established tradition of research in different parts of Africa, particularly with respect to small mammals. Some former students from this university were working at NMK within the framework of the Flemish Organisation for Development Co-operation and Technical Assistance (VVOB), providing expertise and technical support to different departments. After consultation with Kenyan colleagues at NMK, the need was felt for a more comprehensive project that would provide training to local counterparts, enhance the existing collections and would assist with logistical support for field work in biodiversity, conservation and ecology related research. Within the VVOB framework, such support was not possible and, given the relations with the UA, and their experience in this field,

collaboration was sought between the two institutions. Independently, KU also proposed collaboration with the UA in the field of training (within their MSc programme) and research. It was considered an unique opportunity to combine the know-how of the University of Antwerp, the museum and research-related activities of NMK, and the formal education programme of KU into one project proposal that would address a number of objectives of interest to the local counterparts. A formal project proposal was developed jointly by the three institutions and submitted for funding to the Flemish Interuniversity Council (VLIR).

The project officially started on 1 November 1996 and was projected to run for three consecutive years, until 31 October 1999. However, due to a number of unforeseen delays, the project was extended for 9 months and officially ended on 31 July 2000.

During the first year, the emphasis was on starting up the support for the training programme, and the purchase of the necessary equipment for the training and research programmes. Field research activities were initiated for the ornithology and entomology components, but were hampered by the fact that the project vehicle was not delivered until the start of the second year. The mammalogy research programme did not take off until the second year because the scientific co-ordinator for this component, Dr. N. Oguge, was on study leave in the UK during the first year. Several Belgian lecturers participated in the teaching of the M.Sc. programme in Animal Ecology at Kenyatta University during the course of the first year.

At the beginning of the second year, the co-ordinator/resident scientist, Dr. M. De Meyer, left the project to take up a position as Head of the Entomology Department at the Royal Museum for Central Africa in Tervuren Belgium. A new co-ordinator/resident scientist, Mr B. Bytebier, was appointed on 1 March 1998. During the second year the main emphasis was on fieldwork and data gathering. The ornithology and mammalogy research went full swing, but the entomology activities went on a temporary go-slow as the scientific co-ordinator, Dr. M. De Meyer, was settling down in his new position. All field-based activities suffered from the *el-nino* rains, and most had to be suspended during the months March-April-May 1998.

Data gathering for all research components continued unabated during the third year. Data analyses and output was particularly strong for the ornithology component. The move of Dr. De Meyer to the Royal Museum for Central Africa brought in a new partner and new opportunities, and the invertebrate zoology research component expanded greatly during the third year. However, due the aforementioned problems during the first and second year, most of the research activities could not be completed by the end of the third year, as originally planned. Fortunately the budget was not exhausted by the end of the third year, and DGIS approved an extension of the project for a period of nine months.

During the last nine months, field-based research activities were mainly focused on the mammalogy component, with some visits from the invertebrate

zoology researchers The mammalogy group finalised their activities in Taita Hills and then visited mountainous forested areas in other parts of the country to collect comparative material. Field activities literally ended on 29 July 2000, two days before the project officially drew to a close.

2.3. Ornithology research component

2.3.1. Effects of forest fragmentation on the bird fauna

The forests of the Taita Hills of southeast Kenya are of great importance for conservation, holding three endemic birds and many other endemic taxa. Apart from an initial survey and a start of baseline data collection by Dr. Thomas Brooks (Tennessee University, USA) in 1996, very little was known on the present status of its avifauna. Hence, the aim of the ornithological part of THBP was threefold: (i) to document the life-history and present status of seven forest restricted bird species of the Taita Hills, three of which are endemic to this area; (ii) to study the effect of mobility, assessed by the species-specific level of movement between forest fragments, on the population genetics of these species; and (iii) to test whether fluctuating asymmetry (FA), an index of condition, could act as an early warning system for the conservation of these and other species under potential threat of extinction. To realise these objectives, we carried out the following types of field research and lab analyses: (i) capture-recapture of over 3200 individuals of the seven studies with the use of mist-nets; (ii) visual observation of colour-ringed individuals, with special effort towards Taita Thrush, Taita White-eye, Taita Apalis, and White-starred Robin; (iii) radio-telemetry on individuals of Taita Thrush and White-starred Robin; (iv) survival analysis of Taita Thrush based on individual capture-recapture histories; (vi) genetic analysis of the Taita Thrush with the use of microsatellite DNA-markers; (v) qualification and quantification of blood parasites in the Taita Thrush.

A combination of the above techniques showed that bird populations in the most degraded forest fragments were exposed to increased levels of environmental stress, which affected their patterns of social organisation, (micro-)habitat use, territoriality and mobility, and decreased their rates of survival. Fluctuating asymmetry proved to be a highly repeatable estimator of the impact of the stresses on the ‘quality’ or ‘health’ of these natural populations of birds. Moreover, it proved to be a more sensitive estimator compared to traditional life history traits, such as survival, the latter which is much more cumbersome to measure. Apart from increased environmental stress, bird populations in smaller forest fragments also showed reduced allelic diversity, and for one study species we found evidence that it suffered from a recent genetic bottleneck. It can be expected that reduced genetic variability, such as observed in Taita thrushes captured in fragment Chawia, will lead to increased levels of genetic inbreeding. The available demographic and genetic data therefore suggest a substantial threat to the long-term survival of, at least, one endemic bird species of the Taita Hills.

We are currently extending our population genetic work to all seven study species, some of which considerably differ in their level of mobility. The

majority of these results will be available within one year, without the need of additional funding. Results from this comparative study will yield further insight in the overall relationships between environmental stress, genetic stress, mobility, fluctuating asymmetry, and fitness, and ultimately, will allow remedial conservation action to be undertaken.

2.3.2. Ecology of the Taita Thrush

Critically threatened species need focused and problem-oriented studies for their management and conservation. The response of the endemic and Critically Endangered Taita Thrush, *Turdus helleri*, to forest degradation in the Taita Hills forests was studied in three forest fragments (Chawia, Ngangao and Mbololo), which differ significantly in their levels of degradation. Using intensive mist netting, radio telemetry and individual colour banding, population size, social organisation, habitat choice, home range pattern and movements, was studied in relation to forest degradation. The total, and therefore global, population size was estimated as 1,347 individuals. Densities were related to levels of forest disturbance. Home range and flock sizes were larger in heavily disturbed habitats. Furthermore, thrushes in heavily disturbed fragments were demonstrated to have high levels of fluctuating asymmetry (FA), indicating high environmental and/or genetic stress. The three subpopulations also show significant genetic differentiation. The Chawia subpopulation has undergone a recent genetic bottleneck, resulting in nearly 50% loss of its allelic diversity, and an emergence of several unique alleles. The remaining habitat for the species should be intensively protected and managed, with emphasis on restoration of tall, closed canopy forest. Genetic intervention is needed to save the Chawia subpopulation from an eminent extinction. Regular monitoring of the species and a study of local recruitment is advocated.

2.3.3. Ecology of the Taita White-eye

The Taita White-eye (TWE), *Zosterops (poliogaster) silvanus*, is another of the Critically Endangered bird species endemic to the fragmented forests of the Taita Hills and Mount Kasigau. The total population of TWE in the area was estimated to be 7123 birds. Mount Kasigau is the stronghold of TWE, having 80% of the entire population. Epiphytic mosses and other habitat features characteristic of undisturbed forest were the best predictors of TWE abundance. However, the TWE is less specialised than the other Taita Hills endemics, using edge habitats, exotic plantations, scrub and isolated trees in the agricultural matrix. Breeding was only observed in forest fragments with an area of more than 50 ha and predation pressure from snakes and raptors was high.

2.3.4. Ecology of the Taita Apalis

This currently ongoing study is assessing the status, population size and habitat preferences of the Taita Apalis, *Apalis (thoracica) fuscigularis*, the third bird endemic to the tiny, fragmented forests of the Taita Hills. It occurs in only four remnant patches in the main Dabida massif, totalling less than 150 ha. It

is absent, for unknown reasons, from a larger patch of less-disturbed forest on the adjacent massif of Mbololo. Although the apalis is Critically Endangered, very little is known about its status or ecology. Through a combination of individual colour-banding and measurement, territory mapping, and measurement of habitat parameters, this study is investigating the apalis' population size, the condition of birds in the different fragments, the species' micro- and macro-habitat selection, and the suitability of Mbololo and other unoccupied fragments for possible (re-)introduction of this species. This study complements ongoing ecological work on the Taita Hills bird community and the other two threatened bird species, and the results will feed into management plans being drawn up for the forest.

2.4. Mammalogy research component

The level of biological diversity, as determined by species inventories, is a major parameter for setting priorities for conservation particularly in areas of biogeographic importance. The mammalogy programme of the THBP, therefore, aimed to assess mammalian diversity and study population processes in *Praomys*, its phylogeography, population genetic structure, and parasitology.

Over a period of 30 months, small mammal surveys were made, based on removal and capture mark recapture (CMR) studies. Morphometric and craniometric measurements, and sequencing of mitochondrial DNA (mtDNA) were carried out to determine *Praomys taitae* taxonomy and its phylogeographic relationship with other eastern African *Praomys*. Ectoparasites collected from captured animals were also identified.

Twenty-six small mammal species were recorded in 14 forest fragments. These included 15 rodents and 11 insectivore species. Among the rodents, murids were the most common accounting for 60% of all captures. Other rodent groups included African dormice (myoxids), pouched rats (cricetomyines) and climbing mice (dendromurines). White-toothed shrews (*Crocidura*) constituted 70% of all insectivores. The study also reports the first record of climbing shrews (*Sylvisorex*) in southeastern Kenya. The 'endemic' *Praomys taitae* was found to be conspecific to *P. delectorum*. Five species of lice and ticks were also recorded in rodents and shrews.

Pending work includes analysis of 20-month data from CMR work. This will shed light on population processes and habitat use. Microhabitat analysis will reveal information on community variation on a spatial scale and thus use of space by different rodent species. Population genetic structure studies may explain effects of fragmentation on gene flow. Also pending are flea, mite and chigger identifications.

Most of pending analyses will be complete within six months. Exceptions are the population genetic structure and the ectoparasite studies. It is envisaged that on completion of the manuscript on the phylogeography of *Praomys*, funds may be sought for population based genetic studies, in collaboration with the Royal Belgian Institute of Natural Sciences.

Kenyatta University hopes to continue collaboration with the University of Antwerp in biodiversity studies to expand the current applied research on rodent pest control.

2.5. Invertebrate zoology research component

The invertebrate zoology component focused on inventorising the insect and invertebrate fauna of the indigenous forest fragments found in the Taita Hills. Because of the enormous diversity, and the problems related to species identification of the majority of insect and invertebrate groups, the research was limited to a number of particular groups. These included certain Diptera (flies) and Lepidoptera (butterflies and moths) taxa, Diplopoda (millipedes), Mollusca (snails and slugs) and Araneae (spiders). The choice of these groups was determined by the available expertise and the fact that these groups have proved to be applicable as forest quality indicator groups in earlier, similar studies.

Methodical surveys on the invertebrate fauna of the Taita Hills have not been done, but scattered records are available in older literature and from specimens in collections. The first objective of this research component was therefore to gather base line data on the invertebrate diversity of the Taita Hills for the study groups. Other main objectives were (i) to establish the biogeographical relationship of the invertebrate fauna of the Taita Hills with other regions in eastern Africa; (ii) to indicate differences in species composition between the fragments; (iii) to investigate whether observed differences of the invertebrate fauna could be linked to differences in the particular fragments (size, isolation, disturbance, etc.).

The main activities carried out were a combination of intensive field trips by leading specialists to focus on specific sampling of particular invertebrate groups, combined with long-term sampling by means of general trapping methods (in particular Malaise traps, pitfall traps, and water traps). Field trips were conducted at different periods throughout the year, given the seasonality of most invertebrate groups. During these field trips the focus was on sampling efforts for the particular study groups. Material from the general sampling was sorted out and suitable material was sent to specialists willing to study the specimens. The rest was stored for future research.

So far only preliminary results are available. The identification of the material usually takes a long time, since the fauna for most of these groups is poorly known. Records of species new to science are not uncommon, and in some groups like Diplopoda seem to be the general rule. Therefore a lot of the research in the last years has focused on actually identifying the collected material. Any further analyses still have to be conducted. For some groups, however, some interesting findings can already be highlighted.

Diversity of the Taita Hills differs largely according the group studied. For some taxa the material consists largely of generalists found in other areas throughout the country or East African region (as in Syrphidae), some show

restricted endemism (in molluscs and Dolichopodidae), while for others the fauna consists largely of apparently endemic species confined to this area (as in Diplopoda). The record of Gallieniellidae (Araneae: 1 new genus with 2 species) in the area is remarkable, as the family was so far only known from Madagascar and the Cape area in South Africa. Further aspects on biogeographical affinities and species composition of the different fragments are still under investigation. Preliminary results, however, clearly indicate that the fauna of the Taita Hills is not of a purely Eastern Arc fauna, but a more complicated composition of Central Highland, Coastal and Eastern Arc elements.

Further analyses of the collected material will continue over the next years. When specialists can be found who are willing to study material of a particular group, the relevant material will be sorted and sent to them. The scope of groups studied is therefore continuously expanding. Scientific staff members of the Royal Museum for Central Africa (Africamuseum) are also actively searching for further funds to enable specialists to study other groups of the material sampled.

It is anticipated that the major groups now under study, will be largely analysed over the next three years. It concerns here:
Diptera: Syrphidae, Dolichopodidae, Pipunculidae, Diopsidae, Asilidae
Lepidoptera: Noctuidae, Geometridae, Microlepidoptera (leaf mining moths)
Diplopoda: Ammodesmidae, Odontopygidae, Pyrgodesmidae, Stemmiulidae
Araneae: Gallieniellidae, Ctenidae, Cyatholipidae
Mollusca: Streptaxidae, Enidae, Subulinidae, Maizaniidae, Valloniidae, Achatinidae, Bradybaenidae, Urocyclidae, Endodontidae, Vitrinidae

Training has mainly focused on individual training of scientists attached to NMK, by specialists of the Africamuseum. In addition, technicians of NMK, foresters based at the Taita Hills forests and staff members employed by ICIPE have been trained in general collecting techniques within the scope of the project.

The scientists linked to the invertebrate zoology component of the THBP have greatly benefited from this collaboration. The collections made by the project enabled these specialists to study material that would otherwise not have been available. The innovative findings regarding these specimens differ greatly depending on the group studied. For some groups, the material collected is largely new and unknown to science. The faunistic and taxonomic information that is thereby gained cannot be overestimated. In addition the study enabled us to get some insight in the species complexity that is found in relation to the forest fragments of the Taita Hills. The particular fauna of the region can be placed in a broader biogeographical perspective.

Even more important is the fact that the project enabled scientists of the Africamuseum to establish collaborative links with colleagues of the National Museums of Kenya. It is expected that these links will form the basis of a long-term partnership between both institutions and lead to further joint projects.

At the present moment a long-term collaborative programme (5 years) between NMK and the Africamuseum is already in place. This programme focuses on three main objectives: (i) collection enhancement; (ii) training; (iii) development and exchange of databases. Also the Africamuseum has obtained funds for a scientist to specifically study the Graciliridae (Lepidoptera) of the Taita Hills for a period of one year.

2.6. Botany research component

The main aspect of the the botanical research programme is an applied botanical study that links the ethnobotany of the Taita Hills forest resources with the spatial patterns of forest community composition and structure. The overall research goal is to determine the values of plants to the local communities, the composition and structure of plant communities, and to apply these to identification of forest restoration sites in the highly fragmented Taita Hills.

The overall research goal is being addressed through three research objectives: (i) undertake plant community analyses that examine the size class abundance of valued resources and their relationship with environmental conditions; (ii) describe and quantify the value of forest resources to the local communities through participatory ethnobotanical research; (iii) identify adaptive management options for forest restoration across Taita Hills forests.

Data on community structure and composition for Ngangao and Mbololo forests has been collected in a stratified random system. 20m x 50m plots were used to document trees and palms measuring ≥10 cm dbh. Saplings and shrubs measuring >1 m height and < 10 cm dbh were documented in 10m x 20m plots. All seedlings and saplings measuring <1m in height were enumerated in four plots 1m x 1m plots.

Vegetation data collected is being analyzed for the purpose of community analyses, examination of the size class abundances of valued resources and their relationship with environmental condition. Species data on density, basal area, and frequencies has been compiled, and importance percentage calculated from relative values of density, basal area, and frequency. Considering over 60 woody species occur within each forest, the importance percentage of a few species was briefly examined.

Ethnobotanical data for Ngangao and Mbololo forest has already been collected and partly analyzed. Open-ended questions formed the basis of the study. Through discussions with local people and staff of East African Wildlife Society, informants that were knowledgeable on plant uses, and dwelling adjacent to the forests were identified for interviews. The informants were walked into the forest and asked to identify tagged plants, uses, availability, preference ranking and provide any other information that they may have on the plant.

It is evident that Ngangao forest is dominated by disturbance related species that are occurring over a wide geographic range. *Tabernaemontana stapfiana* and *Albizia gummifera*, the two most important species as deduced from importance values are broadly distributed species that are known to occur in disturbed forests. Numerous cut stumps evidence recent human influence in the forest. Species that have been extracted for timber include *Strombosia scheffleri, Albizia gummifera*, *Aningeria adolfi-friedericii, Millettia oblata* ssp. *teitensis, Syzygium sclerophyllum, Newtonia buchananii, Podocarpus latifolia* and *Ocotea usambarensis. Podocarpus latifolia* and *Ocotea usambarensis* are reported to have been common but are noticeably absent in the forest as a result of extraction. While *Podocarpus latifolia* has a high understory density, only two individuals per hectare were recorded at the large tree layer. While this may indicate regeneration as evidenced by numerous young individuals, most of these young individuals do not grow into big sized individuals. Although a couple of large *Ocotea usambarensis* trees were observed growing in the forest, none was documented in the sampling plots. This suggests that *O. usambarensis* is occurring at exceptionally low densities despite having been numerous in the past.

Other human impacts on the forest include the planting of exotic species within the forest by the forest department. These plantations including *Pinus patula*, *Cupressus lusitanica* and *Acacia mearnsii* were established in areas that were otherwise bare mainly to prevent soil erosion.

Ethnobotanical study documented over 40 uses of woody species in Ngangao forest. Five use categories have been identified. These categories are fuel wood, construction, medicinal, technology, edible and commercial uses

A detailed statistical analysis of both vegetation and ethnobotanical data, as well as an analysis of the vegetation data in relation to environmental parameters, remains to be done. Identification of adaptive management options for forest restoration across the Taita Hills' forests is yet to be done through a detailed examination of ethnobotanical data and plant community data.

Future research will aim at drawing upon what is already known to produce a holistic picture of the Taita Hills. Work will continue within Taita hills, and the research will be expanded to encompass the little studied Mount Kasigau, among other forests. The existing sampling plots will be permanently marked to form the basis of a long-term monitoring programme.

Next to this in depth study of the two largest and least disturbed forest fragments Mbololo and Ngangao, more basic vegetation parameters were gathered for all the forest fragments under study. These data allowed us to grade the level of disturbance for each of the forest fragments.

A fairly comprehensive checklist of the plants of the Taita forests was available at the start of this study. However this list did not include the bryophytes. Therefore we inventorised the mosses and liverworts of all the

forest fragments except Sagala. Whilst this work is still in progress, already 14 species new to Kenya, three of which were previously only known from Tanzania, were identified.

An inventory of the orchids of the Taita forests was also conducted. Four species were newly recorded for the floral regions K7 (Coast) and 1 species was confirmed new to Kenya.

Other higher plants were also collected, albeit in a less systematic way. A few were new records for the Taita Hills or for the floral region K7, and at least one species, *Ceropegia verticillata* (Asclepiadaceae), proved to be new to science. This species is only found in Mbololo forest and is therefore a new true endemic of the Taita Hills.

2.7. Other research

After a survey of the bushbabies (Primates, Galaginidae) of the Taita Hills, two species were recorded as present. *Otolemur garnettii*, the Small-eared Galago, is common in and around the forests. A second, much smaller species was also discovered. This dwarf galago was identified as a form of *Galagoides orinus*, a primate that was previoulsy not recorded for Kenya. Whilst the similarities, in vocalization and morphology data with other *G. orinus* populations identify this dwarf galago as *G. orinus,* the differences and the degree of isolation of the Taita hills indicate the possibility that this taxon is a new sub-specific or other form of *G. orinus.*

During a survey of the amphibians and reptiles of the Taita Hills, 6 snake, 10 lizard and 9 frog species were collected. Interesting records include the Forest Vine Snake (*Thelotornis kirtlandii*), which is a typical westeren and central African forest species, and Dickerson's forest gecko (*Cnemaspis dickersonii*), which in Kenya is only found in the Taita Hills. Several interesting frogs were also collected. The Taita reed frog (*Hyperolius viridiflavus glandicolor*) is a species endemic to Kenya. *Callulina kreffti* and *Arthroleptis adolfi-friderici* (France's squeaker) are two species only known from the East Usambara's and the Taita Hills.

Given the nature of the THBP (a study on habitat fragmentation), the need was felt for a detailed insight and clear understanding of how the different forest fragments are topographically and structurally related to each other. In this respect it was necessary to get an idea, not only of the size of the forest fragments and the relative distances between the fragments, but also of the altitudinal differences, the intermediate vegetation structure and any historical vegetation changes. We therefore conducted a detailed landscape analysis of the Taita Hills area and developed a three-dimensional electronic land-use map in a Geographical Information System (GIS). The GIS model consists of an elevation layer, an infrastructure layer, a land use layer, and a layer with the current contours of the indigenous forest fragments. This model is now operational.

2.8 Training

The major part of the training component of the THBP was support to the Master of Science (M.Sc.) programme in Animal Ecology at Kenyatta University. The THBP supported the programme by providing scholarships, visiting lecturers, and logistical support to the department.

The THBP provided two full scholarships for the M.Sc. programme. These were awarded to Mwangi Githiru and Richard Odhiambo. Both students successfully finished their M.Sc. programmes during the time span of the THBP, and both have since embarked on their Ph.D studies. THBP also provided a partial scholarship to a third M.Sc. student, Ronald Mulwa. Mr. Mulwa is currently finishing the write-up of his M.Sc. thesis.

Edward Waiyaki initially started his Ph.D. research with financial assistance from the THBP, but was later awarded a Ph.D. scholarship by the Directorate General for International Collaboration (DGIS), Belgium.

Kamau Wakanene also joined the project as a Ph.D. student. THBP facilitated contacts with potential donors, which resulted in a grant of 5300 $ towards his research expenses. THBP also assisted him with logistical support when and where needed.

Two more M.Sc. students, Daina Samba and Kariuki Ndang'ang'a, started as reseach assistants for Ph.D. student Edward Waiyaki. With the experience they gained under THBP, they later managed to attract their own funding to proceed for M.Sc studies.

THBP also provided funds for Belgian lecturers to travel to Kenya to assist in the teaching of the M.Sc. courses. Prof Matthysen, Dr Luc Lens and Dr. M. De Meyer taught courses during the first year of THBP. However, for a variety of reasons this assistance did not materialise during the second and third year of the project and the conclusion is that this part of the project was only partially successful.

Because of financial constraints at KU, the teaching and research facilities are limited. It was therefore considered a necessity to support the departmental infrastructure with administrative, teaching and scientific equipment. This came under the form of two computers with UPS, a laser printer, a scanner, a photocopying machine, two Leica binocular miscroscopes plus a camera system for these microscopes, a chest freezer and specialised textbooks for the departmental library.

The THBP also provided all logistic support for the field assistants and M.Sc. students while in the field for their research projects.

2.9 Conclusions

In the original proposal two main research objectives were identified.

The first one was a detailed survey of a number of indicator groups for the fauna of the remaining scatter of indigenous Taita Hills' forests, namely birds, small mammals (Rodentia, Insectivora and Microchiroptera) and insects (butterflies, hoverflies and termites).

The results so far show that this objective has not only been reached but was surpassed by far. Detailed surveys were done for the birds, small mammals, hoverflies and butterflies as originally planned. On top of these we also managed to inventorise the following, widely varying groups: bushbabies, snails and slugs, millipedes, moths, spiders, several other families of flies apart from hoverflies, orchids, mosses and liverworts, amphibians and reptiles. However, for a number of reasons, we did not manage to inventorise bats and termites.

The second objective was an in depth study on the impact of habitat fragmentation and degradation on the species diversity and fitness of the fauna for a number of indicator groups like the endemic birds (Taita Trush, Taita White-eye and Taita Apalis), sylvatic genera of small mammals and endemic or near endemic butterflies.

For the birds the study has been carried out on the Taita Thrush and is ongoing on 6 other forest-dependent birds, including the Taita White-eye, but excluding the Taita Apalis as the catch rate of this bird was too low to allow analysis. It is also ongoing for small mammals with a focus on *Praomys taitae*. However, the study on butterflies was abandoned as not enough museum specimens of the endemic butterflies could be traced to warrant a proper statistical analysis, and it was thought unwise to collect any more of these rare butterflies.

Other research activities that were carried out, but were not in the original proposal include:

- Detailed ecological research on the Taita Thrush, Taita White-eye and Taita Apalis
- Collection of basic ecological forest parameters to allow proper fragmentaion and degradation studies
- Development of a digital terrain (GIS) model including infrastructure, elevation, land use and forest boundaries
- A detailed study of forest structure and composition for the biggest two forest fragments
- An ethnobotanical study of the forests.

These studies did not form part of the original proposal and co-financing was attracted to cover the costs involved.

The following training objectives were laid out in the original proposal.

- Allow Kenyan staff to train in Belgium on short term basis for specific techniques, this would include the M.Sc. students as well as other scientific staff directly involved in the project
- Provide research facilities for Kenyan M.Sc. students through the project
- Assistance of Belgian lecturers for specific courses in the M.Sc. Animal Ecology programme for which expertise was lacking at KU
- Extend general educational and research facilities at KU

During the course of THBP, the mammalogy research co-ordinator Dr. Oguge as well as the two M.Sc. students Mwangi and Odhiambo traveled to Belgium (and other places) to familiarize themselves with the latest techniques in their field of research. Furthermore, the M.Sc. students were provided with all research (and other) facilities to carry out their projects successfully.

Belgian lecturers were only involved in the teaching of the M.Sc course during the first year of the project. The objectives here were clearly not fully met and the reasons for this are explained elsewhere (see 4.1.2.).

Educational and research facilities at the Zoology Department of KU were extended, albeit maybe not to the full satisfaction of the department.

In general it can be said that the objectives were reached and in some areas they were definitely surpassed. It was foreseen to train two scientists to the level of M.Sc. In the end, however, THBP was involved with 3 Ph.D. (Edward Waiyaki, Kamau Wakanene, Mwangi Githiru), 4 M.Sc. (Mwangi Githiru, Richard Odhiambo, Ronald Mulwa and Daina Samba), and 2 undergraduate (Janet Midega and Tom Vermeulen) projects.

Another clear indicator of the success of the training programme is that both Mwangi Githiru and Richard Odhiambo who received full M.Sc scholarships from THBP, not only finished their M.Sc. degrees, but were able to attract the necessary funding to continue with a Ph.D. programme.

One of the major concerns for any collaboration is the issue of continuity. What happens when the initial funding dries up? Has the project provided a platform for the initiation for further long-term collaboration and research programmes? We believe it has.

Ornithology research has continued in the Taita Hills since the end of THBP. Both Daina Samba and Mwangi Githiru are still active in the area. Furthermore, the Taita Hills have been recognized as an Important Bird Area (IBA) by BirdLife International, which means that the Ornithology Department of NMK will carry out regular monitoring of the birds in the area. The results of the fragmentation study by the University of Antwerp will be of utmost importance for the development of proper management plans. With respect to the Taita Thrush some of these options are already outlined in this report.

Therefore the collaboration between NMK and UA will continue to exist and hopefully expand

Data on the small mammals of the Taita Hills is still being analysed by researchers from KU and UA. Through THBP a tight collaboration has evolved between KU, UA, the Pest Management Centre (formerly Rodent Research Unit) of Sokoine University in Tanzania, and the University of Rome in Italy. This group successfully applied for funding from the European Union for their project “Protecting staple crops in eastern Africa: integrated approaches for ecologically based field rodent pest management”, which is now underway.

Through THBP strong relations were also built between the Department of Invertebrate Zoology, NMK and the Royal Museum for Central Africa in Belgium. In 1999, the Royal Museum obtained additional funding from DGIS for a 5-year collaborative programme that focuses on extension and improvement of the invertebrate collections at NMK; training of NMK and other personnel and development and exchange of NMK and the Africamuseum collection databases.

It thus seems that while THBP has officially come to an end, the collaboration between UA, NMK, KU and the Royal Museum for Central Africa is alive and kicking.

3. RESEARCH

3.1. Introduction

The THBP tries to strengthen the capacities of KU and NMK in order to enable them to perform modern scientific research in the field of biodiversity and conservation in Kenya. The research component is, therefore, an important part of the project, both for training of scientific staff as well as for familiarisation with the latest scientific methodology.

As a model project, a study on the biodiversity of the isolated forest fragments in Taita Hills was chosen. These forest fragments harbour a high number of endemic plant and animal species, but are under serious threat due to habitat fragmentation and degradation.

The THBP research component deals with three key issues:

- What is the biodiversity still present in the scatter of indigenous forest fragments?
- What is the biogeographical relationship with other regions of eastern Africa?
- What is the impact of the forest fragmentation and degradation on the inhabiting fauna?

The THBP mainly aims at providing sound scientific data on the current status of the forest biodiversity. This data will ultimately be used to design proper management plans for the conservation of the few remaining forest fragments, and to restore other degraded forest remnants. The findings will also be used for development of possible spin-off products and alternative sources of income for the region, like developing the forests as an eco-tourism destination, or environmentally friendly and sustainable revenue generation like bee keeping and butterfly farming. The potential for these kinds of alternative enterprises has been shown in other places in Kenya, like Kakamega and Arabuko-Sokoke forest.

It is important that the data gathered by the THBP is translated back to the communities and to that effect THBP is collaborating closely with the Taita Hills Project of the East African Wildlife Society (EAWLS), which is focusing on conservation and management of the forests through community participation. The EAWLS uses the data gathered by THBP to illustrate the uniqueness and importance of the Taita Hills forest to the local communities living around the edges of the forest.

3.2. Study area

The area known as the Taita Hills is located between 3°15’ - 3°30’ S and 38°15 – 38°30’ E, in the southeast of Kenya, near Voi on the Nairobi-Mombasa highway. At the start of the project the following forest were selected for our study.

3.2.1. Dabida

The main hill complex, comprising the majority of the forest fragments, is also known as Dabida. It lies north of Mwatate (which is situated on the Voi - Taveta road, approximately 30km west of Voi). From Mwatate a tarmac road leads to Wundanyi which is situated in the centre of Dabida and which is the main town in the hills complex and the headquarters for Taita-Taveta District. The following fragments were identified within Dabida:

- Ngangao: main forest fragment of Dabida, comprising 92ha. Highest point 1952m. Indigenous forest mixed with plantation forest. Partly undisturbed, and surrounded by agricultural land.
- Chawia: second largest and southernmost forest fragment in Dabida, comprising 50ha. Highest point 1587m. Heavily disturbed and plantations of exotic trees inside the forest. Surrounded by agricultural land.
- Mwacha: small forest fragment of approx. 2ha. Highest point 1653m. Disturbed, and surrounded by plantation and agricultural land.
- Mwachora: east of Mwacha, also small fragment (2ha) on steep hilltop. Highest point 1627m. Disturbed and surrounded by agricultural land.
- Kichuchenyi: south of Mwacha and Mwachora and opposite Josa trading Centre. Highest point, about 1500m. The smallest fragment (less than 1ha) under study, on steep hill. Disturbed and surrounded by agricultural land.
- Vuria: the highest peak (2208m) and the westernmost forest of the Taita Hills. Only very small fragment (1ha) of closed canopy forest remaining on western slope, the rest is heavily disturbed and has a lot of low secondary vegetation.
- Yale: rocky outcrop mainly devoid of forest. Highest point 2104m. Only two small fragment of indigenous forest on northern and eastern side of rock (1ha) remain. Disturbed and intermixed with plantations.
- Ndiwenyi (Ngerenyi Polytechnic School): small fragment (1ha) behind school premises. Highest point approx. 1600m. Heavily disturbed and surrounded by agricultural land.
- Fururu: partly disturbed small fragment (5ha) with patches of plantation forest. Surrounded by agricultural land.

3.2.2. Mbololo

To the Northeast of Dabida and partly attached to it lies a smaller complex mainly dominated by single ridge that rises up to 1800 m altitude. On top of this ridge lies Mbololo (220ha), the largest and most undisturbed forest fragment of the Taita Hills complex.

To the South of Mbololo lies Ronge, which is basically an extensive *Pinus* plantation with scattered small patches (1ha or less) of indigenous forest at an altitude of about 1400m.

3.2.3. Mount Sagala

To the Southeast of these two formations, and south of Voi lies an isolated hill range, Mount Sagala, which rises to an altitude of 1520m. This also

harbours a few small, indigenous forest fragments, which are completely surrounded by plantation forest.

3.2.4. Mount Kasigau

Fifty kilometres to the South of Mount Sagala, and completely isolated, lies Mount Kasigau. Although not directly a part of the Taita Hills complex, the geological origin of Mount Kasigau is identical to Taita Hills, and at least one of the endemic birds, the Taita White-eye, is also found here. The undisturbed, closed-canopy forest starts at an altitude of about 1400m and extends al the way to the top (1641m). It is surrounded by bushland along its lower perimeter.

3.3. Ornithological research

Report compiled by Dr. L. Lens
Biology Department, University of Antwerp, Antwerp, Belgium

Taita Thrush with radio transmitter
Photograph by Thierry Geenen

3.3.1. The effects of forest fragmentation on the forest-dependent birds of the Taita Hills

3.3.1.1. Introduction

Habitat fragmentation can be defined as the process during which large, continuous habitat blocks become subdivided into smaller, more or less isolated fragments. Study of the effects of habitat fragmentation on the spatial structure and genetic variation of populations across a variety of taxa continues to identify dispersal as a key process in both population regulation and spatial distribution. Being a prerequisite for gene flow, dispersal also has substantial effects on the genetic structure of populations. In combination with detailed studies of the ecology and ethology of the inhabitants of fragmented ecosystems (some of which are poorly known, especially in the tropics), the study of the mechanisms of dispersal, especially of the quantitative relations between an organism's mobility and the structure of the landscape in which it has to move, therefore ranks among the highest priorities for research on the viability and dynamics of fragmented populations.

At the same time, there is a growing need for the development of simple estimators that measure the impact of environmental and genetic stresses on the health and fitness of these populations. In particular, ecologists are challenged to identify populations subject to stress, before the populations are irreversibly affected, as this would greatly increase the effectiveness of conservation programmes. It has been argued that Fluctuating Asymmetry (FA), a measure of condition, could be such an estimator.

The substantial ecological dataset, collected during the THBP, allows to test some of the relationships between environmental and genetic stress, mobility, quality, fitness and fluctuating asymmetry of individuals and populations in a recently fragmented Afrotropical cloud forest ecosystem. Results gained from this study can be expected to yield important insights both from an evolutionary viewpoint, through comparison with other fragmented systems, and an applied viewpoint, including recommendations for the conservation and management of the area and its endemic inhabitants.

3.3.1.2. Aims and objectives

The overall aim was to study the relationships between environmental and genetic stress, dispersal, morphometric differentiation and life-history parameters of a series of Afrotropical forest species in a fragmented landscape. Furthermore we wanted to get up-to-date estimates of the density and population structure of the most threatened Taita species.

The following objectives were therefore pursued: (i) to document the present status of seven forest restricted bird species of the Taita Hills, three of which are endemic to this area; (ii) to study in detail the behavioural ecology of the three endemic and Critically Endangered birds, namely the Taita Thrush, Taita White-eye and Taita Apalis, in comparison with a more widespread species like the White-starred Robin; (iii) to study the effect of

mobility, assessed by the species-specific levels of movement between forest fragments, on the population genetics of these species; (iv) to test whether fluctuating asymmetry, an index of condition, could act as an early warning system for the conservation of these and other species under potential threat of extinction; (v) to test whether blood parasite loads are correlated with characteristics of the individual and the habitat.

3.3.1.3. Material and methods

Fragmentation and degradation of the Taita Hills forests since the 1960s has been substantial, resulting in a conversion of the indigenous forest block to a scatter of twelve remnants, eight of which are smaller than 5 ha. The three larger fragments differ considerably in quality. The least disturbed fragment (Mbololo, 220 ha) has more biomass, higher stem densities, more tree species, higher diversity, higher equitability, greater canopy cover, more open shrub layer, higher leaf litter cover, and less herbaceous cover than the intermediate (Ngangao, 92 ha) and most disturbed one (Chawia, 50 ha).

By a combination of standard ecological techniques (e.g. large-scale ringing and observation) and more advanced ones (e.g. radio-telemetry, genetic markers), we collected extensive ecological and ethological data on the following, forest-restricted bird species: Taita Thrush (*Turdus helleri,* endemic), Taita White-eye (*Zosterops silvanus,* endemic), White-starred Robin (*Pogonocichla stellata*), Olive Sunbird (*Nectarinia olivacea*), Yellow-throated Woodland Warbler (*Phylloscopus ruficapillus*), Stripe-cheeked Greenbul (*Andropadus milanjensis*), and Cabanis's Greenbul (*Phyllastrephus cabanisi*). Together, these seven forest-restricted bird species represented over 92 % of all individuals captured with mist-nets between 1996-2000, and can hence be considered representative of the low- and mid-canopy bird community of the Taita Hills.

Using the data from a large-scale capture-recapture program (1996-2000, over 3200 captures) and a digitised landscape model of the study area (based on 190 aerial photographs, topographic maps and GPS-readings), patterns of movement between fragments by dispersing first-year birds (as an estimate of species-specific mobility) are related to structural features of the embedding landscape (topography, land-cover, land-use). Rather than separately correlating ecological data to single components of the landscape, a global property of the landscape, so-called ‘connectivity’, is applied. The structural connectivity of the landscape (linkage among habitat patches by their physical adjacency) is used to infer its functional connectivity (linkage by processes such as individual movements), and this technique allows, amongst other applications, to assess global or specific isolation parameters for individual fragments. The modelling technique is currently tested and validated in the framework of another landscape ecological study.

Intensive mist-netting in all fragments yielded a sufficiently high number of DNA samples (> 30 individuals per population) to screen a total of 38 populations. Polymorphic micro-satellite markers were developed for the seven Taita Hills study species, and tested in the Laboratory of Animal

Ecology, University of Antwerp, Belgium. Modern genetic techniques allow to study minute amounts of DNA, such as obtained from museum specimens, as well. Hence, between 1997-98, tissue was sampled from specimens that were collected in the Taita Hills before the main habitat fragmentation took place. Comparison of DNA from specimens (before fragmentation) with that of current captures (after fragmentation; same species and localities) allows to examine to what extent the genetic structure of the populations has changed over time.

The above findings are related to patterns of fluctuating asymmetry, a well-studied condition parameter. Statistical tools to estimate levels of fluctuating asymmetry, both at the population- and individual level, were developed at the University of Antwerp.

3.3.1.4. Collaborators

The following collaborators have studied and/or are currently studying material within the scope of the THBP:

Blood parasites

Prof. J. Cooper (Durell Institute of Conservation and Ecology, University of Canterbury, UK)

Genetic variation

Prof. E. Matthysen, Dr. P. Galbusera, Mr. T. Van de Casteele, Ms. T. Schenck (Laboratory of Animal Ecology, University of Antwerp, Belgium)

Morphological variation and developmental stability

Prof. E. Matthysen, Dr. S. Van Dongen, Dr. L. Lens (Laboratory of Animal Ecology, University of Antwerp, Belgium), Dr. S. Kark (Stanford University, California, USA)

Biodiversity & Conservation

Dr. T. Brooks (Department of Biological Sciences, University of Arkansas, USA), Dr. L. Bennun (Department of Ornithology, NMK, Kenya), Ms. C. Wilder (Health Sciences Center, University of Virginia, USA)

Frugivory

Mr. M. Githiru (Zoology Department, Kenyatta University, Kenya)

Behavioural ecology

Mr. E. Waiyaki and Mr. T. Vermeulen (Laboratory of Animal Ecology, University of Antwerp, Belgium), Mr. M. Githiru (EGI, Oxford University, UK), Ms. D. Samba (Wildlife Management Unit, University of Reading, UK), Mr. R. Mulwa (Department of Ornithology, NMK, Kenya)

GIS and connectivity

Dr. M. De Meyer (Royal Museum for Central Africa, Tervuren, Belgium), Dr. L. Lens (Laboratory of Animal Ecology, University of Antwerp, Belgium). Mr. B. Bytebier (Centre for Biodiversity, National Museums of Kenya, Kenya)

3.3.1.5. Time frame of activities

Year 1

Selection of the study species and sites, based on a survey by Dr. Thomas Brooks

Start of the large-scale ringing programme, including ringing and colour-ringing, a selected number of measurements, moult and fat scores, age and sex determination, collection of blood samples and smears

Start of radio-telemetry on Taita thrushes in fragment Chawia, as part of the PhD research programme of Mr. Waiyaki

Start of the frugivore research in fragments Chawia and Ngangao, as part of the MSc research programme of Mr. Githiru

Year 2

Continuation of the capture-recapture programme, with extensions to Mount Kasigau and Mount Sagala

Continuation of the radio-telemetric study by Mr. Waiyaki

Continuation of the frugivore study by Mr. Githiru

Collection of behavioural data of Taita thrushes by Mr. Vermeulen, as part of his BSc thesis

Collection of behavioural data of Taita white-eyes by Mr. Mulwa, as part of his MSc thesis

Collection of tissue samples from museum specimens, collected in the Taita Hills between 1934-1948 and kept in several African and north-American museums

Sexing of Taita thrushes with molecular techniques

Year 3

Continuation of the capture-recapture programme

Continuation of the radio-telemetric study by Mr. Waiyaki

Continuation of the frugivore study by Mr. Githiru

Continuation of the behavioural study of Taita white-eyes by Mr. Mulwa

Screening of microsatellite DNA-markers for all Taita study species

Start of genetic analysis of the blood samples from the Taita thrush

Year 4

Finalisation of the capture-recapture programme

Finalisation of the radio-telemetric study by Mr. Waiyaki

Start of analysis and writing-up of PhD thesis by Mr. Waiyaki

Writing-up of MSc thesis by Mwangi Githiru

Drafting of PhD proposal by Mr. Githuri

Start of radio-telemetric study on the White-starred robin by Mr. Githiru, as part of a Ph.D. study

Continuation of the behavioural study of Taita white-eyes by Mr. Mulwa

Extension of the genetic work to the other study species

3.3.1.6. Results

Ecology and population status

Preliminary results show that all three endemic species, Taita Thrush, Taita White-eye and Taita Apalis, are highly sensitive to habitat disturbance. In the case of the Taita Thrush, for which most data are currently available, heavily degraded habitats support low and more environmentally and genetically stressed populations. Although the estimated population sizes of Taita Thrush and Taita White-eye are higher than originally assumed, populations in

Chawia (and to a lesser extent Ngangao) are under considerable threat. The observation that Taita white-eyes make use of isolated trees in the agricultural matrix (mainly fast-growing exotic trees such as *Cupressus* and *Eucalyptus*) when foraging and resting, suggests that these act as stepping stones when moving between fragments.

Patterns in mobility and sex ratio

We compared patterns of dispersal and sex ratio in the Taita study species, with similar data from various taxa in a historically fragmented, Belgian landscape. The amount of dispersal (documented by recaptures and resightings of ringed birds) between fragments was low and varied considerably between species. The obligate frugivorous and nectarivorous species (greenbuls, sunbird) were more mobile than the mainly insectivorous thrush and robin. The low rates of interfragment dispersal, compared to the Belgian study site, are believed to result from differences in time scale (more recent fragmentation in the tropical site) and spatial scale (strict isolation from neighbouring populations and reduced interfragment dispersal in the tropical site). Taita thrushes show an extremely male-biased sex ratio in the most disturbed forest fragment (Chawia), but less so in more intact areas. This demographic feature might increase the degree of threat imposed to the species, as highly skewed sex ratios presumably lower the reproductive output.

Population genetics of the Taita thrush

Analysis of 155 individuals with seven polymorphic microsatellite DNA markers shows significant genetic differentiation between the three remaining populations, Chawia, Ngangao, and Mbololo. Population levels of heterozygosity do not differ between the three populations, whereas the allelic diversity in Chawia is reduced with nearly 50% compared to Ngangao and Mbololo. This, apparently conflicting, result can be explained by the fact that the Chawia population went through a recent population bottleneck which mainly caused the loss of rare alleles but had little effect on the level of heterozygosity.

Low effective population sizes, particularly at Chawia, warns for genetic deterioration, while its absolute numbers do not warrant against demographic stochasticity, particularly in view of the low dispersal rates between populations. For instance, accidental loss of just one or two females in Chawia might cause immediate extinction of this population. While at species level, the loss of Chawia would not dramatically reduce overall numbers, relatively more genetic diversity is lost with the loss of single individuals when the effective population size is small. Besides, extinction of one population may result in substantial loss of overall genetic variation if the latter is heterogeneously distributed among populations. Thus, both based on genetic and non-genetic evidence, the species' conservation status of globally, Critically Endangered remains fully justified, despite the discovery of larger numbers than originally estimated.

Conservation action for the Taita Thrush appears urgent. Since gene flow rates as small as one immigrant per generation are believed to counteract the

effect of genetic drift in small populations, translocation of individuals to Chawia seems a plausible strategy to reduce the negative effects of the genetic bottleneck. Interbreeding with man-induced immigrants may, however, turn frequent Chawia alleles into rare ones, which could be more easily lost in subsequent generations due to genetic drift. The net result of such translocation would be loss rather than gain of allelic diversity at the population level. A better option might therefore be to restore the habitat in Chawia to allow for natural population growth. It remains, however, doubtful whether habitat restoration at Chawia is realistic at a short term, and a carefully planned translocation of a small number of individuals with known genotypes might still be necessary to prevent this population of going extinct before more sustainable conservation programs can be implemented.

Patterns of fluctuating asymmetry in relation to stress and survival

Levels of fluctuating asymmetry increase in relation to the level of habitat degradation, consistently so across study species and across traits that are expressed during different developmental stages. In Taita thrushes, symmetry, but not survival, is reduced in the moderately disturbed fragment (Ngangao), whereas both symmetry and survival decrease in the most degraded fragment (Chawia). In contrast, other individual covariates, such as size, body condition, or inbreeding, do not show a significant response to habitat disturbance. At the individual level, asymmetric individuals have lower survival prospects compared to more symmetric ones, but the magnitude of the relationship decreases with increasing forest quality: in the most degraded fragment, FA and survival are strongly, inversely related, while in the least degraded one (Mbololo), they are not significantly related. Thrushes with higher residual body masses survive better, irrespective of the degree of habitat deterioration, whereas size and inbreeding are not significantly related to survival.

When using data from projects, such as the THBP, to assess the applicability of FA in conservation planning, it is crucial to take the level of analysis into account. In the vast majority of cases, the ‘population’ constitutes the level of interest to conservationists, who aim to select the most appropriate targets for conservation if resources are restricted, or to assess the extent and rate of recovery after conservation action has been undertaken. Results from the THBP show that population FA does respond to distinct stressful events, and proves more sensitive compared to more direct fitness components. Hence, FA measured at the population level can, indeed, be regarded as a potential ‘early warning system’ in conservation. As the study of asymmetry does not require recaptures, adequate sample sizes are relatively easily obtained, and estimation accuracy can normally be expected to be high.

Study of endoparasite load

As part of the large-scale ringing program, over 2500 blood smears were collected for the study of parasite load. Because this technique required specialized training, Prof. Dr. John E. Cooper organized a teaching seminar at NMK on the collection of endo- and ectoparasites, followed by a practical session on 30-31 July 1997, for all technicians linked to the THBP. A first batch of 200 smears has been screened on the following parameters:

leucocytosis, leucopoenia, monocytosis, thrombocytosis, lymphocytosis, heterophilia, eosinophilia, basophilia, abnormal leucocytes and immature erythrocytes. Tentative results indicate patterns that strongly correspond with those found for fluctuating asymmetry, i.e. high incidence of blood parasites in population Chawia (most disturbed), and lower incidences in populations Nganagao and Mbololo (less disturbed). Besides, there appears to be a negative relationship between the presence of blood parasites and the level of mobility, at species level. A manuscript entitled "A study of avian blood parasites in the Taita Forest, Kenya" is currently in preparation. This paper decribes some methodological problems encountered during our study, stresses the need for standardized techniques in such work, and discusses the relevance of our findings in terms of avian protozoology and pressure on threatened populations of birds.

3.3.1.7. Future activities

(i) translating the ecological and ethological data of the threatened, endemic bird species into practical recommendations for conservation action

(ii) extension of the parasitologic and genetic analyses to all species-fragment combinations for which a sufficient number of blood smears/samples (i.e. at least 30 samples) has been collected; some of the remaining individuals will be sampled by Mr. Githuri as part of his PhD programme

(iii) computing the mean density and mean level of mobility for all species-fragment combinations, based on the complete ringing database

(iv) modelling the probability of survival (and recapture) for all species-fragment combination with the statistical programme MARK, based on the full set of individual capture-recapture histories

(v) finalising the Digital Landscape Model, and using a ‘connectivity approach’ to study the effect of the structure of the landscape on the demography and genetic population structure of the different study species

The above-mentioned analyses do not require additional grants, and will be completed within 1-2 years.

3.3.1.8. Future related activities

After the end of THBP, scientific research has continued in the Taita Hills. Mr. Mwangi Githuri is doing his Ph.D. research on the ecology of the White-starred Robin at Oxford University, UK, with the specific aim to contribute to the general understanding of the effects of habitat fragmentation on small populations. Ms. Daina Samba investigates the status of the Critically Endangered Taita Apalis, the third endemic bird of the Taita Hills, as part of her M.Sc. studies. Furthermore, the Taita Hills are classified as an IBA (Important Bird Area) and will therefore remain under a continuous monitoring program, implemented by Nature Kenya and the Ornithology Department of NMK. Further analyses of the genetic data of Taita Hills’ specimens will be

conducted in the framework of research on temporal patterns in genetic variation in birds by the Laboratory of Animal Ecology.

3.3.1.9. Collaboration and financing

Before the start of the THBP, the Laboratory of Animal Ecology (University of Antwerp) was not explicitly involved in research in the eastern African region. At present, one Kenyan Ph.D. student (Mr. Waiyaki) is supervised, while another one (Mr. Githiru) is co-supervised in close collaboration with Oxford University. At present, there is the intention to set up new, short-term research activities in the Taita Hills, in combination with a long-term, ornithological monitoring programme run by the Department of Ornithology, NMK. The latter is not yet formalised, and will depend on the availability of grants and manpower.

During the course of the THBP, E. Matthysen and L. Lens obtained a research grant (400.000 BEF) of the Research Council of the University of Antwerp (UIA) for the development of a Digital Landscape Model (GIS approach; see above and section 3.9). L. Lens further obtained several travel grants from the National Science Foundation (Flanders) for attending the workshop in Morogoro, for fieldwork and supervisory activities in the Taita Hills, and for sampling museum specimens in Kenya and North America. As an indirect spin-off of the THBP, a research grant (4.000.000) was obtained from the Joint Research Council of the University of Antwerp, for the development of techniques to isolate DNA from museum specimens.

3.3.1.10. Training

An important component of the ornithological work involved the training of technical and scientific staff, directly or indirectly linked to the THBP, in field ecological and analytical techniques.

Prof. J. Cooper provided training in the collection of endo- and ectoparasites from birds, to staff members and students attached to the Department of Ornithology.

Prof. E. Matthysen and Dr. L. Lens provided training in the the use of radio-telemetry and collection of blood samples for DNA analysis, to students E. Waiyaki, M. Githiru, and T. Vermeulen.

Dr. L. Bennun and Mr. C. Jackson (NMK) provided training in standardised mist-netting techniques, to students R. Mulwa and D. Samba and the field assistants associated to the various research projects.

Finally, during the course of the THBP, students Mr. E. Waiyaki and Mr. M. Githiru were invited to the Laboratoy of Animal Ecology for training in statistical analysis and literature study.

3.3.1.11. Evaluation of collaboration

The THBP has proved highly beneficial to both Belgian and Kenyan scientists linked to its ornithological component. In Belgium, the ornithological research activities have directly or indirectly initiated a series of new collaborative research projects, such as the study of blood parasites in relation to environmental and genetic stresses (collaboration with Prof. J. Cooper from Canterbury University, UK), the study of ancient DNA for analysing temporal changes in genetic variation (collaboration with Prof. J. Fjeldså, Copenhagen Museum, Denmark), and the use of genetic assignment tests for estimating gene flow (collaboration with Prof. P. Waser, Purdue University, USA). At the Kenyan side, it has resulted in several theses at the Bachelor, Master and Doctoral level. Past and ongoing research projects have resulted in tight, collaborative links between the Department of Ornithology (NMK, Kenya), The Edward Grey Institute of Field Ornithology (Oxford University, UK), and the Department of Animal Ecology (University of Antwerp, Belgium), which will be continued after the end of the THBP.

3.3.2. Ecological and behavioural response of the critically endangered Taita Thrush, *Turdus helleri*, to habitat degradation in a fragmented landscape

Report by Edward Waiyaki Mangara, Ornithology Department, National Museums of Kenya

3.3.2.1. Introduction

The Taita Thrush, *Turdus helleri*, is a specialised secretive ground-dwelling forest bird, endemic to the highly fragmented Taita Hills mist forests. Of the remaining 12 indigenous forest fragments, breeding populations are only found in the 3 large fragments (Mbololo, Ngangao and Chawia) and in Yale, a smaller but high quality fragment.

Because of its small population size and restricted range, the species is globally recognised as Critically Endangered, the highest category of threat before extinction. Before the start of this study, only scanty and anecdotal ecological information existed on this bird, and crucial conservation information like distribution, population size and habitat use, were unavailable. In addition, the forests of Taita Hills are continuously getting degraded, and hence the urgent need to conserve this species based on focused ecological research findings.

3.3.2.2. Aims and objectives

The study was designed to have both practical and theoretical applications. The general aim of the study was to investigate the ecological and behavioural response of the Taita Thrush to habitat degradation in a fragmented landscape, and to use this information to plan appropriate and realistic management actions for the species conservation. The object of the study was thus (i) to understand some fundamental ecological aspects of the species like general habitat use, population size, feeding, movements,

roosting, breeding etc. (ii) to understand the effects of habitat degradation and structure to the species territorial and social organisational systems (iii) to understand in greater details the territorial behaviour of individuals and to find out if this is related to the individuals condition (iv) to understand the genetic relationship between various study individuals in social groups and lastly, (v) to document environmental and/or genetic stress as expressed by levels of fluctuating asymmetry.

3.3.2.3. Results

Population size and density

Extrapolation of radio-telemetric data on home-range size, home-range overlap and number of non-territorial birds per fragment yielded subpopulations estimates of 38 individuals in Chawia, 250 individuals in Ngangao and 1059 individuals in Mbololo. Including the few individuals that were caught in Yale, the global population of the Taita Thrush is thus estimated just over 1,350 individuals. Densities were lowest in Chawia (1.3 birds per ha), moderate in Ngangao (2.7 birds per ha) and highest in Mbololo (5.3 birds per ha)

In a separate analysis addressing the species genetic variability and gene flow, the *effective population size* (using a mutation rate of 5×10^{-3}) was estimated as 3 for Chawia, 15 for Ngangao and 75 individuals for Mbololo. The estimates are proportional to the estimated subpopulation sizes using radio-telemetric data, and the ratio of effective to estimated subpopulation sizes fall close to the standard mean ratio of 0.06, which confirms the radio-telemetric estimates as accurate.

Home range size and structure

Fourty nine territories were mapped in the 7 equal sized study plots (9 ha) within the 3 fragments (2 plots in Chawia and Mbololo and 3 plots in Ngangao) using radio telemetry. Utilization of distribution curves calculated in RANGES V showed that thrushes have a multinuclear range and that a marked increase of the curve in range's distribution occurred at 80% of the fixes. Home range sizes were calculated using clustering method in RANGES V and varied from 0.01 ha to 1.65 ha. Home range size did not differ between sexes, nor were there differences between seasons.

Habitat quality

Habitat quality was assessed by measuring the structural vegetation composition of the study plots and summarising the various structural components by Principal Component Analysis which resulted into 2 principle axis explaining around 70% of the variation. The first axis had high positive loadings for number of trees, litter cover and litter depth, and a negative loading for herbaceous cover. It thus measures dense forest with a well developed and mature litter layer, void of herbaceous layer. The second axis had high positive loadings for tree canopy height and cover, and thus measures tall well shaded forest. When the two axis are plotted on an XY graph, the heavily disturbed plots as in Chawia showed low values of PC1 and PC2, while less disturbed plots from Ngangao and Mbololo showed moderate

to high values of both PC's. Leaf litter invertebrates, which are the principal food items for the thrush, were estimated separately.

Home range and habitat quality

A significant negative relationship was shown between home range size and habitat quality measures (PC1, PC2 and invertebrates abundance). Thus, small home ranges tend to have high values of PC1, PC2 and invertebrates, while large home ranges tend to have low values of the same. Therefore, thrushes in a high quality habitat (less degraded) maintain smaller home ranges than their counterparts in heavily degraded habitat, who acquire large area. Thus, a more degraded fragment would have lower densities than a less degraded fragment.

Fluctuating asymmetry (FA) and habitat quality

Populations and individuals from heavily degraded habitats have high levels of FA (a measure of environment and/or genetic stress). Such individuals are suspected to have lower fitness and are of lower quality (see also 3.3.1.6.)

Genetic variability and gene flow

Using DNA from 155 individuals, the three subpopulations of the thrush were shown to have undergone significant genetic differentiation. The Mbololo subpopulation was shown to be more different from both Ngangao and Chawia, who appear less different. However, the Chawia subpopulation has undergone a recent genetic bottleneck resulting in nearly 50% loss of its allelic diversity, and an emergence of several unique alleles over time (see also 3.3.1.6.).

Ecology

Habitat Use: At the microhabitat level the Taita Thrush highly prefers dense shaded undergrowth with dense litter cover. Wetter areas along forest valleys and along river/stream courses were also preferred, at particular times of the day and also during the dry periods.

Foraging: Thrushes feed largely, but not entirely, on the ground. Frequent visits to fruiting trees when in season, and occasional/opportunistic foliage and bark gleaning also occur. In over 80 % of the sampling time, thrushes were detected (visual observation or with radio telemetry) foraging on the ground. They prefer foraging in dark well-shaded areas, covered exclusively with litter (void of herbaceous cover) and dead fallen logs. Social foraging between flock members is common, especially in areas with a super abundance of invertebrates (e.g. forest ants). Communication between foraging members is kept at all times by low sounding whistles. Despite this apparent sociality, inter individual foraging distances are maintained when exploiting a potentially limited resource.

Roosting: Roosting behaviour was studied with respect to habitat quality and home range characteristics by radio telemetry in 15 individuals in Ngangao. Thrushes roost at a height of 8 to 15 meters, with a mean of 12.7 meters. An individual has one or two preferred roosting sites that are visited

every night. These sites are within the core area of the individual home range but are not necessarily preferred for foraging. These sites are of high habitat quality with high values of PC1 and PC2. They are thus characterised by a high and dense closed canopy, with a dense mid storey.

Movements: By use of mist netting and colour ring observations, within fragment movements were studied. Local movements are largely within an individual's home range, but longer distance movements of up to 300 meters do occur. Most of these occasional movements were linked to visiting fruiting trees and bathing pools.

Breeding: Breeding in the Taita Thrush is very secretive and extremely difficult to study. This made direct observation and systematic data gathering impossible. Indirect study of breeding was through birds with brood patches caught in the mist net, observation of dependent and independent juveniles, and observation of nesting activity. The few nests that were seen were 15-20 meters high and in dense cover. One of the nests was in an excavated tree hole, which is not typical for thrush species. Breeding occurred all year round, with no obvious peak. In one of the observed nests, three fledglings were observed. While out of the nest, social foraging with other adults and juveniles was common (co-operative juvenile foraging).

Longevity: Evidence from mist netting suggests Taita Thrushes life span to be at least three and a half years. Estimates from survival analysis predict a shorter lifespan.

Social Organisation: Occurrence of Taita Thrush may either be solitary or in a group of conspecifics. Flocks were observed while foraging, bathing, avoiding predation and, during dusk and dawn chorus, close to roosting sites. Loose and closed flocks occur, the former related to opportunistic foraging and roosting, whilst the latter is probably restricted to kin related individuals. Flock sizes seemed to be influenced by habitat disturbance, at least at the plot level. In heavily disturbed plots, flock sizes were smaller compared to flocks in less disturbed plots. At the microhabitat level, individuals formed larger flocks while foraging in open, than in closed undergrowth.

3.3.2.4. Conclusions

The Taita Thrush was shown to be a species highly sensitive to habitat disturbance. Heavily degraded habitats support low and more environmentally/genetically stressed populations. In Chawia, the most degraded fragment, local recruitment is predicted to be low due to a highly skewed male-biased sex ratio.

There is a preference for high, well-shaded forest with a high abundance of leaf litter invertebrates. Home ranges are thus smaller in like habitats and therefore "cheaper" to maintain. A decrease in habitat quality is compensated by an increase in home range size and therefore "expensive" to maintain. Habitat degradation, and thus reduced habitat quality, seems to affect this very sensitive species in more other critical ways as reflected in the social organisation dynamics with habitat quality.

Although the total population size is higher than was prior remarked, the Chawia and Ngangao populations are under considerable environmental/ genetic stress. Their habitats especially Chawia are increasingly being altered by man, putting the population future survival at risk of extinction. Coupled with the recent genetic bottleneck, the Chawia population urgently begs for an intervention to promote its chances for future survival.

3.3.2.5. Recommendations

(i) The remaining habitat for the Taita Thrush should be intensively protected and managed with emphasis on restoration of a closed canopy structure

(ii) There should be a complete ban on all levels of logging and other forms of timber utilisation to ensure high quality habitat

(iii) Genetically well-selected individuals (especially females) should be translocated to Chawia to boost variability and increase local population recruitment to save this population that is at the brink of extinction

(iv) To avoid loss of Chawia specific alleles in case the population goes to extinction, some individuals from Chawia should be translocated to Ngangao

(v) Since inter fragment dispersal is almost absent, a study focused on the breeding ecology of the species in Ngangao and Chawia is needed, to document and shed light on local population recruitment

(vi) A strict monitoring programme for the species is recommended. The programme would best be guided by severity of threat to subpopulations (Mbololo-annual; Ngangao-biannual and Chawia-quarterly)

(vii) Continuous habitat monitoring/surveillance is recommended

3.3.3. Avian frugivory and seed dispersal in some of the Taita Hills forest fragments

Report by Mwangi Githiru, Ornithology Department, National Museums of Kenya

3.3.3.1. Introduction

The increasingly rapid destruction and fragmentation of tropical forests are well known to have negative effects on the populations of forest-dependent plants and animals. The Taita Hills forests, a centre of endemism and an important area for bird conservation in Kenya, are an example of extreme habitat fragmentation with a landscape mosaic made up of scattered forest fragments of different sizes and disturbance levels surrounded by different land-uses. Yet, until fairly recently, few studies focused on the effects of disturbance on the interactions between taxa, such as between flowers and

their pollinators, or fruiting trees and their vertebrate seed dispersers; these interactions are crucial and may potentially be complex.

3.3.3.2. Aims and objectives

This was a study aimed at examining (i) variations in fruit and avian frugivores densities; (ii) the effects of habitat fragmentation on the interaction between the two; and (iii) for selected plant species, the spatial patterns of adults and regenerating individuals.

3.3.3.3. Material and methods

This work was chiefly carried out in seven forest fragments in the Dabida massif of the Taita Hills, namely Ngangao, Chawia, Fururu, Ndiwenyi, Macha, Mwachora and Yale, between September 1997 and June 1998. The forest on Mt. Kasigau was also included for some analyses.

Transects were laid in all fragments and used for bird and fruit censuses, and for assessment of regeneration. Timed watches were used to describe frugivore assemblages at selected trees.

3.3.3.4. Results and discussion

Data on fleshy fruits and avian frugivores were collected from transects in Dabida and grouped into sections (each comprising of 2-5 transects) for the analyses. Three rounds of data were collected in two distinct time periods, wet season (September to November) and dry season (January to March). In total 110 plant species (trees, shrubs and climbers) were identified of which about 76% were fleshy fruit-producers. Overall tree diversity was lower in the smaller fragments, which were also the most disturbed. Fruit density varied spatially and temporally, peaking in January in Ngangao and in October-November in Chawia and the smaller fragments. Sections with the highest fruit densities fluctuated most. Fourteen avian frugivores were recorded, of which five (Cabanis's and Stripe-cheeked Greenbuls, Hartlaub's Turaco, Taita Thrush and Taita White-eye) were relatively important in terms of density, distribution and frugivory levels. In general, frugivore densities were not linked to total fruit densities. During the period of lowest fruit abundance, but not at other times, significant explanatory variables for frugivore densities in a General Linear Model (GLM) included fragment size and tree diversity (corrected for fragment size). The relationship was positive in both cases. Frugivore numbers did not appear to track fruit supplies; density fluctuations were more likely connected with seasonal breeding behaviour, as the recorded densities of both frugivores and non-frugivores changed in a similar way, and showed declines during peaks in breeding activity.

Using Mantel statistics the frugivore assemblages of 58 individual trees belonging to 11 species growing in seven forest fragments, six in Dabida plus Kasigau, were examined. Overall, there was little evidence of specialized frugivorous interactions. Site and fruit size significantly affected similarity of frugivore assemblages among conspecific and heterospecific tree species, respectively. Effect of location of tree could be attributed to forest fragments of

different sizes varying in densities and composition of focal fruiting trees, and in the fruiting phenologies of these trees. Consequently, these findings indicate that at least one important processes of seed dispersal, i.e. fruit selection, may have been affected by habitat fragmentation.

Lastly, the spatial patterns of young and adult individuals of mainly bird-dispersed plants (five tree and one climber species) were looked at. Regenerating individuals (both of the trees and climber) occurred more on species that were also fleshy fruiting, than expected from their relative densities in the habitat. This could be attributed, at least partly, to the foraging patterns of the avian frugivores, which suggests some potential to 'shape' their habitats. Secondly, little congruence was found between the spatial patterns of young and regenerating individuals of the five tree species, which was consistent for all sections. This could imply that the avian frugivores were unlikely to be highly efficient seed dispersers for these trees; and that they had fairly comparable dispersal efficiencies. Lastly, pioneer species regenerated better in disturbed areas, whereas the non-pioneer species, since they do not require large gaps for germination and establishment, were found to regenerate better in larger, less disturbed fragments.

3.3.3.5. Constraints

The main problems encountered during the course of data collection were based on weather and transport. The unpredictability of the weather (which made it totally impossible to work some times) made overall planning very difficult. In future, it is important to have ample spare time as contingency. This was worsened by poor transport plus difficult terrain all of which made life and work there extremely frustrating, but only sporadically. There was, on most occasions, a very positive attitude from the local people; and most other aspects of the research work went on quite well. Towards the end living expenses were quite high and this caused some strain.

3.3.4. The population status and ecology of the Taita White Eye, *Zosterops (poliogaster) silvanus*, in the fragmented forests of Taita Hills.

Report by Ronald Mulwa, Ornithology Department, National Museums of Kenya

3.3.4.1 Introduction

The forests of Taita Hills in southeast Kenya are of exceptional conservation importance. They are a hot spot of biodiversity, having three endemic bird taxa, all of which are Critically Endangered. These are the Taita Thrush (*Turdus helleri*), the Taita Apalis (*Apalis (thoracica) fuscigularis*) and Taita White-eye (*Zosterops (poliogaster) silvanus*).

Habitat fragmentation is one of the main threats to biodiversity worldwide. The Taita Hills forests are today reduced to tiny fragments, ranging in size from 200 ha to less than 1 ha, and covering only 500 ha in total. Human

pressure on these minuscule forest patches remains extremely high, and many are already severely degraded.

This study focused on the Taita White-eye. Prior to this study little was documented about its current population status and habitat utilisation.

3.3.4.2. Aims and objectives

The main objectives of this study were to estimate the population of the Taita White-eye (TWE) as well as to determine the habitat factors best explaining its presence, flock sizes and densities. More specifically the objectives were: (i) to assess the distribution and population of the TWE in forest fragments of different sizes and disturbance levels; (ii) to study habitat use and selection by the TWE and its possible use of the surrounding agricultural matrix; (iii) to document any information that could lead to better understanding of the ecology of the TWE; and (iv) to recommend appropriate measures for the conservation of this species.

3.3.4.3. Material and methods

The work was carried out in all the eleven forest fragments of the Taita Hills (Mbololo, Ngangao, Chawia, Macha, Mwachora, Rong'e, Fururu, Ndiwenyi, Vuria, Yale and Sagala) and the virtually undisturbed Mt Kasigau, 50 km from the main Taita Hills massif. Data was collected between November 1998 and September 1999. Line transects were used for the TWE census as well as habitat parameter measurement. Existing tracks and footpaths were used as far as possible. Transect lengths ranged between 100 - 600 meters long and depending on the size of the fragment, 4 to 12 transect lines were marked. Each transect was surveyed and mapped and marked with flagging tape at 20 m intervals to help in mapping TWE sightings. For each fragment, at least one randomly selected transect, 1km in length, was placed running from the forest edge into the agricultural matrix. These transects were used to assess if the TWE makes use of trees outside the forest boundaries. By walking slowly along transects and recording TWE flock sizes as well as the perpendicular distances from the tree they were in to the transect, population sizes and population densities will be calculated by use a computer software " DISTANCE". To assess TWE habitat choice, habitat parameters at the spot where they were located were recorded. These were: canopy height, % canopy cover, tree species utilised, % moss cover on trees, presence/ absence of tree-fall gaps, tree species in fruit or flower, and part of trees used by TWE. Flagging tapes were used to mark these exact points. Later habitat parameters were measured at other randomly selected points for comparison between the TWE present and absent points. Transect lines were walked between 07:30 and 12:00 am and again from 3 to 4 pm, when weather allowed it

3.3.4.4. Results and discussion

The total population of TWE in the area was estimated to be 7123 birds. Densities and populations in the various fragments were as follows (in descending order of fragment size): Mbololo, 2.96 birds/ha, 651 individuals;

Ngangao, 5.2 and 478; Chawia, 4.4 and 220; Vuria, 3.7 and 39, Yale, 4.6 and 23, Fururu, 7.0 and 32, Macha, 9.7 and 29, Mwachora, 15.5 and 31 and Ndiwenyi 15.5 and 26. No TWEs were encountered in Sagalla and Ronge forests. On Mt Kasigau, TWE density was estimated at 25.9 birds/ha, much higher than in any of the Taita Hills forests with an estimated population of 5594 birds. The largest TWE flock sighted during this study was at Kasigau with 135 birds, and flocks of over 80 birds were not uncommon here. Clearly, this is the main stronghold for this species.

The selectivity index analysis revealed that, at a macro-habitat level, the TWE prefers riverine and edge habitats. The micro-habitat parameters positively predicting its presence, flock size and density (based on normal and logistic regression models) are, % epiphytic moss cover, canopy height, % mean canopy cover above 15 m height and % mean canopy cover. Though the TWE uses a broad spectrum of trees, certain species are preferred like *Xymalos, Macaranga*, *Syzygium*, *Strombosia*, *Albizia, Trema*, *Milletia* and *Maesa* sp.

The TWE also utilises some exotic tree species like *Eucalyptus*, *Acacia mearnsii*, and *Cupressus*, especially in the smaller fragments. *Pinus* stands, however, were almost entirely avoided. The TWE feeds mainly on insects (84% of the observations) and to a lesser extent on fruits. The TWE makes use of isolated trees in the agricultural matrix and, therefore, establishing and maintaining a network of corridors between the fragments (e.g. hedge rows) using the plant species utilised by TWE will promote mobility and thus gene flow between different populations.

Breeding was observed only in the larger fragments > 50 ha. In one site, Mbololo, nest predation by African Goshawk (*Accipiter tachiro*) and Vine Snake (*Thelotornis kirtlandii*) was extremely high (87% of observed cases).

At Mbololo the TWE associates a lot more with other bird species than in any other forest. The possible interspecific competition coupled with the high predation pressure could explain the low densities at this site.

TWEs in Mount Kasigau forest are restricted to higher altitude between 850 m and the top, 1680 m. The absence of this species at lower altitudes could be due to a lack of suitable habitats. A second possibility is that the microclimate at the lower altitude may be too hot and hostile to the TWE. It is not known if the Mount Kasigau TWE population is completely isolated from the other populations in the Taita Hills forests, separated by a 50 km stretch of dry woodland and sisal plantations at 500 m altitude. Mount Kasigau is of high conservation value because it holds a large TWE population. However, this white-eye population is vulnerable to human-induced habitat destruction and/or catastrophic events e.g. a forest fire. Mount Kasigau has an abundance of TWE-preferred habitats and this could explain its high density here. Furthermore there could be a competitive release since there are few other small insectivore/frugivores in Mount Kasigau forest perhaps due to the isolation from similar forests.

3.3.5. An investigation into the population size, habitat preferences and conservation status of the critically endangered Taita Apalis, *Apalis (thoracica) fuscigularis,* endemic to the Taita Hills

Report by Daina Samba, Ornithology Department, National Museums of Kenya

3.3.5.1. Introduction

This ongoing study is assessing the status, population size and habitat preferences of the Taita Apalis *Apalis (thoracica) fuscigularis*. This species is endemic to the tiny, fragmented forests of the Taita Hills, where it occurs in only four remnant patches, totalling less than 150 ha in area, on a single massif. It is absent, for unknown reasons, from a larger patch of less-disturbed forest on the adjacent massif of Mbololo. Although the apalis is critically threatened, very little is known about its status or ecology. Through a combination of individual colour-banding and measurement, territory mapping, and measurement of habitat parameters, this study investigates the apalis' population size, the condition of birds in the different fragments, the species' micro- and macro-habitat selection, and the suitability of Mbololo and other unoccupied fragments for possible (re-)introduction of this species. This study complements ongoing ecological work on the Taita Hills bird community and the other two threatened bird species, and the results will feed into management plans being drawn up for the forest.

3.3.5.2. Aims and objectives

This study investigates the conservation biology of the Taita Apalis, *Apalis (thoracica) fuscigularis*, a critically endangered bird species presently confined to three tiny forest fragments on one massif of the Taita Hills. Specifically, the project aims: (i) to determine overall population size and density in each fragment; (ii) to determine micro-habitat selection with particular respect to vegetation structure and forest disturbance; (iii) to determine the suitability of Mbololo forest and five other fragments on the Dabida massif for establishing an introduced population of the Taita Apalis as an immediate conservation measure.

3.3.6. Endemic forest birds of the Taita Hills: using a model species to understand the effects of forest fragmentation on small populations.

Report by Mwangi Githiru, Ornithology Department, National Museums of Kenya

Habitat fragmentation has been singled out in recent studies as the greatest single threat to biodiversity. The Taita Hills forests, a centre of endemism and an important area for bird conservation in Kenya, are an example of extreme habitat fragmentation with a landscape mosaic made up

of scattered forest fragments of different sizes and disturbance levels surrounded by different land-uses.

This currently ongoing study will generate clear information on some demographic and genetic parameters of different populations of the White-starred Robin (WSR), *Pogonocichla stellata helleri.* This species is used to model effects of forest disturbance and fragmentation on endemic bird species in these habitats. The parameters measured will be evaluated in relation to the quality of the habitats in which the birds occur, and used to predict the effect of forest destruction and degradation on this and other bird species. Thus, the goal is to provide insights into processes producing changes in demographic parameters and consequences of such changes in population sizes and trends to enable development of appropriate techniques for conservation of threatened species.

The fieldwork has a broad spatial scale incorporating seven fragments (one large, one medium and five small) within the Dabida massif, with varying habitat qualities. It has a temporal scale spanning about 1.5 to 2 years. Morphological and physiological parameters are measured for each bird captured to assess the health of the individuals and repeated measurements are taken to check for fluctuating asymmetry. They are then ringed (with both metal and colour rings) to study dispersal, and blood-sampled are taken for genetic analyses and sexing. A few individuals were radio-tagged for intensive observations on behaviour and territoriality. Plots are visited in different seasons to assess seasonal variation in the condition of both the birds and their habitat.

Thus, to address the conservation problem, it is envisaged to (i) help build in a strong component of the scientific side of conservation to be incorporated in future management planning; and (ii) demonstrate that some areas or forest component may not be vital for the maintenance of populations, and hence can be wisely used for human needs while we engage in more expensive and long-term measures of conservation of this landscape as a versatile, functional complex e.g. agroforestry and reforestation/afforestation. Additionally, useful comparisons will be possible as the studies on other threatened species are progressing as well, which will shed light on how related the demographies of common and rare species are in their responses to disturbance. From this, we can tell how applicable findings (and bird-habitat models) based on demographic studies of common species are likely to be when making wide-ranging management decisions for endangered species.

3.4. Mammalogical research

Report compiled by Dr. N.O. Oguge
Zoology Department, Kenyatta University, Nairobi, Kenya

Laur, Oguge and Agwanda measuring rodents
Photograph by Benny Bytebier

3.4.1. Core mammalogical research

3.4.1.1. Introduction

Loss of biological diversity is extreme in tropical forests due to disturbance and clearance, yet data on impacts, particularly of concealed or less conspicuous species (e.g. small mammals) remains scarce. There is a need to survey biological resources as a first step in developing management strategies. Such strategies are essential for establishing legislation and other guidelines to save biological resources for the future.

Effective conservation is reliant on good quality information, underpinned by research. The level of biological diversity, as determined by species inventories, is a major parameter for setting priorities for conservation particularly in areas of biogeographic importance. Habitat fragmentation results into a number of local populations some of which may fit the metapopulation concept. This may result in both extinction and colonisation occurring over time in some population subsets.

The fragmentation of forests in the Taita Hills may allow us to assess this concept on small mammals. The mammalogy study was designed to make a detailed survey of the Insectivora and Rodentia of Taita Hills and other southern Kenyan montane forests. Subsequently, surveys were made of other moist forests in central and western regions of the country. The study has provided base line information on the diversity of small mammal fauna in forest patches of varying size and experiencing different anthropogenic activities. The phylogeography of *Praomys* species was then assessed for the East African populations. Our in depth studies focussed on the population ecology, genetic structure and distribution patterns of *Praomys taitae*. We further assessed microhabitats in eight trapping grids within five forest patches. Subsequent analyses of our results may thus reveal how patch area, inter-patch distance and vegetation structure affect distribution pattern, population structure and density of small mammals here. Given the geographic isolation between some populations, molecular measurements of divergence may in turn reveal polymorphism among such populations.

3.4.1.2. Aims and objectives

This study sets out to determine (i) small mammal taxonomy and diversity in montane forests of southern Kenya; (ii) population ecology of *Praomys taitae* in fragmented forests of the Taita Hills; (iii) phylogeographic relationships of *Praomys* in eastern Africa; (iv) population genetic structure of *Praomys taitae;* (v) macro- and microparasites of the small mammal fauna in southern montane forests.

3.4.1.3. Material and methods

Mammal survey

*Rodents***.** Captures of unharmed animals were made using mammal box (Sherman) traps. These were baited with small cubes (1 cm^3) of fried coconut

in peanut butter and corn oil. This has proved to be most effective and stable bait type in our survey of forest rodents. Traps were arrayed at equal intervals along two transects, randomly set within each fragments (total of two hundred traps). Trapped animals were identified at least to generic level, euthanised in diethyl ether and prepared into voucher specimen. Morphometric measurements, ectoparasites and muscle biopsy were obtained. Specimen were then preserved in 10% buffered formalin and later on transferred into 70% ethanol.

*Shrews***.** To capture shrews, we used pitfall traps operated in conjunction with a drift fence. Such traps consisted of 10 liter buckets, placed in the ground so that their open end is flush with the soil surface. A drift fence was a plastic sheet-barrier dug into the ground and crossing the open pits to direct in the animals. Three pitfalls transects were operated with 16 traps at 5 m intervals. Pit-traps were inspected at 00.00 h and 06.00 h and remained open for five days. Shrews were processed as described above for rodents.

Population ecology and habitat use

These were carried out at Chawia, Yale, Macha, Mbololo and Ngangao forests and involved the setting of one (Yale and Macha) or two (Ngangao and Mbololo) one ha grids, 100 m apart at each site. In each grid, 100 traps were set at 10 m intervals. Traps remained open for three consecutive days. Trapped animals were identified, sexed, weighed, reproductive condition assessed, marked and released at point of capture.

To understand the community processes in Taita Hills forest fragments better, it was necessary to make extensive vegetation microhabitat measurements. This was to provide us with robust measures both of habitat availability and use, within study grids. Such vegetation measurements included metrics of spatial cover by various strata, number and density of tree species, and overall forest density at various heights. The design was developed such that each alternate trap line in the grid was a transect and alternate trapping points, quadrants for vegetation sampling.

Phylogeography of *Praomys taitae*

We analysed 24 tissue samples to assess the relationships between *Praomys* species from moist forests in 13 localities within East Africa. Samples came from Kenya (Chyulu Hills, Taita Hills and Mt. Kasigau, Kakamega Forest, Kaptagat Forest and Aberdares Range), Tanzania (Pare Mts., Uluguru Mts., Udzungwa Mts, Mt. Rungwe and the Simbawanga) and Malawi (Zomba plateau).

The samples (muscle and heart) were preserved in 25 % dimethylsulphoxide (DMSO)- sodium chloride solution, or 70% ethanol and stored at -20°C. The published sequence of *Hylomyscus kaimosae* was used to assess its phylogenetic relationship with *H. endorobae* and with East African *Praomys.* Multiple out groups included cosmopolitan species (*Mus musculus*) and other African murids (*Mastomys natalensis, Arvicanthis nairobae* and *Lemniscomys striatus*).

Parasitology studies

From each captured animal, ectoparasites were obtained by gently brushing off fur. Ectoparasites were then preserved in 70% ethanol prior to identification.

3.4.1.4. Collaborators

Prof. L. A. Durden (Institute of Arthropodology and Parasitology, Georgia Southern University, USA): tick identification

Prof. J. E. Keirans (Institute of Arthropodology and Parasitology, Georgia Southern University, USA): lice identification

Prof. W. Verheyen (Department of Biologie, Evolutionairy Biology Unit, University of Antwerp, Antwerp, Belgium): rodent identification

Dr. R. Hutterer (Section of Mammals, Zoological Research Institute and Alexander Koenig Museum, Bonn, Germany): shrew identification

Dr. E. Verheyen (Section of Biochemical Taxonomy, Royal Belgian Insitute of Natural Sciences, Brussels, Belgium): phylogenetic studies

Dr. C. Fadda (Rodent Research Unit, Sokoine University of Agriculture, Morogoro, Tanzania): rodent cytogenetics

Dr. Njue (Department of Botany, Kenyatta University, Nairobi, Kenya): rodent microhabitats

Mr. R. Odhiambo (Department of Zoology, Kenyatta University, Nairobi, Kenya): small mammal diversity & *Praomys* population ecology

Mr. M. Odongo (Department of Zoology, Kenyatta University, Nairobi, Kenya): small mammal diversity

Mr. B. Agwanda (Department of Zoology, Kenyatta University, Nairobi, Kenya): small mammal diversity & population ecology

3.4.1.5. Time frame of activities

Field activities

Year 1

The mammalogy coordinator was in the UK for a postdoctoral assignment while the M.Sc. student was on first year of study that involved only course work. Thus, no field activities took place

Year 2

Preliminary surveys were carried out in November 1997 to inspect the field sites and map out sampling areas. Field studies commenced in February and proceeded as per Table 1. Field studies involved inventory collection using pace line method and pit-fall trapping. Capture-mark-recapture (CMR) using live-trapping techniques was used in ecological studies

Year 3

Continuation of ecological studies and microhabitat assessment

Year 4

Completion of small mammal survey around Taita Hills

Completion of ecological studies in southern Kenya

Survey of moist mountainous forests in central and western Kenya

Table 1: Survey itinerary of small mammals in moist forests in southern montane areas in Kenya.

Forest fragment	Size (ha)	Period of survey
Ngangao	92	4 - 13 February 1998
Macha	4	13 - 22 February 1998
Yale	2	27 February – 6 March 1998
Chawia	50	14 - 27 March 1998
Mwachora	3	30 March – 9 April 1998
Fururu	12	21 - 30 May 1998
Ndiwenyi	3	31 May – 8 June 1998
Mbololo	200	10 - 23 June 1998
Ronge	4	22 June – 1 July 1998
Kasigau	>100	21 - 30 July 1998
Sagala	4	4 - 12 August 1998
Shimba Hills	>100	16 - 29 August 1998
Chyulu Hills	>100	4 - 13 September 1998
Vuria	2	4 March – 2 May 2000
Aberdares	>3000	2 - 12 April 2000
Mt. Kenya	>3000	June 2000
Mumias	>2000	July 2000

Laboratory activities

Year 2

Laboratory activities during this period were limited to specimen preservation measures.

Year 3

Preliminary genetic studies

Morphometric and craniometric studies of *Praomys* at the University of Antwerp, Belgium by Mr. R. Odhiambo (11 January - 20 February 1999).

Morphometric and craniometric studies of shrews at the Bonn Museum, Gemany, and DNA studies of *Praomys* and shrews at Royal Belgian Institute of Natural Sciences, Brussels, Belgium by Dr. N. Oguge (8 May - 11 July, 1999)

Cytogenetics at the Sokoine University of Agriculture (SUA), Morogoro, Tanzania by Mr. R. Odhiambo (26 March - 10 April, 1999)

Year 4

Identification of rodents and shrews through morphometric and craniametric studies at the University of Antwerp, Belgium, by Dr. N. Oguge (13 May – 7 June, 2000) and DNA studies of *Praomys* and completion of gene sequencing studies at the Royal Institute of Natural Sciences, Belgium by Dr. N. Oguge (8 June - 30 July, 2000)

3.4.1.6. Results

Table 2: Small mammals species distribution

Species	Ngangao	Macha	Yale	Chawia	Mwachora	Fururu	Ndiwenyi	Mbololo	Ronge	Vuria	Sagala	Kasigau	S/Hills	C/hills
MURIDAE														
Aethomys	+	0	0	0	+	+	0	0	0	0	0	0	0	0
Arvicanthis	0	0	0	0	0	0	0	0	0	0	0	0	0	+
Grammomys	+	+	+	+	+	0	0	+	+	+	+	+	+	+
Mastomys	0	+	0	+	0	+	+	0	0	0	+	+	0	+
Mus 1	0	0	0	0	0	0	0	0	0	0	0	0	0	+
M. triton	0	+	0	+	+	0	0	0	0	+	0	0	0	0
M. minutoides	+	+	+	+	+	+	+	+	0	+	+	+	0	+
Pelomys	0	0	0	0	0	0	+	0	0	+	0	0	0	0
Praomys taitae	+	+	+	+	+	+	+	+	+	+	0	+	0	+
MYOXIDAE														
Graphiurus 1	+	+	+	+	+	+	+	+	+	+	0	0	0	+
Graphiurus 2	0	0	0	0	0	0	0	0	0	0	0	+	0	0
CRICETOMYINAE														
Beamys sp.	0	0	0	0	0	0	0	0	0	0	0	0	+	0
Cricetomys	+	?	?	+	?	+	+	+	+	?	0	?	0	
DENDROMURINAE														
Dendromus 1	0	0	0	0	0	0	0	0	0	0	0	0	0	+
Dendromus 2	0	+	+	+	0	+	+	0	0	+	0	0	0	0
Species number	6	7	5	8	6	7	7	5	4	7	3	5	2	8
SORICIDAE														
Crocidura														
C. olivieri	0	0	0	+	0	0	0	0	0	+	0	0	0	0
C. viaria	0	0	0	0	0	0	0	0	0	+?	0	0	+	+
C. cf *selina*	0	0	0	0	0	0	0	0	0	0	0	0	0	+
C. nigrofusca	0	0	0	+	0	0	+	0	0	?	+	0	0	0
C. jacksoni	+	+	+	+	+	+	+	+	0	?	+	+	0	0
C. hildegardea e	+	+	+	+	+	+	+	+	0	?	+	+	0	+
C. fuscomurina	0	0	0	+	0	0	0	0	0	0	0	0	+	0
C. luna	0	0	0	0	0	0	0	0	0	0	0	0	0	+
Suncus														
S. aequatorius	0	0	0	+	0	0	0	0	0	0	+	0	0	0
Sylvisorex														
S. megalura	0	0	0	0	0	0	0	+	0	0	0	0	0	0
MACROSCELIDINAE														
Petrodromus														
P. tetradactylus	0	0	0	0	0	0	0	+	0	0	0	0	0	0
Species number	2	2	2	6	2	2	3	4	0	2	4	2	2	4

We surveyed 14 southeastern forest fragments over an eight-month period and captured a total of 1200 rodents and shrews (Table 2).

There are 15 species of rodents, 10 species of insectivores and one elephant shrew, recorded from our survey. The rodents include nine murids, two myoxids, two cricetomyines and two dendromurines The shrews are eight species of *Crocidura*, a *Sancus* and a *Sylvisorex*.

Mus minutoides was the most widespread occurring in all forest fragments. *Praomys* and *Grammomys* were each recorded in 11 fragments.

Some of the ectoparasites collected from all the trapped mammals have been identified (Table 3). Hitherto, the ectoparasites identified include five species of lice and ticks, respectively. These were isolated from four species of rodents and two shrew types.

Table 3: List of ectoparasites and hosts from south-eastern montain forests in Kenya.

Ectoparasite	Host
Lice	
Hoplopleura inexpectans	*Praomys taitae*
Polyplax waterstoni	*P. taitae*
P. reclinata	*Crocidura viaria*
Schizophthirus graphiuri	*Graphiurus* sp
H. setzeri	*Grammomys* sp
Tick	
Ixodes alluaudi	*C. hildegardeae*
I. cumulatimpunctatus	*P. taitae*
I. muniensis	*Graphiurus* sp
Amblyomma sp	*Beamys*
Haemophysalis sp	*C. viaria*

In our population studies, we made 22,680 trap nights over a 20-month period and marked 1350 animals. Data from CMR studies are currently being inspected for errors before analyses. Identification of all vegetation has been made and analyses in process.

Molecular studies group *Praomys taitae* with *P. delectorum* from Tanzania and northern Malawi. *P. delectorum* will remain the valid name. They are, however, different from *Praomys* sp. from central and western Kenyan highlands or Kisangani in the Democratic Republic of Congo. It is clear that the *Praomys* of all southeastern forest mountains in Kenya is one species.

3.4.1.7. Future activities

Data analysis
Rodent identification
Population ecology of *Praomys* and habitat use
Effects of microhabitats on small mammal distribution
Rodent parasitology
Analyses will be completed in six months.

3.4.1.8. Future related activities

New research at Taita Hills
Rodents as food
Effects of small mammal diversity on rodent diseases

Similar research activities

Work in Shimba hills was inadequate and needs further surveys in more intact forests

Mau forest was not looked at and will be incorporated in future surveys

Future of trained personnel

Richard Odhiambo will be involved in taxonomic studies of pest rodents building from his experience at THBP

Bernard Agwanda and Ernest Obanda to be involved in future surveys in the above-mentioned areas

3.4.1.9. Financing

Currently no funding is available for THBP-related activities. However, plans are underway to develop a proposal to fund surveys at Shimba Hills. This will be submitted to the Third World Academy of Sciences for funding.

The Desert Locust Control Organisation (DLCO) has approached us to carry out studies in areas of *Quelea quelea* control.

Information gathered in THBP is highly beneficial to future funding of similar activities.

3.4.1.10. Training

Richard Odhiambo was trained under this programme, and graduated with an MSc in animal ecology.

Two research assistants, Paul Odongo and Bernard Agwanda, also received training. Odongo left the project after a couple of months after which Agwanda took over. THBP has been actively assisting Agwanda to secure a M.Sc. scholarship from the Belgian government, but due to a change in policy the application was unsuccessful.

Julia Muench, a Geman undergraduate student, joined the mamalogy team for two months as a volunteer, and received training in basic mammalogical and ecological techniques.

3.4.1.11. Evaluation of collaboration

Kenyatta University's collaboration with the National Museums of Kenya, the University of Antwerp and the Royal Belgian Institute of Natural Sciences started through the THBP. This collaboration has been of great value and will hopefully continue.

Another collaboration with the University of Antwerp is going on in development of ecologically-based rodent control in areas growing staple crops in eastern Africa

Kenyatta University has further approached the University of Antwerp (RUCA) for collaboration in further biodiversity studies in Kenya.

On completion of phylogeography studies, we hope to continue collaboration with Royal Belgian Insitute of Natural Sciences in population genetics studies

3.4.2. An ecological study of *Praomys taitae* (Rodentia : Muridae) Heller 1911 and other small rodents in the fragmented forest habitats of Taita Hills

Report by Richard Oketch Odhiambo, Zoology Department, Kenyatta University

3.4.2.1. Introduction

Anthropogenic activities that enhance subdivision, conversion and fragmentation of tropical rain forests continue to pose a serious threat to biological diversity. The rain forests of Taita Hills, other Eastern Arc mountain forests and the coastal forests of Kenya and Tanzania are under severe threat due to demand for hardwood products and agricultural land. These forests are of biological importance due to their high level of endemicity. They are also important as catchment areas. In order to make informed conservation decisions, an inventory of the species and an understanding of their ecology are important. This work, therefore evaluated, small mammals, especially rodent diversity in seven fragmented forest habitats of the Taita Hills between January 1998 and April 1999. It tested pertinent hypotheses on the theory of island biogeography and effects of disturbances on diversity. It then compared aspects of population processes and behaviour of an endemic forest-dependent rodent, *Praomys taitae,* in two habitats (Ngangao and Chawia) with a different geometric structure using the Capture-Mark-Recapture (CMR) technique. Diversity was assessed through removal studies using baited traps. The work also assessed possible taxonomic differences among *Praomys* populations, which appear polymorphic in coat colour, using morphometric, craniometric and cytogenetic techniques.

3.4.2.2. Aims and objectives

This study was aimed at providing the general baseline data on the diversity of small mammals, especially rodent species found in the Taita Hills forests. The work was further interested in determining the effects of habitat disturbance on community and population dynamics of small rodents in these forest fragments. The objectives of the study were thus (i) to identify the rodent species that are present in the forest fragments of the Taita Hills; (ii) to determine species diversity and abundance of small rodents in such fragments; (iii) to collect ecological data on an endemic rodent species *Praomys taitae*, (iv) to provide a basis for understanding how fragmentation impacts on this species.

3.4.2.3. Material and methods

Data was collected in seven forest fragments of the Dabida massif of Taita Hills, namely Ngangao (large forest fragment), Chawia (medium-sized), Fururu, Ndiwenyi, Macha, Mwachora and Yale (small). Reconnaissance surveys were done in October/November 1997 to help select the appropriate study sites. Actual fieldwork began in January 1998 and ended in April 1999. The work mainly involved three methods: (i) the paceline (line transect)

method was used during the removal studies, (ii) the grid method (two, 1ha grids/fragment) was used for the capture-mark-recapture studies and (iii) the pitfall traps method. For method (i) and (ii) Sherman LFA live traps were used and baiting was by peanut butter on fried coconut cubes with addition of edible corn oil.

3.4.2.4. Results

Community ecology of small rodents of Taita Hills

The community structure and dynamics of small mammals, especially rodents was studied in the seven forest fragments in the Dabida massif (Ngangao, a large forest; Chawia, a medium-sized forest; and five small fragments), between January and April 1998. Paceline and pitfall trapping methods were used to collect the animals. Captured animals were euthanised, identified at least to the generic level, weighed, sexed and measured. Muscle tissues were then biopsied before preserving the carcasses in 10% neutral buffered formalin. Most of these specimens were later transported to the University of Antwerp (RUCA) for further identification.

During this study, a total of 848 captures of eight species of rodents and shrews were made in 7220 trap nights. Trap success varied between fragments, being lowest in one of the smaller fragments, Ndiwenyi (6.8%) and highest in the medium-sized fragment, Chawia (19.5%). Chawia had the highest number of rodent species and Ngangao the lowest. *Praomys taitae* comprised the highest proportion of rodents caught in all the fragments, accounting for 96% of rodent captures in Ngangao. *Praomys* and *Graphiurus* showed a wide distribution being captured in all fragments. Other species captured included *Mus*, *Grammomys, Dendromus*, *Aethomys, Mastomys* and *Tatera.* Overall, species richness increased with increasing remnant size up to the medium-sized fragment Chawia. However, it decreased from Chawia to the larger and more intact remnant, Ngangao. Ngangao showed only the presence of forest-dependent species, *Praomys* and the more ubiquitous rodent species *Graphiurus*, and the pigmy mouse *Mus*. The medium sized but more degraded fragment, Chawia, in addition showed invasions by grassland (*Mastomys, Tatera* and *Aethomys*) and woodland (*Grammomys*) species (see also 3.4.1.6.).

The abundance of the forest-dependent *P. taitae* also followed the same trend. Chawia (c. 50ha) recorded higher numbers of *Praomys* than the smaller fragments and the largest fragment Ngangao. The number of the next common rodent species, *Graphiurus* and *Grammomys* were found in smaller and in disturbed forest sites. The fall in species numbers and abundance as the size of the fragment increases i.e. from Chawia (c*.* 50 ha) to Ngangao (c*.* 92 ha) could have resulted from either a decrease in edge effect, decrease in vegetative cover, food or increase in predation pressure or competition. The increase in diversity with increasing disturbance reported in this study should not literally be taken to mean that the study is in support of fragmentation. This increase in diversity resulted from the fact that these smaller and more disturbed habitats were invaded by generalist grassland species. This shows that fragmentation favours the generalists over the forest-dependent *Praomys*. Given the fact that they are non-specialised in their habitat use, they have the potential of replacing other species. Therefore, any intensive competitive

interaction between the generalists and the resource-limited *Praomys* will be in favour of the generalists. This interspecific competition may then act as a driving force for “extinction” of *Praomys.*

Craniometric, morphometric and cytogenetic study of Praomys taitae

During the initial survey, it was noticed that *P. taitae* specimens captured in the various forest fragments showed a polymorphic coat colouration, which appeared independent of age group or sex. Thus it became important to determine whether these morphotypes are important as far as specific divergence in this species is concerned.

Biometric study

Measurements used in the morphological study were obtained from the animals captured during the removal study. All the measurements were taken by one person. Five standard external measures (morphometric characters) used in this study were obtained from freshly killed rodents: head-body length, tail length, weight, left hind foot length and left ear length. Statistical comparisons of these external measurements were initially made by means of the Student t-test.

On each skull, nineteen cranial and four dental dimensions were measured from representative specimen. All craniodental studies were carried out at the Department of Evolutionary Biology, University of Antwerpen (RUCA) under the guidance of Prof. Walter Verheyen. Craniodental measurements were done under a stereomicroscope using hand-held digital calipers accurate to 0.03 mm.

Comparing the external and craniodental dimensions of *P. taitae* of different sexes and coat colours revealed only small differences in dimensions and proportion. There were no significant differences between the measurements of males and females. Although the darker individuals appeared smaller with relatively shorter extremities than the light coat form individuals, there was no significant difference between their measurements. Likewise, canonical variate analysis of the morphometric and craniodental measurements did not indicate any discrimination between the groups.

Cytogenetic study

Due to the fact that biometric studies did not reveal any parallel variation on the different groups (coat colours, sexes, localities of capture), a cytogenetic study was carried out to compare metaphase chromosomes particularly in the two morphotypes. Live rodents of both sexes and coat colours were captured from Ngangao and Chawia and transported to the Rodent Research Unit, Sokoine University of Agriculture, Morogoro, Tanzania, where they were karyotyped under the guidance of Dr. Carlo Fadda. Further analysis was then done at the University of Rome, La Sapienza, Italy in Prof. Marco Corti’s laboratory.

The diploid number of the two *P. taitae* morphotypes is 2n=48. The structure of the karyotypes is identical as far as both the autosomal and sex

chromosome sets are concerned. Thus the cytogenetic studies showed no differences in chromosomal types between the two colour morphs.

The lack of any significant variation in morphometric, craniodental and cytogenetic variables in the two colour morphs suggests a single species. For the population dynamic study of *Praomys* they were treated as a single species.

Population ecology and behaviour of *Praomys taitae*

Aspects of population processes and behaviour of the endemic forest-dependent rodent, *Praomys taitae,* in two habitats (Ngangao and Chawia) with different geometric structures were compared, using a Capture-Mark-Recapture (CMR) technique. In each fragment, two permanent one-hectare grids were laid out with 100 traps each at 10 m intervals. Each trapping station was marked with white painted stones. The two grids were 100m apart and trapping was done for three consecutive days each month. Trapping was done with baited Sherman Live traps

Captured animals were weighed, sexed and then individually marked by toe clipping. Processed animals were released at point of capture. In case of accidental deaths the animals were processed as those in the removal trapping. In each case, traps were thoroughly cleaned in water after each collection.

During the live-trapping study in Chawia and Ngangao, the same pattern was seen for species composition and abundance as during the removal study. This was also evident in Chawia grids where grid 2, which had more forest gaps and appeared more disturbed, had the highest number in terms of species richness but with proportionally fewer *P. taitae* than grid 1. Overall, during the CMR study, a total of 963 captures, consisting of 380 rodent individuals and 58 shrew individuals, were made in 6000 trap nights. The highest species number (seven) was recorded at Chawia and lowest (three) at Ngangao. Chawia recorded higher values in terms of population estimates, individual captures and biomass ($P<0.001$) as compared to Ngangao forest. There were no significant differences between the monthly population estimates in the grids of the different forest fragments. Likewise, the number of individuals caught did not vary significantly from month to month in Chawia. In Ngangao, significant ($P<0.05$) variation did occur between April 1998 and the other months. *Praomys* was, however, found to move within small home ranges, breed throughout the year and to maintain a 1:1 sex ratio irrespective of habitat quality.

3.4.2.5. Conclusion

This study gives the first report on the small mammal diversity in the forests of the Taita Hills. The work reported attrition, degradation and fragmentation of these forest habitats to cause significant changes in the diversity and abundance of small mammal species. Disturbed forests supported higher densities and biomass of rodents than the more intact forests. This work also reported that intact forests support stable populations of specialized species

while the more disturbed habitats show greater diversity of invasive ones. The implication of these findings is that if the Taita Hills forests continue to be disturbed beyond what it is today, they stand to lose their biodiversity. This will be in the form of specialized species being pushed to extinction by the invasive species. It also reported that all *Praomys taitae* in the Taita Hills' forests belong to one panmictic population. This is the first report on cytogenetics of *P. taitae*, which therefore provides a basis for zoogeographic comparisons with other *Praomys* species within the Eastern Arc ecosystems. Furthermore, the study has shown *P. taitae* to move within small home ranges, breed throughout the year and to maintain a sex ratio of 1:1.

4.4.2.6.Recommendations

Although the present study has added to the scant knowledge on how forest disturbance has impacted on small rodents of the Taita Hills forests, it may also be regarded as contributing to a database for small rodents of these fragmented forest habitats. Unfortunately, there are few detailed studies on small mammals of African mountains and none on Taita Hills for comparison with the present study. This means that there is nothing concrete that can be used to determine whether these results typify these habitats. Nonetheless, this study has opened doors to certain crucial studies that need to be undertaken. These include:

(i) a study to determine the specific factors *e.g*. food availability, predators, vegetation cover, disease dynamics that may explain the trends observed in *P. taitae*

(ii) a long term and intense population ecology study of *P. taitae* to determine the long term stability of their population in an array of fragments of different sizes and experiencing different levels of disturbances. Such studies should include home range and adult sex ratios

(iii) a study on the edge effect on community dynamics of rodents in the different forest fragments and the interaction between the forest-dependent species and the invading generalist species

(iv) there is also a need to compare the morphometric, craniodental and karyological data of *Praomys* from Taita Hills and the *Praomys* from the other mountainous region in Tanzania and Kenya

3.4.2.7. Constraints

The main problem encountered at the initial phase of the research was transport. This was later solved by the arrival of the project Land Rover, which made movement much easier and convenient. Also with the hard economic times facing Kenya, living expenses were quite high and the amount of subsistence given was slightly inadequate. Another drawback is that it took a whole 11 months from the first thesis draft to my thesis defense, a situation that was largely beyond my control.

3.5. Invertebrate zoology research

Report compiled by Dr. M. De Meyer
Entomology Department, Royal Museum for Central Africa, Tervuren, Belgium

Taitastreptus flavipes, a new genus and species of millipede
Photograph by Didier Vandenspiegel

3.5.1 Introduction

The entomology component focused on inventorising the insect and invertebrate fauna of the indigenous forest fragments found in the Taita Hills. Because of the enormous diversity, and the problems related to species identification of the majority of insect and invertebrate groups the research was limited to a number of particular groups. These include certain Diptera and Lepidoptera taxa, Diplopoda, molluscs and arachnids. The choice of these groups was determined by the available expertise and the fact that these groups have proved to be applicable as forest quality indicator groups in earlier, similar studies.

The Taita Hills form the northernmost part of the Eastern Arc Mountains, and the sole representative of the formation in Kenya. The Eastern Arc mountains were recently classified as one of the world's biodiversity hot-spots. No preliminary surveys on the entomofauna of the Taita Hills are known, although scattered records are available in older literature and from specimens in collections. Insects, and invertebrates in general, are often good indicators for diversity of any given ecosystem, and disturbance thereof. The study of invertebrate groups was therefore considered a prerequisite to obtain necessary base line data on the forests' condition.

3.5.2. Aims and objectives

Because of the limited knowledge of the entomological and invertebrate fauna, the first objective was to gather base line data on the invertebrate diversity at the Taita Hills for the study groups. Other main objectives were (i) to establish the biogeographical relationship of the invertebrate fauna of the Taita Hills with other regions in eastern Africa; (ii) to indicate differences in species composition between the fragments; (iii) to investigate whether observed differences of the invertebrate fauna could be linked to differences in the particular fragments (size, isolation, disturbance, etc.)

3.5.3. Material and methods

Most invertebrate groups require a specific sampling method. Specimen collecting therefore requires in most cases a specialized fieldworker. This not only because of the sampling technique but also because an extensive knowledge of the subject's behaviour and niche is necessary in order to completely sample a certain area. We have opted for a combination of short field trips by specialists, working on one of the particular study groups, combined with long term sampling by means of general trapping methods (in particular Malaise traps, pitfall traps, and water traps), which could be conducted by technicians.

Specialized sampling techniques included light sampling (with a Robinson trap), soil sieving, hand catching of spiders by night, Winkler extraction, net sampling and pitfall trapping. Field trips were conducted at different periods throughout the year, to cater for the seasonality of most invertebrate groups. Although not as effective as specialized sampling, the general trapping

methods nevertheless provided useful additional material. Moreover, it provided material that can later on be studied by any other specialist who was not involved in the programme from the start.

3.5.4. Collaborators

The following collaborators have studied and/or are currently studying material within the scope of the THBP:

Diptera:
Dr. M. De Meyer (Royal Museum for Central Africa, Tervuren Belgium): Syrphidae, Pipunculidae, Diopsidae (incl. Centrioncidae)
Dr. J. Londt (Natal Museum, Pietermaritzburg, South Africa): Asilidae
Mr. M. Foldvari (Hungarian Natural History Museum, Budapest, Hungary): Pipunculidae
Dr. I. Ya. Grichanov (All-Russian Institute of Plant Protection, St. Petersburg, Russia): Dolichopodidae
Lepidoptera:
Dr. U. Dall'Asta (Royal Museum for Central Africa, Tervuren Belgium): Heterocera
Dr. J. De Prins (Royal Museum for Central Africa, Tervuren, Belgium): Gracillariidae
Mr. S. Hanot (Royal Museum for Central Africa, Tervuren, Belgium): Noctuidae
Mr. M. Fibiger (DK-4180 Soro, Denmark): small Noctuidae
Diplopoda:
Dr. D. Vandenspiegel (Royal Museum for Central Africa, Tervuren, Belgium)
Dr. H. Enghoff (Zoologisk Museum, Copenhagen, Denmark): Harpagophoridae - genus *Obelostreptus*
Dr. R. Hoffman (Virginia Museum of Natural History, Virginia, USA): Harpagophoridae - genus *Apoctenophora*
Araneae
Dr. R. Jocqué (Royal Museum for Central Africa, Tervuren, Belgium): Cyatholipidae
Mr. J.-F. Vander Donck (Royal Museum for Central Africa, Tervuren, Belgium): Ctenidae
Mr. C. Warui (National Museums of Kenya, Nairobi Kenya): Gallieniellidae
Mollusca:
Mr. C. Lange (National Museums of Kenya, Nairobi Kenya): Streptaxidae, Enidae, Subulinidae, Maizaniidae, Valloniidae, Achatinidae, Bradybaenidae, Urocyclidae, Endodontidae and Vitrinidae

3.5.5. Time frame of activities

Year 1
Field trips took place at the following dates
8-17 February 1997 (De Meyer)
9-19 August 1997 (De Meyer)

In Year 1, the only entomologist attached to the project, Dr. De Meyer, also was the co-ordinator of the project. Most of his activities in the first year focused on launching the project and teaching MSc courses (first half of the first year was largely occupied by teaching).

Year 2

Dr. De Meyer left Kenya, in order to take up a position as head of the entomology section of the Africamuseum in December of 1997. Because of his new responsibilities, the entomological activities were largely dormant in the second year. However, his new position enabled other researchers to become involved in the project. The following field trip took place

17 July – 18 August 1998 (Dall'Asta)

Year 3

Field trips took place at the following dates

3-23 March 1999 (Dall'Asta)
14 June – 2 July 1999 (De Meyer & Vandenspiegel)
2 August – 3 September 1999 (Dall'Asta)

Year 4

Field trips took place at the following dates

18-26 March 2000 (Jocqué)
22 March – 15 April 2000 (Dall'Asta)
1-14 December 1999 (Vandenspiegel & Michiels)

The entomology component of the THBP was conducted in conjunction with researchers from the International Centre of Insect Physiology and Ecology (ICIPE). Dr L. Rogo of the ICIPE was also doing biodiversity research in the Taita Hills and there was no need to duplicate efforts. When the need arose, THBP and ICIPE have assisted one another logistically. THBP and ICIPE work focused on different groups of insects, and there was a continuous exchange of material and knowledge.

3.5.6. Results

Most results so far available are preliminary. The identification of the material usually takes a long time since the fauna for most of these groups is poorly known. Records of species new to science are not uncommon, and in some groups like Diplopoda seem to be the general rule. Therefore a lot of the research in the last years has focused on actually identifying the collected material. Any further analyses still have to be conducted. For some groups, however, some interesting findings can already be highlighted. These are summarized, according the taxonomic group studied.

3.5.6.1.Diptera

Diptera groups studied in detail so far are Syrphidae (hoverflies), and Dolichopodidae. For the hoverflies results are available for biogeography of the fauna and inter-fragment diversity.

A large proportion of the species of Syrphidae encountered in the study area are fairly general and abundant. This abundance can in first instance refer to the whole of the Afrotropical region (generalist which have a widespread distribution in the region). Remarkable in this respect, however, is that several of these general species are not abundant in the Taita Hills and are only encountered in one, or a few, of the forest fragments (often based on single specimens). In second instance there are a number of species that are predominantly restricted to eastern Africa, or eastern and southern Africa, but are abundant in the subregion (Kenya, Tanzania, and Uganda). Only a few species within East Africa seem to be restricted to forested and mountainous zones, and occur in Taita Hills. These could be considered as indicator species for habitat quality in the forest fragments of Taita Hills. However, the Taita Hills do not seem to harbour any endemic taxa, or any species that show a direct link to the Eastern Arc Mountains. Biogeographical affinities, if any, tend to be closer to the Central highlands of Kenya. Of the 35 species found in the study area, none of the forest fragments harbours more than half of the fauna. The largest fragments (Mbololo, Ngangao, and Chawia) harbour the largest diversity with 15, 10 and 13 species respectively. Some of the smaller fragments seem to harbour a relatively large proportion of the fauna, although the number differs greatly between the fragments. It still has to be established whether this can be related to disturbance of the particular fragments.

The family Dolichopodidae is very large, with approximately 6500 species and 200 genera. They are mostly predatory flies, distributed all over the world including the tropics and high-latitude islands. At present more than 600 Afrotropical species are known to occur. Sixty-six species are recorded and described from Kenya, but the real number may reach 200 species. Many rare species are only known from their type locality. When such species are only known from small blocks of remnant or disturbed vegetation, their long-term survival is more problematical, especially in highly altered agricultural and urban areas. Species reported from Taita Hills show different geographical affinities, with some showing links to Central Africa, while others show relations to several mountainous zones in East Africa (Zomba, Malawi; Shimba Hills & Ngong Hills, Kenya; Amani & Kilimanjaro, Tanzania). Also there is a fairly large proportion of endemism found, with species new to science and only reported from the study area. Some of the new species that have already been described are: *Tenuopus taitensis*, *Condylostylus pseudoparicoxa*, *Condylostylus ulrichi*, and *Mesorhaga garamba*.

3.5.6.2. Lepidoptera

A total of 55 moth samples were taken in the central part of the Taita Hills region, in or nearby the forest patches of the following hills: Chawia (9), Mbololo (16), Ngangao (16), Macha (7), Mwachora (1) and Yale (6).

Amongst these there are samples taken in primary forests, in degraded parts of forests and in Cypress or mixed Cypress and indigenous forests. The samples were taken during 4 different periods: June - July 1998, March 1999, August 1999 and March 2000.

One of the peculiarities of the sampled forests of the Taita Hills is that they are all situated at rather high altitudes ie between 1600 and 2.000 m. In all seasons, fog can be present not only in the morning or in the evening, but also throughout the day. Invariably, when fog is present during the sampling, the catch is very rich in specimens. This is also the case when the fog is combined with a strong wind. The wind has always been known among lepidopterists as a negative element during night trapping, but combined with fog it loses apparently its status of a drawback. Another phenomenon occurs in this situtation: when the wind is strong most of the moths do not rest on the side of the blanket exposed to the lamp, but on the shaded side. This phenomenon has also been recorded during a night catch in the Aberdares during which there was a heavy rain. During this last sampling the catch was also massive, but only large specimens : Sphingidae and large Noctoidae, not the smaller specimens as during sampling in foggy conditions. But here also, most moths set to rest on the shade side of the blanket. This specimen abundance in rainy or foggy conditions is one of the elements that make moth samples difficult to analyse statistically.

By far the most common group represented in the Taita Hills moth samples are the Noctuidae. So these were the first to be identified. The identification was first done by comparing the specimens with those of the collection of the Royal Museum for Central Africa, next with those of NMK and lastly with the collection at the Natural History Museum, London. A provisional list of the Noctuidae caught on the Taita Hills holds 83 species and will shortly be published. It is surprising that even the Geometridae are much less represented and other families, which are usually numerous in tropical forests (Lymantriidae and Notodontidae), are nearly absent. A second surprising fact is that the samples taken during July 1998 are very different from those August 1999, although they were taken in comparable periods. By far the most common Noctuid in July 1998 (*Tathorhynchus homogyna*) was found in only one specimen in August 1999, and many of the common noctuids of last year were not found at all during the last mission of this year. An analogous phenomenon was also recorded from a tropical rainforest in Ivory Coast and before long these observations will be worked out statistically.

For butterflies, a preliminary analysis was made, based on collection records at NMK, the Natural History Museum London and private collections in Nairobi. Those results were presented as a poster at the Eastern Arc conference. From this analysis is was shown that the biogeographical affinities of the Taita Hills fauna is a combination of Central Highlands, coastal and Eastern Arc components.

3.5.6.3. Diplopoda

The Diplopoda fauna of the Taita hills proved to be extremely interesting because of the intensive degree of endemism that is reflected at both the generic and the specific level. Specimens belonging to 11 families (Ammodesmidae, Furmanodesmidae, Gomphodesmidae, Harpagophoridae, Odontopygidae, Oxydesmidae, Paradoxomatidae, Pyrgodesmidae, Spirobolidae, Spirostreptidae, Stemmiulidae) have been collected. Although the available material has not yet been fully studied, 80% of the species

appear to be new for science. Interestingly some of these taxa occur in all the forest fragments of the Taita Hills suggesting recent connections between them.

Among the material already sorted out, 29 (morpho-) species were found. None of the fragments harbour the totality of the fauna, but as for the other invertebrates, the largest fragments (Mbololo, Ngangao and Chawia) have the largest diversity with 16,17,18 species respectively. Remarkable is that some of the smaller fragments also contain a large diversity with 13 species for Mwachora, 11 for Fururu and 10 for Yale. The low number of species (4 species) found in Macha is surprising. Macha is situated next to Mwachora and has almost the same size. Furthermore, the two fragments were equally sampled. The same observation was made for the Syrphidae, and again we have no immediate explanation for the difference in fauna between these two fragments.

Most of the diplopoda occur in the soil and in leaf litter, but some live in trees, and the Taita Hills harbour a very nice arboreal spirostreptid. This species with yellow legs is remarkable due to the fact that males have completely unique gonopods. A new genus, *Taitastreptus*, has been defined to accomodate this specialised arboreal millipede.

Another remarkable finding is the occurrence of three species of Ammodesmidae. O.F. Cook created this poorly known family in 1896 to accommodate two monotypic genera he discovered in Liberia. *Ammodesmus granum* was based upon a single specimen*; Cenchrodesmus volutus* upon three, and since then nobody has ever seen a member of this group until the discovery of *Elassystremma pongwe* by Hoffman (1981) in Tanzania. The exact relationship between Ammodesmidae and the other Diplopoda is unknown, but the large number of specimens (262) collected in the Taita Hills will allow us to reconsider the place of this family systematically.

The major difficulty in the study of the Taita fauna is in deciding which species are really confined to the Taita forest fragments, and which have simply been overlooked at lower elevations and different biotopes. Therefore, we compared our records with those of three areas in Tanzania that can be considered as reasonably well known: the East Usambaras around Amani, the northern Ulugurus, and the easternmost end of the Udzungwas at Mwanihana. The Taita Diplopoda have no species in common with any of these three regions. However, links with the Usambara mountain forests are evident at the generic level.

Some of the new species that have already been described are *Apoctenophora spinata*, *Apoctenophora taita*, *Stemmiulus discotarsus* and *Stemmiulus mauriesi*.

New species that are currently being described are:
Family Ammodesmidae: *Elassystremma levi*, *Elassystremma michielsi* and *Elassystremma pustulapage*
Family Harpagophoridae: *Obelostreptus langei* and *Obelostreptus bilamellatus*
Family Spirostreptidae: *Taitastpreptus flavipes* (new genus, new species)

3.5.6.4. Mollusca

Ten main groups of terrestrial snails have so far been isolated. They include the following families: Streptaxidae, Enidae, Subulinidae, Maizaniidae, Valloniidae, Achatinidae, Bradybaenidae, Urocyclidae, Endodontidae and Vitrinidae. The most widespread snails were those belonging to the family Streptaxidae, Maizaniidae, Subulinidae and Urocyclidae. These were mainly characterized by big snails usually more resilient to most environmental alterations. The rest of the groups, particularly the Endodontidae and Valloniidae, are dominated by micro-snails were highly restricted in distribution.

The overall diversity pattern shows that the largest forest fragments support the highest species richness compared to the smaller fragments. Field observations indicated that the smaller fragments were also more prone to disturbances compared to the larger forests. It is thus likely that the impoverished malacofauna recorded in the small fragments were as a result of increased forest disturbance compared to the large forests. Similar observations on the effect of forests disturbance on molluscan biodiversity have previously been documented.

Identification to species level is in progress and so far, no new species have been reported. Most of those snails identified to species level generally have a wide biogeographical range. Some show links with Kenyan central highlands as wells as the western tropical rainforests. It is only those snails belonging to the family Streptaxidae that are more restricted to the Eastern Arc. One species, *Gulellla spinosa*, is newly reported from Kenya and so far seems to be restricted to the Taita hills.

3.5.6.5. Araneae

The findings regarding Araneae are still very preliminary. All material collected during the THBP sampling activities has been sorted to family level. Some families like Ctenidae will be studied in detail. For the majority however, no specialists are available. The major finding so far is the record of Gallieniellidae Araneae: 1 new genus with 2 species). Occurrence of this family in the area is remarkable, as it was so far only known from Madagascar and the Cape area in South Africa.

3.5.6. Conclusion

In general it can be said that the diversity of the Taita Hills differs largely according the group studied. For some, like the Syrphidae, the material consists largely of generalists found elsewhere in the country, East Africa or even the rest of the world. While for others, like the Diplopoda, the fauna consists largely of apparently endemic species confined to this area. Aspects on biogeographical affinities and species composition of the different fragments are still under investigation. Preliminary results, however, clearly indicate that the fauna of the Taita Hills is not a purely Eastern Arc fauna, but a more complicated composition of Central Highland, Coastal and Eastern Arc elements.

Regarding inter-fragment diversity, the larger forest fragments in most cases harbour a higher diversity. However, several of the smaller fragments also contain a proportionally high diversity, which is often surprising given their size and/or degree of habitat degradation. This implies that conservation of the smaller fragments is equally as important.

3.5.7. Future activities

The analyses of the collected material will continue over the next years. When specialists who are willing to study material of a particular group can be found, the relevant material will be sorted and sent to them. The scope of groups studied is therefore continuously expanding. Scientific staff members of the Africamuseum are also actively searching for further funds to enable specialist to study other group of the material sampled.

It is anticipated that the major groups now under study, will be largely analysed over the next three years. These are:
Diptera: Syrphidae, Dolichopodidae, Pipunculidae, Diopsidae, Asilidae
Lepidoptera: Noctuidae, Geometridae, Microlepidoptera (leaf mining moths)
Diplopoda: Ammodesmidae, Odontopygidae, Pyrgodesmidae, Stemmiulidae
Araneae: Gallieniellidae, Ctenidae, Cyatholipidae
Mollusca: Streptaxidae, Enidae, Subulinidae, Maizaniidae, Valloniidae, Achatinidae, Bradybaenidae, Urocyclidae, Endodontidae, Vitrinidae

3.5.8. Future related activities

Scientists of NMK and Africamuseum will continue research in the Taita Hills and other regions in Kenya. In 1999, the Africamuseum obtained additional funding for a long term collaborative programme (5 years) that focuses on three main objectives: (i) extension and improvement of the invertebrate collections at NMK; (ii) training of NMK and other personnel; (iii) development and exchange of NMK and the Africamuseum collection databases.

This will be partly a continuation of the THBP, albeit on a much smaller scale. The Taita Hills and its environs will remain one of the priority areas under study. The surrounding area will get more attention, in order to put the fauna of the actual forests in a wider context. Similar studies will also be conducted in other areas of Kenya, especially some of the National Parks.

Scientists of NMK who were involved in the THBP will continue to participate in these research activities. They will continue to receive training from researchers of the Africamuseum.

3.5.9. Financing

During 1998, 1999 and 2000 activities of the Africamuseum were already partly financed through the Zoology departmental funds (travel and field expenses), and through funds from the Directorate General for International Collaboration (DGIS) A budget of approximately 1,000,000 BEF/year is expected to be available for the period 2001 and 2002.

Furthermore, the entomology section of the Africamuseum received funding from the Service of Scientific and Cultural Affairs (Belgium) for a postdoctoral fellow to study the Graciliridae (leaf mining moths) The funding provides salary for one year (Total cost: 1,509,000 BEF, for the period October 2000 - September 2001; extension possible for one more year).

3.5.10. Training

Within the scope of the funding obtained by the Africamuseum for collaboration with NMK a training component for NMK staff is included. This involves intensive sessions of personal training by a staff member of the Africamuseum.
During the tenure of the THBP two such training sessions have already taken place:

Mr. C. Lange of Invertebrate Zoology was trained by Dr. D. Vandenspiegel on Diplopoda taxonomy and collecting techniques.
Mr. C. Warui of Invertebrate Zoology was trained by Dr. R. Jocqué on Araneae taxonomy and collecting techniques.

Although not directly part of the THBP, both staff members were involved in the project, and the training partly benefited from infrastructure and modalities set up by the THBP (like transport, collecting equipment, etc.).

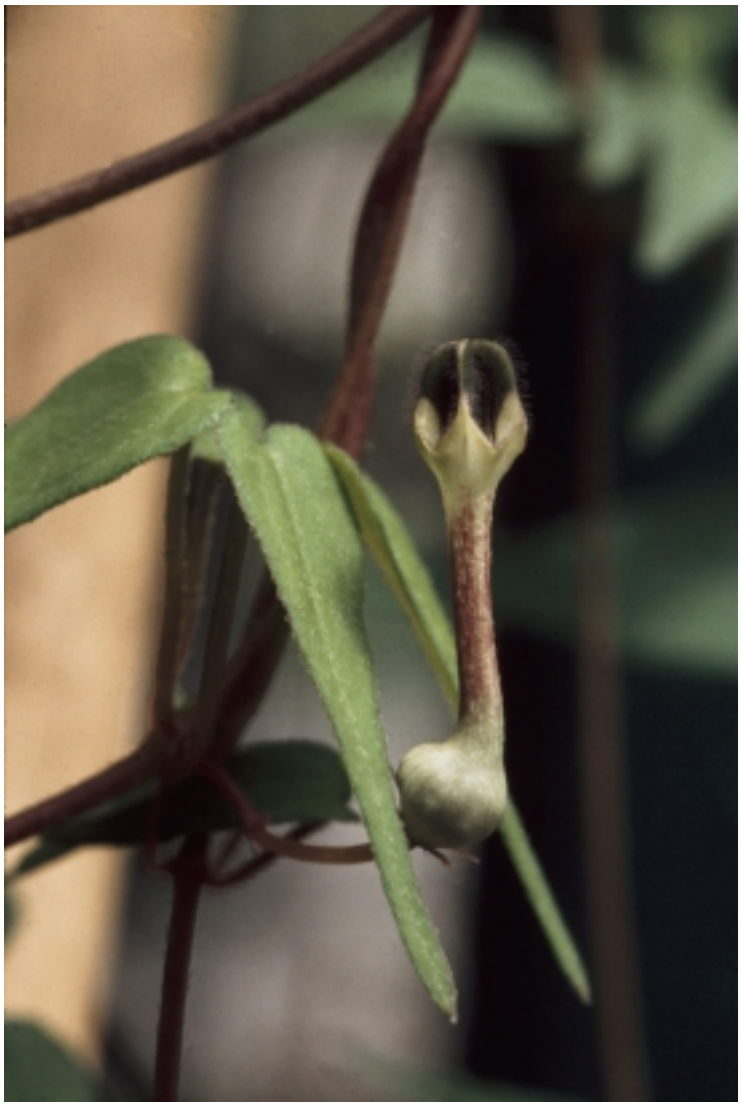
3.5.11. Evaluation of collaboration

The scientists linked to the invertebrate zoology component of the THBP, both Belgian and Kenyan, have greatly benefited from this collaboration. The collection activities enabled these specialists to study material that would otherwise not have been available. The innovative findings regarding these specimens differ greatly depending on the group studied. For some groups, the material collected is largely new and unknown to science. The faunistic and taxonomic information that is thereby gained cannot be overestimated. In addition the study will enable us to get some insight in the species complexity found in the forest fragments of the Taita Hills. We will also be able to place the particular fauna of the region in a broader biogeographical perspective.

Even more important is the fact that the project enabled scientists of the Africamuseum to establish collaborative links with colleagues of the National Museums of Kenya. It is expected that these links will form the basis for a long term partnership between both institutions and lead to more joint projects.

3.6. Botanical research

Report compiled by Benny Bytebier
Centre for Biodiversity, National Museums of Kenya, Nairobi, Kenya



Ceropegia verticillata, a new endemic plant
Photograph by Benny Bytebier

3.6.1. Ethnobotanical and ecological analyses for forest restoration in the Taita Hills

Report by Mr. Kamau Wakanene Mbuthia
Centre for Biodiversity, National Museums of Kenya

3.6.1.1. Introduction

The Taita Hills are located in Taita Taveta District, Coast province, in the southeast of Kenya. These hills form the northern part of the Eastern Arc mountains, which is one of the 25 globally recognized biodiversity 'hotspots'

The Taita Hills harbour forests of high importance to conservation, containing numerous endemic plant and animal species. These forests occur on the peaks of a massif complex at an elevation between 1000m and 2200m above sea level. The area receives approximately 1200 mm of rainfall per year. High rainfall and the moisture-laden southeast trade winds originating from the Indian Ocean are responsible for the luxuriant forest cover found on these hills.

The Taita people are smallholder farmers, cultivating fruits and vegetables along the slopes of the hills. Their culture is founded upon and supported by an agricultural economy. Millet, maize, sugarcane, bananas, beans and cassava are important staple foods, cultivated for local consumption and the Mombasa market. Small-scale irrigation systems are utilized in the cultivation of these crops. Pipes, furrows, hollow banana stems and palm troughs channel water originating mainly from the forests over long distances for limited irrigation. Most farms are located between 800 and 1700m above sea level in high potential agricultural or forested zones. The hills comprise only about 11% of the total district area but support the bulk of the district population estimated to be over 200,000. The community recognizes a need to own dry lands at the base of the hills, as well as garden plots in the mid-elevations and boggy bottomlands at any elevation. These traditional land policies safeguard families against crop failure at any particular time, by owning land at different elevations and in different rainfall zones. This has resulted in much forest clearing and an extremely fragmented pattern of land ownership. In contrast, a consolidated land tenure system threatens food security and access to important forest resources.

3.6.1.2. Aims and objectives

An applied botanical study is undertaken that links the ethnobotany of the Taita Hills forest resources with the spatial patterns of forest community composition and structure. The overall research goal is to determine the values of plants to the local communities, the composition and structure of plant communities, and apply these to identification of forest restoration sites in the highly fragmented Taita Hills.

The overall research goal is addressed through three research objectives. These are: (i) to undertake plant community analyses that examine the size class abundance of valued resources and their relationship with environmental conditions, (ii) to describe and quantify the value of forest resources to the local communities through participatory ethnobotanical

research, (iii) to identify adaptive management options for forest restoration across the Taita Hills forests.

3.6.1.3. Material and methods

Vegetation sampling

Fieldwork for this study is focusing on two closed forest canopy forests, Ngangao (92 ha) and Mbololo (220 ha) that occur between 1550 - 1950m above sea level, selected for their big size and relatively good forest, with a history of utilization. Community structure and composition for these forests were measured using a stratified random sampling method. At the start of sampling, the forest was subdivided into six blocks measuring 400 m wide. Random points were established within the blocks to determine the positions of the east to west transects. Sampling points were then placed at 100 m along the transect. Beginning at these points, 20 m x 50 m plots were established perpendicular to the slope. Smaller plots measuring 10 m x 20 m and 1 m x 1 m were nested within the large plot. Plots measurements were adjusted to account for the steep slope.

Plots measuring 20 m x 50 m (0.1 ha) were used to document trees measuring ≥10 cm dbh. Saplings and shrubs measuring ≥1 m height and ≤10 cm dbh were documented in 10 m x 20 m plots (200 m^2). All seedlings and saplings measuring ≥1 m in height were enumerated in four plots 1 m x 1 m plots. Scientific names of plants within the plots were recorded. Local name (where known), dbh and crown height were also noted. Voucher specimens were collected and deposited at the East African herbarium (EA) in Nairobi and the W.S. Turrell Herbarium (MU) in Miami University, Oxford, Ohio, USA.

Topographic elevation at the center of the 0.1 ha plots was recorded by use of an altimeter. Using an 8-cm diameter soil auger, soil samples were collected from all the sample plots. Measuring tapes were laid all around the plot to facilitate collection of soil sub samples at every 10 m interval resulting into 18 soil sub samples from a 50 x 20 m, which were thoroughly mixed. Out of this, approximately 1 kg of soil was obtained for analyses of chemical and physical properties. The samples were collected up to a depth of 30 cm, air-dried, packaged and transported to Coffee Research Foundation at Ruiru for analysis.

Ethnobotanical data collection

Ethnobotanical data was collected in a series of line transects at Ngangao and Mbololo forests. Existing trails that avoid steep slopes were used as transects. Representative woody species measuring ≥ 3cm dbh were tagged and identified along the transects. People knowledgeable on the forest resources were informally interviewed to record their knowledge of some of the approximately 120-tagged plants. In addition, open-ended interviews were conducted to document knowledge of non-tagged species. Informants were interviewed individually so as to minimize the possibility of one informant's answer directly influencing another person's answer. They choose the appropriate time for their interviews and were compensated for their time. Informants were aged above 50 years, and were mainly subsistence farmers with a history of forest utilization neighboring the forest.

3.6.1.4. Results and discussion

Species richness and composition

Within Ngangao forest, a total of 76 woody species were encountered out of a total of 5603 documented trees. There were an average of 15 species of large trees per plot. A graph of “average number of species per plot” levels after sampling 15 plots indicating that adequate sampling has been achieved for Ngangao forest.

A total of 26 plant families were represented in the large tree category while a total of 33 plant families were represented in the understory layer. In the large tree category, 16% of the species were Rubiaceae, while the rest were Euphorbiaceae (10%), Sapotaceae (8.6%), Araliaceae (6.5%), Apocynaceae (4.8%), Meliaceae (4.8%), Myrtaceae (4.8%) and Ulmaceae (4.8%). Within understory category, 21.6% of the species were Rubiaceae, while the rest were Euphorbiaceae (9.5%), Apocynaceae (8.1%) and Rutaceae (5.4%). Family importance values (FIV) will be calculated as the sums of the family relative diversity (number of species in a family/total number of species), family relative density (number of individuals in a family/total number of individuals), and the family relative basal area is total basal area of individuals in the family/total basal area of all individuals).

Calculations for the various phytosociological parameters were performed as follows. Density is expressed as number of individuals per hectare. Frequency is the number of samples in which a species occurred divided by the total samples. Basal area is the area occupied by a cross section of the stem at breast height. In case of multiple stems at breast height, basal areas were calculated individually and then summed. Relative frequency is the number of plots in which a species occurred/total number of plots of occurrence for all species, relative basal area is the total basal area of the species/total basal area of all individuals, while relative density is number of individuals of a species/total number of all individuals. The importance value index (IVI) for each species was calculated as the sum of the relative values of frequency, density and basal areas then divided by 3.

The ten most important understory species based on importance % values for Ngangao forest are *Craibia zimmermanii* (7.3%), *Strombosia scheffleri* (6%), *Cola greenwayi* (5.6%), *Oxyanthus speciosus* (5.2%), *Tabernaemontana stapfiana* (4.5%), *Pauridiantha paurcinervis* (4.5%), *Teclea trichocarpa* (3.7%), *Psychotria petitii* (3.7%), *Garcinia volkensii* (3.6%), *and Millettia oblata* ssp. *teitensis* (3.6%). The ten important tree species as deduced from importance values are *Tabernaemontana stapfiana* (11.7%), *Albizia gummifera* (9.6%), *Macaranga conglomerata* (9.5%), *Aningeria adolfi-friedericii* (6.3%), *Craibia zimmermanii* (5.3%), *Syzygium sclerophyllum* (4.8%), *Millettia oblata* ssp. *teitensis* (4.3%), *Strombosia scheffleri* (3.9%), *Cola greenwayi* (3.4%), *Newtonia buchananii* (3%).

The total basal area occupied by trees ≥10cm dbh was 46.4 m^2/ha. Basal areas of primary forest have been reported as 35 $C^{\cdot}$ /ha. The ten tree layer species that represents the largest basal area per hectare are *Albizia gummifera* (7.0 m^2), *Tabernaemontana stapfiana* (6.3 m^2), *Aningeria adolfi-friedericii* (6.1 m^2), *Macaranga conglomerata* (5.9 m^2), *Craibia zimmermanii* (2.3 m^2), *Syzygium sclerophyllum* (3.2 m^2), *Millettia oblata* ssp. *teitensis* (1.9 m^2), *Strombosia scheffleri* (1.8 m^2), *Cola greenwayi* (1.7 m^2), and *Newtonia*

buchananii (1.4 m^2). These species occupy a total of 37.6 m^2 (81%) of the occupied basal area, while 8.8 m^2 (19%) was occupied by 57 other species. This high basal area is due to the fact that pioneer and secondary tree species together with primary forest species dominate Ngangao forest. Pioneer species, in particular *T. stapfiana, A. gummifera* and *M. conglomerata* occurred frequently, comprising 41% (19.2 m^2) of the total basal area. This may be explained by the fact that heavy logging changes light levels and soil conditions through the creation of large forest gaps. Such gaps favor pioneer tree species that are characterized by rapid dispersal and fast growth. Pioneer species are subsequently replaced by secondary tree species together with some primary forest species.

The ten tree species with the highest density (individuals per hectare) were *Tabernaemontana stapfiana* (84), *Albizia gummifera* (44), *Macaranga conglomerata* (53), *Craibia zimmermanii* (36), *Syzygium sclerophyllum* (17), *Millettia oblata* ssp*. teitensis* (25), *Strombosia scheffleri* (19), *Cola greenwayi* (21.9), *Newtonia buchananii* (18.4) and *Maesa lanceolata* (16.1). *Aningeria adolfi-friedericii* has a lower density of 14 individuals per hectare despite a high basal area. There were 25 species represented by less than two individuals per hectare.

The ten tree species with the largest relative frequency were *Tabernaemontana stapfiana* (5.9), *Albizia gummifera* (5.3), *Macaranga conglomerata* (5.7), *Craibia zimmermanii* (4.2), *Syzygium sclerophyllum* (4.4), *Millettia oblata* ssp. *teitensis* (4.2), *Strombosia scheffleri* (4.4), *Cola greenwayi* (2.4), *Newtonia buchananii* (2.6) and *Maesa lanceolata* (3.3).

Species endemic to Taita Hills that were found to occur in Ngangao forest include *Chassalia discolor* ssp *teitensis, Coffea fadenii, Impatiens engleri* ssp. *teitensis, Impatiens teitensis* ssp. *teitensis, Memecylon teitense*, *Psychotria petitii*, *Zimmermannia ovata*. Species endemic to Eastern Arc forests that were found in Ngangao forest include *Syzygium sclerophyllum*, *Psychotria pseudoplatyphylla*, *Podocarpus usambarensis* ssp. *usambarensis*, *Polyscias struhlmanii*, *Ouratea schusteri*, *Macaranga conglomerata*, *Dicranolepis usambarica*, *Dasylepis integra*, *Cola greenwayi* and *Aningeria adolfi-friedericii.*

It is evident that Ngangao forest is dominated by disturbance related species that are occurring over a wide geographic range. *Tabernaemontana stapfiana* and *Albizia gummifera*, the two most important species as deduced from importance values are broadly distributed species that are known to occur in disturbed forests. Numerous cut stumps are evidence of recent human influence in the forest. Species that have been extracted for timber include *Strombosia scheffleri, Albizia gummifera*, *Aningeria adolfi-friedericii, Millettia oblata* ssp. *teitensis, Syzygium sclerophyllum, Newtonia buchananii, Podocarpus latifolius* and *Ocotea usambarensis. Podocarpus latifolius* and *Ocotea usambarensis* are reported to have been common but are noticeably absent in the forest as a result of extraction. While *Podocarpus latifolius* has an understory density of 355 individuals per hectare, only two individuals per hectare were recorded at the large tree layer. While this may indicate regeneration as evidenced by numerous young individuals, most of these young individuals do not grow into big sized individuals. Although a couple of large *Ocotea usambarensis* trees were observed growing in the forest, none was documented in the sampling plots. This suggests that *O. usambarensis* is

occurring at exceptionally low densities despite having been numerous in the past.

Other human impacts on the forest include the planting of exotic species within the forest by the forest department. These plantations include *Pinus patula*, *Cupressus lusitanica* and *Acacia mearnsii*. Local residents indicate that establishment of plantations dates back to 1955. More recent plantations took place in 1971 and 1973. However, local residents indicate that planting of exotic species was concentrated in areas that were bare so as to prevent soil erosion, with limited enrichment plantings within the forest. The history of exotic plantations will be examined in detail through an examination of forestry records. Forest department is also responsible for planting other important species e.g. *Vitex keniensis*, an indigenous tree that only occurs on Mt. Kenya.

Preliminary analysis of ethnobotanical data

The ethnobotanical study documented over 40 uses of woody species in Ngangao forest. A tally of the total number of species per use, as well as number of informants who cite the use will be compiled. To analyze the results of the study, 5 use categories were identified. These categories are fuel wood, construction, medicinal, technology, edible and commercial uses. The categories do not necessarily reflect the local people's use categories and may be changed later. These uses are briefly examined, identifying the important species associated with each use category.

Firewood: All woody species are utilized as firewood. Local residents tend to collect any fallen branches and tree trunks irrespective of the species. However, the highly preferred species as deduced from preference ranking are *Craibia zimmermanii* and *Cola greenwayi*. All the informants interviewed used fuel wood from the forest or their farms to meet their domestic energy needs.

Construction material: Species preferred for construction are *Strombosia scheffleri, Albizia gummifera*, *Aningeria adolfi-friedericii, Millettia oblata* ssp. *teitensis, Syzygium sclerophyllum, Newtonia buchananii, Podocarpus latifolius* and *Ocotea usambarensis.* While each of these species has unique characteristics to warrant their preference e.g. hardwood, bole length, they are generally chosen for their durability. *M. oblata* ssp. *teitensis*, *S. sclerophyllum* and *S. scheffleri* are particularly preferred for poles and rafters. The Taita community considers *M. oblata* ssp. *teitensis* the single most important species for construction purposes. The traditional houses were constructed of a circle of *M. oblata* ssp. *teitensis* poles plastered with mud, and covered by a conical roof of grass thatch. However, present day homesteads are made of clay bricks, timber from *M. oblata* ssp. *teitensis* among other species, and iron sheets roofing.

Medicinal: Plant species identified in the forest have been used as remedies for stomachache, toothache, against coughs, asthma and high blood pressure. Other remedies include de-worming, against parasites such as lice and ticks. Woody species identified as having medicinal value include *Trema orientalis*, *Turrea holstii*, *M. oblata* ssp. *teitensis Tabernaemontana*

stapfiana, *Lobelia*, *Bequaertiodendron natalense*, and *Rapanea melanophloeos* among others. Non-woody species include *Dracaena steudneri* and *Culcasia scandens*. These medicinal uses are however not widespread as only a small fraction of the informants were able to identify and associate the use with a particular species. Moreover, no evidence of extraction for medicinal purpose was observed in the forest.

Edible: Plants whose fruits were identified as edible include *Phoenix reclinata* and *Vangueria volkensii*. *Toddalia asiatica* and *P. reclinata* were used as refreshments. *P. reclinata* was as also used to make a popular local brew. *P. reclinata* appears to be the single most important species in terms of local consumption.

Technology: Technological uses identified included making of water troughs, pestle and mortars, arrow sticks, and implement handles. Important species used for these purposes include *Phoenix reclinata, Cussonia spicata, Dracaena laxissisma* and *Memecylon teitense* respectively.

Commerce: Phoenix reclinata was documented as the only species with commercial value. To a limited extent, tender shoots are used for making baskets and mats that are offered on sale.

Population analyses of important plants

Based on the informant's responses, seven species appear to be important timber trees with a long history of extraction. These are *Millettia oblata* ssp*. teitensis, Strombosia scheffleri*, *Albizia gummifera*, *Aningeria adolfi-friedericii*, *Newtonia buchananii*, *Syzygium sclerophyllum*, and *Podocarpus latifolius. Craibia zimmermanii* and *Cola greenwayi* were identified as the two most important fuel wood species*. Tabernaemontana stapfiana,* the most important tree species in terms of importance percentage has a limited use and is hardly extracted for any purposes. This may be due to the fact that this species is soft and fast growing, making it unsuitable for timber and other uses.

In a detailed report, the size class distributions of these ten important species will be examined.

A preliminary analysis shows that the size class distributions are these of a typical natural forest regenerating from seeds, with high stem counts in the smaller size classes. Details of size class distribution for the 10 species targeted for detailed population study are available. These are *Strombosia scheffleri, Albizia gummifera, Aningeria adolfi-friedericii, Craibia zimmermanii, Cola greenwayi, Tabernaemontana stapfiana, Millettia oblata* ssp*. teitensis, Newtonia buchananii, Syzygium sclerophyllum* and *Podocarpus latifolius*. Most species have 66-92% of the individuals in 1-10 cm dbh size class, except for *Albizia gummifera* and *Aningeria adolfi-friedericii* that had 49% and 42% of individuals in this class.

For interpretation of size class data of these important species, additional background information on these species needs to be gathered. For instance it will be necessary to identify the actual sizes extracted by the local people. This information will be gathered through participatory interviews. Individuals who extracted these species will walk into the forest and asked to

demonstrate the sizes of individuals they extracted. Already such people have been identified through the ethnobotanical survey.

Dead trees in the plots will be examined with the aim of trying to identify them to the species level. Size distribution of dead individuals is useful in interpreting the results, especially on mortality rates. Also from other studies, background information on the biology of the species will be examined. This will provide an understanding of how non-human factors may impact on the size distribution of these species. Important information that will be sought includes mortality rates, as different size classes may have different mortality rates, growth rates, and trends in reproduction and predation.

3.6.1.5. Future activities

For Mbololo and Ngangao forests, detailed statistical analysis of both vegetation and ethnobotanical data remains to be done. Analysis of the vegetation data in relation to environmental parameters also remains to be done. These analyses will be the main activity during the year 2001.
The third objective, the identification of adaptive management options for forest restoration across the Taita Hills' forests is yet to be realised through a detailed examination of ethnobotanical and plant community data.

A final field visit is also planned for May - August 2001 for ethnobotanical re-interviews, and to consult historical records at the Taita-Taveta district headquarters.

Future research will aim at compiling all the existing knowledge to produce a holistic picture of the Taita Hills forests.

Research will continue within Taita hills, and will be expanded to the little studied Mount Kasigau, among other regional forests. It will also be examined what plant species contribute to the diversity of forest resources and how they have changed over time.

Finally at landscape level, factors that seem to influence the distribution of forest and human-occupied land on the slopes of these mountains, and their dynamics over time will be investigated. This research will build upon what was achieved in the course of THBP.

Finally, the existing sampling plots will be permanently marked to form the basis of a long-term monitoring program.

3.6.2. Vegetation structure of four small Taita Hills forest fragments

Report by Ms.Joyce Chege
East African Herbarium, Nairobi, Kenya

3.6.2.1 Introduction

One of the main objectives of the Taita Hills Biodiversity Project is to relate forest fragmentation and degradation to the loss of unique biodiversity. In order to carry out this research, it is important to understand the basic ecological parameters, which describe the forest. These parameters were already documented for Sagalla, Ronge, Mbololo, Ngangao, Chawia, Fururu, Vuria and Mwachora, but not yet for Kichuchenyi (Josa), Macha, Ndiwenyi and Yale, four other small forest fragments under study by the THBP.

This report presents the main results of the study regarding the structure and species composition of four 400m^2 plots in these four fragments.

3.6.2.2. Material and methods

Four 400 m^2 plots (20 x 20 m) were surveyed. In each plot all trees >5 m high were identified, their dbh was measured, the status of the trees was classified, the presence of buttresses for trees >15 m tall was noted, and the height and dominant species of each vegetation stratum were recorded. All shrubs 1-5 m tall were also identified and counted, and plot disturbance was noted. Five 1 m x 1 m subplots, at the center and in each corner, were then established within the large plot and % cover of bare ground, herbaceous growth and leaf litter were estimated. Furthermore, leaf litter depth was measured. Half-sight measurements of the shrub layer at 1 m and 2 m height were taken and % canopy cover was estimated.

3.6.2.3. Time frame of activities

The four forest fragments were visited between 2 and 7 March 2000.

3.6.2.4. Results

Table 4 gives structural data of the four forests, which shows indistinct structural differences. Although Ndiwenyi has the least number of trees per given area, it has the highest basal area. The forest is characterized by very big trees and no intermediates. Yale has the highest number of trees per area. However, the bulk belongs to the small diameter size class. The basal area for Josa (=Kichuchenyi) is greatly influenced by a large *Ficus thoningii*.

All the forests except Yale are heavily disturbed as indicated by their low stratification. The amount of litter differs considerably in all the forests. Generally, the steepest (Josa) had the least litter while Ndiwenyi and Macha with the least slope had the most litter.

The average height of canopy trees is highest in Ndiwenyi (20 m) followed by Josa whereas Macha and Yale have approximately the same average height of upper canopy trees. Ndiwenyi has the densest undergrowth.

The most frequent and common tree species are *Albizia gummifera*, *Phoenix reclinata* and *Tabernaemontana stapfiana*. *Xymalos monospora* is common in Yale and Macha forests.

Common understorey trees and shrubs include *Psychotria* sp., *Dracaena steudneri* and *Agelaea heterophylla*. Common herbs present were *Piper capensis* and *Culcasia falcifolia*.

3.6.2.5. Conclusions

The vegetation of the forests has been greatly influenced by man. The effect of earlier selective logging is evidenced by the presence of secondary successional species such as *Phoenix reclinata* and *Tabernaemontana stapfiana*. In Ndiwenyi and Josa, we observed very recent tree-poaching.

Table 4. Structural data from 20 m x 20 m plots. Standard deviation is given for all means except mean litter depth where values of skewness are given instead.

Parameter	Yale	Macha	Ndiwenyi	Josa
Range of strata	3	2	2	2
Mean litter depth (mm)	15(2.1)	18(1)	18(0.5)	4(-0.4)
Mean litter cover (%)	78±10	73±19	35±29	17±10
Mean herb layer (%)	14±13	15±12	59±31	30±16
Mean half-sight: 1m	10±12	23±3	19±8	8±10
Mean half-sight: 2m	4±8	11±8	16±12	5±10
Dead trees (%)	3	0	7	0
Artificially cut trees (%)	0	0	3	12
Buttressed trees/400 m^2	2	0	0	0
Number of trails/400 m^2	0	1	2	4
Basal area/m^2 (cm^2/m^2)	65	25	76	48

3.6.3. Inventory of the orchids and bryophytes

Report by Mr. Benny Bytebier
Centre for Biodiversity, National Museums of Kenya

3.6.3.1. Introduction and objectives

"An ecological and floristic study of the forests of the Taita Hills, Kenya" was published by H. Beentje in 1988. Although this publication contains a fairly comprehensive checklist of the forest plants, it does not cover the bryophytes. Furthermore, from experience we know that orchids are often poorly covered in checklists as a lot of them are epiphytes growing high up in trees, while others are only seasonably visible.

The objectives of this study therefore were (i) to compile an inventory of the bryophytes; (ii) to update and expand the checklist of the orchids (iii) to investigate the phytogeographic relations of the bryophytes and orchids of the Taita Hills with other (Eastern Arc) forests.

3.6.3.2. Material and methods

Specimens collected by Bytebier were deposited at the East African Herbarium (EA), with duplicates at the National Botanic Garden of Belgium (BR) and the Kew Herbarium (K). Bryophyte specimens collected by Chuah were deposited at the University of Nairobi Herbarium (NAI). All forest fragments, except Sagala, were sampled for bryophytes and orchids.

3.6.4. Collaborators

Mr. B. Bytebier (National Museums of Kenya, Nairobi, Kenya): orchids, bryophytes and other plants

Dr. M. Chuah-Petiot (Botany Department, University of Nairobi, Nairobi, Kenya): bryophytes

Dr. P. Masinde (East African Herbarium, National Museums of Kenya, Nairobi, Kenya): description of *Ceropegia verticillata*

Mr. O. Mwangangi (East African African Herbarium, National Museums of Kenya, Nairobi, Kenya): plant identification

3.6.5 Time frame of activities

Bytebier collected between 1998 and 2000 at different times of the year in the different forests. Chuah collected bryophytes in March 1999 in Mbololo, Ngangao.

3.6.6. Results

Over 130 orchid specimens have been collected, mostly as sterile living plants. These are kept at the orchid nursery of the Nairobi Botanic Garden of the National Museum of Kenya. Herbarium specimens are made when the plants are in flower. *Ypsilopus viridiflorus* has been confirmed as a species new to Kenya. Several species new for the floral region K7 (Coast) have also been identified. These are *Angraecum chamaeanthus*, *Angraecum humile*, *Bolusiella iridifolia* ssp.*iridifolia* and *Polystachya fusiformis*. Several specimens, however, remain to be identified and the data has not yet been compiled.

In his list, Beentje mentions *Ypsilopus sp. nov*. as an endemic species for the Taita Hills. However, this turned out to be *Tridactyle tanneri*, a species which is endemic to the wider Eastern Arc mountains but not to the Taita Hills only. This species is quite common in Ngangao and Mbololo. Furthermore, Beentje mentions *Angraecum sacciferum* as “possible rare in world sense”. This plant is actually quite common, but is small and grows high up in the trees and is therefore easily overlooked.

Concerning the bryophytes, Bytebier collected a total of 328 specimens, in the following fragments: Mbololo (110), Ngangao (90), Vuria (30), Chawia (35), Yale (30), Macha (14), Mwachora (12) and Kichuchenyi (7). Chuah collected about 300 specimens, 230 in Mbololo and 70 in Ngangao. Roughly 80% of the material has so far been identified. A compilation of the available literature shows that previous to this study only 27 species were recorded for the Taita Hills, most of them from Vuria. It is clear, however, that the diversity of bryophytes is much higher. Several species new to Kenya were already identified. Amongst these are *Neorutenbergia usagarae, Pterobryon flagelliferum* and *Renauldia lycopodioides*, previously only known from Tanzania. Others are *Lopidium pennaeforme*, *Bazzania rocatii*, *Andrewsianthus bilobus*, *Plagiochila strictifolia*, *Radula ankefinensis*, *Radula fulvifolia, Radula madagascariensis, Cheilolejeunea usambarana, Leucolejeunea unciloba, Asterella wilmsii* and *Plagiochasma rupestre*.

Other higher plants were also collected, albeit in a less systematic way. A few were new records for the Taita Hills or for the floral region K7, and at least one species proved to be new to science. Patrick Masinde, from the East African herbarium, named *Ceropegia verticillata* (Asclepiadaceae) after its whorled leaves, which is unique in this genus. This species is only found in Mbololo forest and is therefore a new true endemic of the Taita Hills.

3.6.7. Future activities

Identification of the bryophytes is nearly complete and a paper on the findings is in preparation.

Most of the orchids have also been identified but the data stiil needs to be compiled into a publication.

3.7. A Survey of the bushbabies (Primates, Galagonidae) of the Taita Hills

Report by Mr. A. Perkin
Nocturnal Primate Research Group (NPRG), Department of Anthropology, Oxford Brookes University, UK

3.7.1. Introduction and objectives

Prior research indicates that the number of galago (bushbaby) 'species' may be underestimated, when the differences in vocalizations, reproductive anatomy and genetics are considered. To this end the principle investigator is conducting a project to assess "the distribution and conservation status of the galagos of the Eastern Arc Mountains and the Coastal Forests of East Africa". Surveying the Taita hills (SE Kenya) was seen as an integral part of this project, as it is an isolated Eastern Arc mountain with a known assemblage of several endemic and rare species.

3.7.2. Material and methods

Surveys were conducted along existing paths recording galagos and other taxa as they are seen or heard using torches, binoculars and tape recorders. Species were then identified from observational and vocalization data. Biometric data and tissue samples were collected when possible for genetic analysis, using Chardonneret live traps and mist nets for live animal capture. Any captured animals were released.

3.7.3 Collaborators

Dr. S. Bearder, Nocturnal Primate Research Group (NPRG), Department of Anthropology, Oxford Brookes University, UK

Dr. T. Butynski, Africa Biodiversity Conservation Program, Zoo Atlanta, National Museums of Kenya, Nairobi, Kenya

Mr. B. Agwanda, Zoology Department, Kenyatta University, Nairobi, Kenya

3.7.4. Time frame of activities

Two sites in the forest fragments of Ngangao and Mbololo forest reserve were surveyed between the 8 - 23 July 1999 and the 18 – 27 July 2000.

3.7.5. Results

3.7.5.1. Greater galagos

Otolemur garnetti were encountered every night and were abundant both in the indigenous forest and in exotic tree plantations and farmlands. In Mbololo eight *O. garnetti* were trapped and in Ngangao forest fragment, four were trapped. The pelage of this population seemed to be lighter in color than

populations in the coastal forests. The penile morphology of this species was consistent with other populations studied. The following calls were recorded; 1) 'cries', 2) 'squalks', 3) 'trailing' calls, and 4) the 'cackle' call.

3.7.5.2. Dwarf galagos

Dwarf galagos of one species were observed and heard. These looked similar in coloration to the Zanzibar galago *Galagoides zanzibaricus* and were as small as a Rondo galago (60-100 grams). This galago population was not the Senegal galago, *Galago senegalensis*, due to morphology, size and vocalization differences. The possibility that this population is *Galagoides zanzibaricus, Galagoides rondoensis* or *Galago senegalensis* was therefore excluded. Preliminary analysis shows three types of call were recorded: a 'double unit call' followed by an 'incremental call', 'yaps and shrieks', and a 'whistle' call. These calls are mostly consistent, but with some differences, with the mountain galago, *Galagoides orinus*, a species endemic to the Eastern arc Mountains.

3.7.6. Conclusions

O. garnetti were found in good numbers, and the vocalisations and morphology appeared mostly consistent with other populations in E. Africa.

The dwarf galagos seen were identified as a form of *Galagoides orinus,* a species not previously recorded in Kenya. The habitat type and elevation of the Taita Hills forests are consistent with other Eastern Arc forests where *G. orinus* occurs. Whilst the similarities in vocalization and morphology with other *G. orinus* populations identify this dwarf galago as *G. orinus,* the differences and the degree of isolation of the Taita hills indicate the possibility that this taxon is a new subspecies of *G. orinus.*

3.7.7. Recommendations and future activities

These surveys provide a new primate taxon for Kenya and may even represent a new *G. orinus* subspecies. Through the collaboration with THBP, the data obtained about the presence of *G. orinus* in Taita Hills contributes important new information about galago distributions in East Africa. It is now important to trap a sample of this population for the completion of morphological and genetic analyses and to confirm the taxonomic status of this *G. orinus* population. Further efforts to facilitate Mr. Bernard Agwanda, of Kenyatta University, Kenya, and/or myself, to follow this up are recommended, as the present funding has ceased.

3.7.8. Acknowledgments

This survey would not have been possible without the assistance and collaboration of the Taita Hills Biodiversity Project (THBP). Particularly I would like to thank Mr. Benny Bytebier and Bernard Agwanda. I would also like to thank Dr. Tom Butynski (Zoo Atlanta) for his help and scientific contribution.

.

3.8. A survey of the amphibians and reptiles of the Taita Hills

Report by Mr. K. Malonza
Department of Herpetology, National Museums of Kenya, Nairobi, Kenya

3.8.1. Introduction

The present herpetological survey covered Ngangao, Yale, Chawia, Sagalla, Mbololo, Macha, and Mwachora forest fragments. Forest patches not sampled include, Vuria, Fururu, Diwenyi and Kasigau. Most of the forests are quite small and the only larger patches of indigenous forest are Mbololo, Ngangao, and Chawia.

The amphibians and reptiles of the Taita Hills have not been comprehensively surveyed. However, as a general rule, the herpetofauna in montane habitats is poor, as amphibians and reptiles are ectotherms and need outside heat, which is not readily available in montane forest. Nevertheless, for forests which rise from dry bushland ground, like Mbololo and Sagalla, the lower slopes are usually quite rich especially for reptiles.

3.8.2. Aims and objectives

The main objective of this survey was to investigate and document the various amphibian and reptile species found in the Taita Hills. In particular this survey intended: (i) to determine the distribution of different species within the various forest fragments, (ii) to investigate the conservation status of the various species, with particular emphasis on endemic and/or rare species, (iii) to provide baseline information for long-term monitoring studies of the herpetofauna of the Taita Hills.

3.8.3. Materials and methods

A standard systematic search-and-seize sampling method was used for the survey. The method involves selecting the habitat to be sampled and carrying out an intensive search of all the possible amphibians and reptiles microhabitats. Spatial boundaries may not be important other than staying within the study habitat. Day searches were done mainly for reptiles and night searches for amphibians and nocturnal reptiles using spotlights.

The species identity of each specimen captured and/or observed plus any other biologically important information such as breeding, basking, and calling was recorded. The captured animals were then released or preserved to form a voucher collection and later deposited at the Department of Herpetology. National Museums of Kenya. Collections were only made for species that are lacking or not well represented at the departments collections.

To supplement the efforts of search-and-seize method and to eliminate some problems and biases of this manual survey, one trapping technique was employed. A straight-line drift fence with pitfall traps was set up to increase catchability. Also for reptiles, especially snakes and lizards, snake tongs (sticks) and rubber bands were used.

3.8.4. Collaborators

Mrs. D. Rotich, Herpetology Department, National Museums of Kenya
Mr. V. Wasonga, Herpetology Department, National Museums of Kenya

3.8.5. Time frame of activities

Sampling was done in all the major forest fragments that is Ngangao, Yale, Chawia, Mbololo, Sagalla, Macha and Mwachora. Mt. Kasigau was not surveyed as it's more separated from the rest. This survey was carried out between 3 and 11 December 1999. The sampling time for each fragment was mostly a day or less.

3.8.6. Results

The amphibians and reptiles collected and/or observed are given below. These include 4 snake species, 8 species of lizards, and 9 species of frogs. Other researchers involved in the Taita Hills Biodiversity Project had earlier collected two more species of lizards and snakes. Some brief notes on each species distribution are given.

3.8.6.1. Snakes

Forest or Western Vine snake (*Thelotornis ? kirtlandii*)

This specimen differs from the more common *Thelotornis capensis mossabicanus* in its larger body length and scale counts. A close examination of an earlier specimen collected from Mbololo forest proved to be similar. This is typically a western and central African forest species with its eastern limit known from some parts of western Uganda and Mahali Peninsula along Lake Tanganyika and at Massisiwi in the Uduzungwa Mountains in southern Tanzania

Herald or red-lipped snake (*Crotaphopeltis hotamboeia*)

Specimens of this harmless snake were collected from Ngangao and Mbololo forests. This species is widespread in many forested areas of Kenya. A single specimen had also been earlier collected in Mbololo forest.

Battersby's or northeastern green snake (*Philothamnus battersbyi)*

A specimen of this species had been collected earlier by the forest guard in the Ngangao forest. It is a species also common in many areas in Kenya.

Common House snake (*Lamprophis fuliginosus*)

A dead specimen of this species was found on a roadside in Ngangao forest but not collected. Generally this snake is very common in Kenya in a cross section of habitats.

Savanna or Eastern Vine snake (*Thelotornis capensis mossabicanus*)

This is a very common tree snake along the coastal lowland forests of Kenya. One researcher had earlier collected one specimen from Mt. Kasigau.

Flowered snake (*Coluber florulentus*)

A sporadically common dryland species. A single specimen of had been collocated at Ndi near Voi by another researcher.

3.8.6.2. Lizards

Usambara forest gecko (*Cnemaspis africana*)

This is a dull coloured gecko with conspicuous stripes on the lips. Specimens were collected at Chawia forest. Known from the Taita Hills and Kakamega forest, elsewhere in the Usambara Mountains of Tanzania. Earlier on, specimens had been collected from Chawia, Kasigau, and Ngangao.

Dickerson's forest gecko (*Cnemaspis ? dickersoni*)

A dull black gecko with enlarged dark dorsolateral tubercles in at least 5 rows. However on preservation most of the tubercles faded beyond recognition and only a fresh specimen before preservation can give the correct identification characteristics. Ventral part whitish with under throat heavily spotted black as compared to few spots on the ventrum. One specimen was collected in Mbololo and several seen in Chawia and Macha forests. Common on tree stems and rock caves but very agile and hard to capture. Possibly found only in the Taita Hills in Kenya. Not collected earlier but locally common in suitable microhabitats in the Taita Hills.

Cnemaspis sp.

Unidentified specimens of *Cnemaspis* species had been collected from Chawia and Macha forests by other researchers in 1998.

Jackson's forest lizard (*Adolfus jacksonii*)

This lizard is locally common in forested areas such as Kakamega, Nyambene, Mau Hills, Kinangop, Chyulu Hills, and Taita Hills. Common on tree stems where they can be captured by shooting them down. A specimen was collected in Chawia forest and another observed in Yale forest. Earlier on, specimens had been collected from Mwachora, Yale and Chawia forests.

Kilimanjaro two-horned chameleon (*Bradypodion tavetanum*)

Several specimens were collected in Ngangao, Chawia and Mwachora forests. This is a species with restricted range in both Kenya and Tanzania. In Kenya found only in Taita and Chyulu Hills. Elsewhere it occurs on Mt. Kilimanjaro, Mt. Meru and the Usambara Mountains in Tanzania. This species was commonly observed basking on palm trees in the forests.

Kilimanjaro five-toed skink (*Leptosiaphos kilimense*)

This species is very common in the highlands of Kenya. Several specimens were collected in Mbololo, Chawia, Ngangao and Yale forests. In Diwenyi some specimens were collected earlier on.

Common striped skink (*Mabuya striata*)

This species of skink is locally common in many areas of Kenya even in urban centers since its quite insensitive to human habitation. Some specimens were observed on buildings at the Ngangao forest camp.

Variable skink (*Mabuya varia*)

A species mainly confined to the highlands of Kenya. In Taita Hills some individuals were seen in Yale and Chawia forests. Earlier on specimens were collected from Ngangao forest.

Common or red-headed agama (*Agama agama lionatus*)

This agama lizard is very common mainly in the drylands. It prefers mostly rocky areas with plenty of crevices for refuge. A number of individuals were observed on rock surfaces on the lower slopes of Sagalla and Mbololo Hills that are covered by deciduous bushland vegetation. Others were also seen in Ngangao forest on rock surfaces. Similar specimens were earlier collected from Mwachora and Kasigau forests.

Flat-headed tropical house gecko or baobab gecko (*Hemidactylus platycephalus*)

Several specimens were earlier collected at Mt. Kasigau.. This species is very common along the coast and northern eastern Kenya.

Rainbow skink (*Mabuya margaritifera*)

A rock dwelling species restricted to southeastern (Makueni and Taita-Taveta districts) Kenya. Some specimens were earlier collected from Mt. Kasigau. Possibly the species should also be present on the lower slopes of Sagalla and Mbololo Hills.

3.8.6.3. Frogs

Taita reed frog (*Hyperolius viridiflavus glandicolor*)

A species endemic to Kenya and known only from the Taita Hills and the surrounding lowlands of Mwatate, Bura and Lake Jipe. A number of specimens were collected from Chawia forest.

Callulina kreffti

This burrowing species was previously thought to be endemic to the Usambara Mountains but was first recorded in 1985 from the Taita Hills. A species known only from the Taita Hills in Kenya, elsewhere present in the Usambaras of Tanzania. A single specimen was collected under rotting log in Chawia forest. Several specimens of this rare species were earlier collected in Diwenyi, Fururu, Ngangao, and Chawia forests in 1998 in small mammal pitfall traps.

France's squeaker (*Arthroleptis adolfi-friderici*)

Several specimens were collected in Chawia forest. This species in Kenya is known only from the Taita Hills, otherwise present also in the Usambara Mountains of Tanzania.

Guttural toad (*Bufo gutturallis*)

This is the most common toad in Kenya occurring virtually everywhere. Specimens of this species were collected in Chawia, Ngangao, and Sagalla forests.

Common cricket frog (*Phrynobatrachus ukingensis*)

One of the very small frogs but locally common in suitable habitats. Some specimens were collected in Chawia forest.

Common or Upland clawed frog (*Xenopus laevis*)

This species is normally common in the Kenyan highlands. A number of specimens were seen but only one was collected in a pool of water in Ngangao forest.

Common Rana or dusky-throated frog (*Rana angolensis*)

A very common frog species in suitable habitats in Kenya. Several specimens were collected in Ngangao, Iyale and Chawia forests.

Savanna ridged or plain grass frog (*Ptychadena anchietae*)

The most widespread grass or ridged frog in Kenya. Some specimens were collected in Chawia and Mbololo forests.

Mottled shovel-nosed frog (*Hemisus marmoratum*)

This burrowing frog is widespread in most parts of Kenya. A single specimen was collected from a pitfall trap in Chawia forest.

3.8.6.4 Human Impact Assessment

The Taita Hills forests are small patches of forests on the hilltops like islands in a sea of intensive agriculture. None of the forests is free from human impacts. All the forests have portions of exotic forest planted several decades ago. To the extreme side, the whole of Sagalla forest is almost covered with exotic *Eucalyptus* forest with only a small patch of indigenous forest. Worth mentioning is the present subsistence firewood collection and animal grazing in Yale and Chawia forests which are opening up the forest.

3.8.7. Recommendations and future activities

(i) This survey of reptiles and amphibians was opportunistic and timing is very important. Surveying at the right time (season) can reveal species not known to occur or even rare in any given area. Therefore, the higher the frequency of surveys at different times and season, the better. In future surveys over a whole complete breeding season are required, covering both dry, transition and wet seasons.

(ii) This survey was carried out for a comparatively short period of time and there is no doubt that it gave a snapshot view of the species occurring in the Taita Hills. An intensive long-term sampling is indispensable. The endemic Taita purple-glossed snake *Ambloydipsas teitana* lastly collected in 1934 at Mbololo is not represented in the herpetological collection. The rare Taita or Percival's limbless skink, *Acontias percivali percivali*, is also known from Mbololo. The rare Voi wedge-snouted Amphisbaenian (worm lizard), *Geocalamus acutus*, also only known from Mblololo has not been collected recently. The Taita caecilian, *Boulengerula taitanus*, is restricted to specific microhabitats and its status remains uncertain. The conservation status of

these endemic and near-endemic species is currently unknown due to lack of research information on their distribution and population size.

(iii) Future intensive surveys should be done to investigate the conservation status of the reptiles and amphibians of the Taita Hills. Similar surveys are required in other areas with endemic and near endemic species, like the Shimba Hills and Tana River Delta.

(iv) Future research of the Taita Hills can give a clear picture on the effect of habitat loss, fragmentation and degradation on biodiversity with particular emphasis on herpetofauna. Frogs in particular can be used as indicators of environmental change in quality and quantity.

(v) The present survey established that future research should focus mainly on the large forest fragments like Mbololo, Ngangao, Chawia, Yale and Kasigau. However, some forests have good microhabitats for amphibians while others are good for both amphibians and reptiles.

3.8.8. Acknowledgements

I wish to acknowledge the efforts, company, and technical assistance of my colleague Vincent Muchai who assisted during the survey. I am also grateful to Reuben Mwakodi, our local field assistant, whose knowledge of the forest fragments made the survey a success. Many thanks goes to Damaris Rotich and Victor Wasonga of the department of herpetology for their inputs. I also wish to acknowledge researchers attached to the THBP for collecting and donating specimens to the department. Lastly but not the least I am indebted to the Taita Hills Biodiversity Project which financed the survey work.

3.9. Landscape analysis

3.9.1. Introduction

The indigenous forests of the Taita Hills have been subject to intense fragmentation since the early 1960s. Apart from degradation of the forest remnants, the intermediate habitat matrix has become largely deforested too. The resulting decrease in habitat connectivity is believed to negatively affect the ability of organisms to disperse between remaining forest fragments.

Given the nature of the THBP (a study on habitat fragmentation), the need was felt for a detailed insight and clear understanding of how the different fragments are topographically and structurally related to each other. In this respect it was necessary to get an idea, not only of the size of the forest fragments and the relative distances between the fragments, but also of the altitudinal differences, the intermediate vegetation structure and any historical vegetation changes.

3.9.2. Aims and objectives

The aim of this component was to conduct a detailed landscape analysis of the Taita Hills area. Furthermore, THBP wanted to develop a three-dimensional electronic land-use map in a Geographical Information System (GIS). The GIS model would have to consist of the following layers: an elevation layer, an infrastructure layer, a land use layer, and a layer with the current contours of the indigenous forest fragments.

3.9.3. Material and methods

The digital terrain model is mainly based on the existing 1:50,000 topographic map for the Taita Hills. From this map the elevations were extracted at 100m intervals, by copying these contours on transparent paper. These contours were digitised and geo-referenced, using the Arc/Info GIS-software. Finally the altitude lines were transformed in a continuous surface, taking into account the elevation between lines.

A 190 aerial photographs, taken during an aerial survey in 1993, were purchased from Photomap. The land use was scored from 12 aerial photocompilations each consisting of number of individual aerial photographs. Each compilation was overlaid with a transparent plastic sheet on which a 3.3 x 3.3 mm. grid was printed. Each square was then scored for the underlying land use in 9 different categories (field; forest; forest/field; bush; bush/field; rocks; sisal plantation; water body and human structure/infrastructure). The manually coded grid cells of every individual compilation were then entered into an electronic format grid. This transformation was also done manually and quality control checks were performed. Afterwards, each grid was geo-referenced, based on control points that could be recognised on the original aerial photographs and for which the co-ordinates could be found on the topographical map. A major problem with the photo compilations was that the scale of the photos, and hence the cells of the grid, was not uniform; and that the compilations are not geometrically correct entities. Because of this, the

original electronic grids were re-transformed into a standardized grid, whereby each individual cell of the grid has the same ground resolution (30x30m). Finally all compilations were merged into a single land use layer.

The final layer of the GIS model consists of the current boundaries of the forest fragments under study. The forest contours were measured using Trimble differential GPS equipment. This type of equipment allows measuring the boundaries with an accuracy of about 5 m, whereas conventional GPS equipment would only give an accuracy of up to 100m. This is due to an introduced error called Selective Availability, which can be eliminated through the use of differential GPS equipment. dGPS data was further corrected using the Pathfinder Office software, and then converted into an Arcview shape-file and included in the geographical database.

3.9.4. Collaborators

Mr. R. Verwimp (Ground for GIS, Research & Development Organisation, Catholic University of Leuven, Leuven, Belgium): GIS model compilation

Dr. L. Lens (University of Antwerp, Antwerp, Belgium): compilation of aerial photographs, geo-referencing, general co-ordination

Dr. M. De Meyer (Royal Museum for Central Africa, Tervuren, Belgium): purchase of aerial photographs and maps, preparation of elevation contours, geo-referencing, general co-ordination

Mr. B. Bytebier (Centre for Biodiversity, National Museums of Kenya, Nairobi, Kenya): compilation of aerial photographs, dGPS forest boundary measurements

Mr. R. Mulwa (Ornithology Department, National Museums of Kenya, Nairobi, Kenya): land use scoring

Mr. A. Rosie (Engineering and Utility Management Ltd., Nairobi, Kenya): provision of dGPS equipment

Ms. A. Notenbaert (PolyGIS, Kenya Polytechnic, Nairobi, Kenya): compilation of Mt. Kasigau map

Ms. A.M. Nguthu (PolyGIS, Kenya Polytechnic, Nairobi, Kenya): digitisation of Mt. Kasigau map

3.9.5. Time frame of activities

Year 1

Purchase of topographical maps and aerial photographs

Extraction of elevations at 100m interval from the 1:50,000 topographical map, by copying these contours on transparent paper.

Year2

Collation of the aerial photographs into 12 different photocompilations

Visual scoring of the compilations for the underlying land use in 10 different categories.

Year 3

Digitisation and geo-referencing of the contours using the Arc/Info GIS-software

Entering of the manually coded grid cells of every individual compilation into an electronic format grid
Measurement of the forest boundaries with dGPS equipment
Merging of the compilations into a single land use layer

Year 4
Quality checking and adjustment
Digitisation of the topographical map of Mount Kasigau

3.9.6. Results

The GIS model for Taita Hills is now operational. Furthermore the Poly GIS unit of the Kenya Polytechnic digitised Mount Kasigau. Although in this case land use was not scored, this GIS map forms a very useful addition to the model.

Appendix 1 gives examples of the kind of maps that can now be produced

3.9.7 Future activities

There are still some areas that need to be scored for land use. These are mainly at the edges of the different compilations, and where clouds obscured the aerial photographs. This will be done shortly.

The GIS model will allow us to analyse the landuse in the Taita hills in relation to the elevation; to develop 3D terrain models; to measure and analyse the current coverage of the individual fragments. This landuse database will also form the basis for a connectivity analysis of the landscape in which the indigenous forests are embedded.

3.9.8. Financing

The GIS model was developed by “Ground for GIS”, the landscape unit of the Research & Development Organisation of the Catholic University of Leuven (KUL). The Research Council of the University of Antwerp (UIA Onderzoeksraad) funded the major part of this work, through a 400.000 BEF grant to Luc Lens and Erik Matthysen. THBP funded the purchase of the aerial photographs, the cost of the land-use scoring and the forest boundary measurement exercise.

Digitisation of the Mount Kasigau was done as a student project, and was financed by the PolyGIS unit of the Kenya Polytechnic.

4. TRAINING

4.1. M.Sc. animal ecology

One major aspect of the training component of the THBP was support to the Master of Science (M.Sc.) programme in Animal Ecology at KU. This M.Sc. programme runs for two consecutive years. During the first year the emphasis is on theoretical courses, while during the second year the students focus on a research project. The THBP supported the M.Sc. programme in Animal Ecology by providing M.Sc. scholarships, visiting lecturers and logistical support to the department.

4.1.1. M.Sc. scholarships

The THBP provided two full scholarships for the M.Sc. programme in Animal Ecology. After a proper selection procedure, these were awarded to Mwangi Githiru and Richard Odhiambo. Both students successfully finished their M.Sc. programmes during the time span of the THBP, and both have since embarked on their Ph.D studies. More details are provided in section 4.2.

THBP also provided a partial scholarship to a third M.Sc. student, Ronald Mulwa. Mr. Mulwa self-sponsored his tuiton fees, but THBP covered all costs for his fieldwork. Mr. Mulwa is currently finishing the write-up of his M.Sc. thesis (see also 4.2 for more details).

4.1.2. Visiting lecturers

As part of the support of the M.Sc. programme, it was agreed that Belgian lecturers would travel to Kenya to assist in teaching some of the courses of the Animal Ecology programme.

The following courses were completely or partly taught by visiting lecturers from the university of Antwerp during the first year of THBP:
Population Ecology by Dr E. Matthysen
Ecological Techniques by Dr L. Lens
Evolutionary Ecology and, Behaviour and Wildlife Management by Dr M. De Meyer

During the second year of THBP only one student was registered for the M.Sc. programme, and it was therefore thought uneconomical for lecturers from the university of Antwerp to travel to Kenya.

The request for assistance from Belgian lectures during the third year of THBP year came when the M.Sc. teaching was already well underway. Belgian lecturers were unable to avail themselves at such a short notice. Therefore, no Belgian lectures participated in the M.Sc. programme during the second and third year.

In general, this kind of assistance requires long term planning. To avoid incompatibilities, the Belgian lecturers need to plan the Kenyan teaching assignment at least a year on beforehand, so that they can fit it in with their academic responsibilities at home. Due to recurrent student protests,

Kenyatta Uinversity has been closed several times over the past few years. Therefore, it was extremely difficult for the Kenyatta University M.Sc. course organisers to do any long term course planning, and as a result the planned assistance by Belgian lecturers could only take place during the first year of THBP.

The conclusion is that this part of the project was only partially successful.

4.1.3. Logistical support

Because of financial constraints at KU, the teaching and research facilities are limited. It was therefore considered a necessity to support the departmental infrastructure with administrative, teaching and scientific equipment. This came under the form of two computers with UPS, a laser printer, a scanner, a photocopying machine, two Leica binocular miscroscopes plus a camera system for these microscopes, a chest freezer and specialised textbooks for the departmental library.

The THBP provided all logistic support for the field assistants and M.Sc. students while in the field for their research projects. THBP provides the students and staff with all collecting and research gear needed, general logistics like camping equipment, transport, and a field allowance (on top of their monthly scholarship stipend) for additional costs while in the field.

4.2. M.Sc. and Ph.D. training

THBP supported several M.Sc. and Ph.D. students in various ways.

Mwangi Githiru and Richard Odhiambo were fully sponsored by the project for their M.Sc. studies at Kenyatta University, Nairobi. Ronald Mulwa, a third M.Sc.student at KU, was partially sponsored.

Two more M.Sc. students, Daina Samba and Kariuki Ndang'ang'a, started as reseach assistants for Ph.D. student Edward Waiyaki. With the experience they gained under THBP, they later managed to attract their own funding to proceed for M.Sc studies. Kariuki Ndang'ang'a registered at the FitzPatrick Institute African Ornithology, University of Cape Town, South Africa, while Daina Samba registered at the University of Reading, UK. Samba is currently doing her field project within the framework of THBP and is investigating the ecology of the Taita Apalis.

Edward Waiyaki initially started his investigation on the ecology of the Taita Thrush with financial assistance from the THBP, but was later awarded a Ph.D. scholarship by the Directorate General for International Collaboration (DGIS), Belgium.

Kamau Wakanene joined the project later. He investigates the structure as well as the ethnobotanical aspects of the Taita forests. THBP facilitated contacts with potential donors, which resulted in a grant of 5300 $ towards his research expenses. THBP also assisted him with logistical support when and where needed.

As part of the collaborative research programme between THBP and the International Centre for Insect Physiology and Ecology (ICIPE), Janet Midega, a B.Sc. student at Kenyatta University, received assistance for field data collection in Taita Hills, and transport between Kenyatta University and ICIPE, where she carried out laboratory analysis under the supervision of Dr. N.O.

Oguge and Dr. L. Rogo on the population genetic structure of *Papilio desmondi teita* in three forest fragments of the Taita Hills.

More details on each of the students and their projects are given below.

4.2.1. M.Sc. students

Mwangi Githiru
Ornithology Department, National Museums of Kenya
M. Sc. Student (Animal Ecology) registered at Zoology Department, Kenyatta University (Kenya)

Thesis Title
Avian frugivory and seed dispersal in some of the Taita Hills forest fragments

Supervisors
Dr. C.K.P.O. Ogol, Zoology Department, Kenyatta University
Dr. L.A. Bennun, Ornithology Department, National Museums of Kenya

Financing
M.Sc. scholarship provided by the Taita Hills Biodiversity Project
THBP offered a full scholarship, including tuition fees and field-related expenses and all logistical support needed for fieldwork and thesis write-up, which included attendance of a scientific conference in Tanzania and a short study visit to the University of Antwerp in Belgium

Time frame
January 1997: Scholarship was awarded
January1997 - July 1997: Theoretical framework at KU
September 1997 - June 1998: Fieldwork in the Taita Hills
December 1997: Attendance of conference on Eastern Arc Mountains in Morogoro, Tanzania
October 1998 - July 1999: Data analyses and write up at NMK
January 1999 - February 1999: Data analyses at the UA, Belgium
July 1999: Submission of thesis to KU
September 1999: Successful thesis defence at KU
October 2000: Graduated from KU

Future activities
Currently in his second year of a D.Phil. programme in the Edward Grey Institute of Field Ornithology, Department of Zoology, University of Oxford, UK

Thesis title
Endemic forest birds of the Taita Hills: using a model species to understand the effects of forest fragmentation on small populations

Supervisors
Prof. C. Perrins, Zoology Department, University of Oxford
Dr. L.A. Bennun, Ornithology Deapartment, National Museums of Kenya
Dr. L. Lens, Biology Department, University of Antwerp

Financing
This D.Phil. study is financed through a Rhodes scholarship. THBP offered partial support for some fieldwork-related expenses such as radio receiver, some camping and mist-netting equipment
Time frame
December 1998: Rhodes scholarship was awarded
October 1999 - April 2000: Theoretical framework at Oxford University (OU)
May 2000 - October 2000: Fieldwork in the Taita Hills
October 2000 - Januari 2001: Preliminary data analyses at OU
Januari - Februari 2001: Short visit to the University of Antwerp, Belgium
March - October 2001: Fieldwork in the Taita Hills
October 2001 - October 2002: Data analyses, thesis write-up, manuscript preparation and genetic analyses at OU and UA

Richard Oketch Odhiambo
Zoology Department, Kenyatta University
M.Sc. student (Animal Ecology) registered at Zoology Department, Kenyatta University, Nairobi (Kenya)

Thesis title
An ecological study of *Praomys taitae* (Rodentia : Muridae) Heller 1911 and other small rodents in the fragmented forest habitats of Taita Hills, Kenya

Supervisors
Dr. N.O. Oguge, Zoology Department, Kenyatta University
Dr. C. Ogol, Zoology Department, Kenyatta University
Prof. R. Okello, Zoology Department, Kenyatta University

Financing
M.Sc. Scholarship provided by the Taita Hills Biodiversity Project
THBP offered a full scholarship including tuition fees and field-related expenses and all logistical support needed for fieldwork and during write-up of the thesis, which included attendance of scientific conferences in Tanzania and Denmark, and short study visits to the University of Antwerp in Belgium, and Sokoine University in Tanzania

Time frame
January 1997 - June 1997: Course work
October 1997 - November 1997: Reconnaissance of study site
November 1997 - December 1997: Attendance of conference on Eastern Arc Mountains in Morogoro, Tanzania
January 1998 - April 1998: Removal studies
April 1998 - August 1998: CMR Study
September 1998 - January 1999: Data entry and collation
January 1999 - February 1999: Biometric work and data analysis at the University of Antwerp, Belgium
February 1999: Attendance of rodent conference in Greve, Denmark
March 1999 - April 1999: Cytogenetic work at Sokoine University in Morogoro, Tanzania
April 1999 - June 1999: Completion of data analysis

June 1999 - December 1999: Thesis write-up
January 2000: Thesis submission for examination
April 2000 - May 2000: Defense and final thesis submission
October 2000: Graduation
Future activities
Due to begin his Ph.D. degree at the Pest Management Centre (formerly Rodent Research Unit) of the Department of Crop Science and Production, Faculty of Agriculture, Sokoine University, Morogoro, Tanzania

Thesis title
A study of taxonomy, community structure and diets of rodents involved in staple crop losses in eastern Africa

Supervisors
Prof. M. Corti, University of Rome, Italy
Prof. R. Verhagen, Biology Department, University of Antwerp, Belgium
Dr. R. Makundi, Sokoine University, Morogoro, Tanzania

Financing
Provided under a EU project entitled “Protecting staple crops in eastern Africa: integrated approaches for ecologically based field rodent pest management”

Ronald Mulwa
Ornithology Department National Museums of Kenya
M.Sc. Student (Animal Ecology) registered at Zoology Department, Kenyatta University (Kenya)

Thesis Title
The populations status and ecology of the Taita White Eye, *Zosterops (poliogaster) silvanus*, in the fragmented forests of Taita Hills

Supervisors
Dr. C.K.P.O. Ogol, Zoology Department, Kenyatta University
Dr. L.A. Bennun, Ornithology Department, National Museums of Kenya

Financing
M.Sc. scholarship partly provided by the Taita Hills Biodiversity Project
THBP paid for all field-related expenses, field assistants and all logistical and administrative support needed for fieldwork and during write-up. Tuition fees were self-sponsored

Time frame
September 1997 - May 1998: Course work
October 1998: Reconnaissance survey of the Taita Hills forest fragments
November 1998 - September 1999: Field work in Taita Hills
October - December 1999: Entering data in to spreadsheets
January 2000 - February 2001: Data analysis and thesis write up
Expecting to submit thesis by February 2001
Expecting to defend thesis by April 2001
Expecting to graduate October 2001

Future ambitions
Expecting to publish at least three papers from this work by December 2001
Register for a Ph.D. to do further work on the TWE as a follow up of the questions arising from the findings of this study

Daina Sophie Samba
Ornithology Department, National Museum of Kenya
M.Sc. student (Wildlife Management: Conservation and Control) registered at the University of Reading, UK

Thesis title
An investigation into the population size, habitat preferences and conservation status of the critically endangered Taita Apalis, *Apalis (thoracica) fuscigularis,* endemic to the Taita Hills in Kenya

Supervisor
Dr. L.A. Bennun, Ornithology Department, National Museums of Kenya
Dr. K. Norris, Biology Department, Reading University

Financing
Scholarship provided by the Welcome Trust

Time frame
October 1999 - October 2000: Theoretical framework at the University of Reading
December 2001: Reconnaissance of sites
January 2001 - May 2001: Field work and data-gathering
June 2001 - August 2001: Data- analysis and thesis write-up

4.2.2. Ph.D. students

Edward Waiyaki Mangara
Ornithology Department, National Museums of Kenya
Ph.D. student (Animal Ecology) registered at Biology Department of the University of Antwerp, Belgium

Thesis Title
Ecological and behavioural response of the critically endangered Taita Thrush, *Turdus helleri,* to habitat degradation in a fragmented landscape

Supervisors
Dr. E. Matthysen, Biology Department, University of Antwerp
Dr. L. Lens, Biology Department, University of Antwerp
Dr. L. Bennun, Ornithology Department, National Museums of Kenya

Financing
Ph.D. scholarship provided by DGIS (Directorate General for International Collaboration, Belgium)

Time frame
July 1997 - March 1998: Field work in Taita Hills
December 1997: Attendance of Conference on Eastern Arc Mountains in Morogoro, Tanzania
April 1998 - May 1998: Study visit to the University of Antwerp
June 1998 - March 2000: Field work and data compilation in Kenya
April 2000 - March 2001: Analysis and thesis write-up in Antwerp, Belgium
April 2001 - November 2001: Analysis and thesis write-up in Kenya
December 2001: Thesis defence in Antwerp, Belgium

Kamau Wakanene Mbuthia
Centre for Biodiversity, National Museums of Kenya
Ph.D. student (Forest Ecology and Ethobotany) registered at Botany Department, Miami University, Oxford, Ohio, USA

Thesis title
Ethnobotanical and ecological analyses for forest restoration in the Taita Hills, Kenya

Supervisors
Dr. K. Medley, Geography Department, Miami University
Dr. D.L. Gorchov, Botany Department, Miami University
Dr. H. Eshbaugh, Botanny Department, Miami University
Dr. A.M. Greenberg, Anthropology Department, Miami University
Dr. M. Vincent, MU Herbarium, Miami University

Financing
Ph.D. scholarship and research funds from a variety of sources
Funding for research has mainly come from the Botany Department and the Willard Sherman Turrell Herbarium, Miami University
The “British Airways Assisting Conservation” programme (BAAC) provided a return ticket between Kenya and USA
The Taita Hills Biodiversity Project (THBP) provided support for a reconnaissance trip to the Taita forests at the onset of my research
THBP also provided initial links with UNESCO’s People and Plants Program that has financially supported the research project to the tune of US$ 5300
THBP also provided considerable logistical support whenever necessary

Time frame
June 1999: Taita Hills reconnaissance survey
July 1999 - December 1999: Field work in Taita Hills
January 2000 - May 2000: Data analysis at Miami University, USA
June 2000 - August 2000: Field work in Taita Hills
September 2000 - May 2001: Data analysis at Miami University, USA
June 2001 - August 2001: Final field visit to Taita Hills
September 2001 - December 2001: Compile dissertation and publications
January 2002 - May 2002: Dissertation defense

4.3. General training

Within the scope of the project, technicians and/or research scientists affiliated with the THBP got the opportunity of training in any particular techniques deemed necessary for the project's objectives. This training was occasional and provided when the need arose. More details can be found under sections 3.3.1.10, 3.4.1.10 and 3.5.10.

5. PUBLICATION LIST

5.1. Lectures

Bytebier, B. 1998. The Taita Hills Biodiversity Project. *Third Darwin Specialist Workshop on Species Reintroduction and Habitat Restoration*. Voi, Kenya.

Bytebier, B. and E. Waiyaki 1999. The Taita Hills Biodiversity project. *National Stakeholders Workshop – Management of Agrobiodiversity for Sustainable Land Use and Global Environment Benefits*. Ngerenyi, Kenya

Bytebier, B. 2001. The Taita Hills Biodiversity Project. *Nature Kenya Seminar*. Nairobi, Kenya

Cooper, J. 1997. Collecting endo- and ectoparasites of birds – an introductory lecture. *Department of Ornithology Seminar.* Nairobi, Kenya

De Meyer, M., E. Waiyaki and L. Lens. 1997. Progress of Taita Hills Biodiversity Project. *Proceedings Workshop on Integrated forest conservation and sustainable management of forests at Taita Hills region.* Ngerenyi, Kenya

Dall'Asta, U. 1999. Moths of the Taita Hills. *2nd International Lepidopterists' Conference of Africa.* Kirstenbosch National Botanic Garden, Cape Town, South Africa

De Meyer, M. 1999. Unidentified Flying Objects. *Info Lunch Africamuseum*. Tervuren, Belgium

Dall'Asta, U. 1999. Les Pappilons de Nuit des Taita Hills (sud-est du Kenya). *Royal Belgian Society for Entomology*. Brussels, Belgium

Dall'Asta, U. 2000. Faunistic affinities of the Taita Hills (south-east Kenya) based on an analysis of moth samples. *XIIth European Congress of Lepidopterology.* Bialowieza, Poland

Dall'Asta, U. 2000. Faunistic affinities of the Taita Hills (south-east Kenya) based on an analysis of moth samples. *Biodiversity Training Programme Seminar (United Nations University).* Ghent, Belgium

Githiru, M. 1999. Avian frugivory and seed dispersal in some of the Taita Hills forest fragments. *Department. of Ornithology Seminar*. Nairobi, Kenya

Githiru, M. 1999. Avian frugivory and seed dispersal in some of the Taita Hills forest fragments. *Biology Department Seminar*. Antwerp, Belgium

Githiru, M. 2000. Recruitment patterns of some fleshy fruit-producing plants species in Taita Hills forests, Kenya. *Tenth Pan-African Ornithological Congress*. Kampala, Uganda

Lens, L. 1997. Effects of landscape structure on the morphology, dispersal and gene flow of three tropical forest endemic birds. *First meeting of the European Ornithological Union*. Bologna, Italy

Lens, L. 1998. Tiny Parids and enigmatic endemics: what does the one tell about the other?" *Ohio State University Seminar.* Columbus, USA

Lens, L. 1998. Dispersal studies in recently and historically fragmented forests: a comparison between Kenya and Belgium. *XXIInd International Ornithological Congress.* Durban, South-Africa

Lens, L. 2000. Fluctuating asymmetry in bilateral traits: concept, analysis, and relevance for conservation. *Laboratory for Forest, Nature and Landscape Research Seminar.* Leuven, Belgium

Lens, L. 2000. Analysing individual developmental stability: a case study from Kenya. *University of Cochabamba Seminar.* Cochabamba, Bolivia

Lens, L. 2000. Study of bilateral trait asymmetry in stressed populations: paradigm or conservation tool? *Xth Pan-African Ornithological Congress.* Kampala, Uganda

Matthysen, E. 1999. Population structure and dispersal in birds. *EGI Student Conference on Bird Biology.* Oxford, UK

Matthysen, E. 1999. Islands in the landscape: metapopulations or patchy populations? *Netherlands Ecological Society symposium "Faunal Change".* Wageningen, The Netherlands

Matthysen, E. 2000. Habitat fragmentation and population viability in a biodiversity hotspot: a case study from Kenya. *Biodiversity Training Programme Seminar (United Nations University).* Ghent, Belgium

Lens, L. 2001. Fluctuating asymmetry as an indicator of genetic stress and fitness: how consistent are the patterns ? *Ecological Genetics Meeting.* Antwerp, Belgium

Lens, L. 2001. Fluctuating asymmetry acting as 'early warning system' in three isolated populations of the critically-endangered Taita thrush *(Turdus helleri). Insular Biotas Conference.* Wellington, New-Zealand

Odhiambo, R.O. 1999. An ecological study of small rodents in the fragmented forest habitats of Taita Hills, Kenya. *Rodent Populations Dynamics: Pest Control and Environmental Monitoring*. Greve, Denmark

Oguge, N.O. 1999. The Taita Hills Biodiversity Project. *Swedish University of Agricultural Science Seminar*. Uppsala, Sweden

5.2. Publications

5.2.1. Popular

Bytebier, B. 1999. The Taita Hills Biodiversity Project: Conservation and Collaboration. *NMK Horizons* **3(1)**: 3-5.

Brooks, T.M., Lens, L. & Waiyaki, E. 1997. How long will it take for us to lose biodiversity? - in the Taita Hills. *Kenya Birds* **5**: 9-10.

Dall'Asta, U. 1998. Vlinders als bioindicatoren. In: Africa Museum Tervuren 1898-1998. Tervuren, pp 149-155.

Githiru, M. 1999. Thick-billed Cuckoo in the Taita Hills. *Kenya Birds* **7**: 71.

Imboma, T. 1998. Bird crew heads to the hills. *Kenya Birds* **6**: 5-6.

Imboma, T. 1998. Bird research in the Taita Hills - a view from the ground. *Kenya Birds* **6**: 6-8.

Lange, C.N. 1999. Kenya's latest snail discovery. *EANHS Bulletin* **29**: 3-4.

Lens, L. and M. De Meyer. 1997. Biodiversity and forest fragmentation in the Taita Hills. *NMK Horizons* **1**: 15.

Lens, L. and M. De Meyer. 1997. Forest fragmentation in the Taita Hills: its effects on the fauna. - *Kenya birds* **5**: 92-93.

Lens, L. and M. De Meyer. 1998. Taita team steams ahead. *Kenya Birds* **6**: 5-6.

Oguge, N.O. 2000. Eastern Arc Mountain Forests: a world heritage. *Augustana College News Letter*

Vandenspiegel, D. and B. Bytebier. 2000. Millipedes. Climbing the Taita Hills with a thousand legs. *NMK Horizons* **4(2)**: 14-15.

5.2.2. Posters and abstracts

Brooks, T., L. Lens, M. De Meyer, E. Waiyaki and C. Wilder 1997. Ornithological research in the Taita Hills I: biogeography. *Abstracts Int. Conference Eastern Arc Mountains.* Morogoro, Tanzania

Dall'Asta, U. 2000. Faunistic affinities of the Taita Hills (south-east Kenya) based on an analysis of moth samples. *Abstract volume XIIth European Congress of Lepidopterology.* Bialowieza, Poland.

De Meyer, M., M. Clifton and L. Lens. 1997. Entomological research in the Taita Hills I: diversity and biogeography of butterflies (Lepidoptera). *Abstracts Int. Conference Eastern Arc Mountains.* Morogoro, Tanzania. p.32.

De Meyer, M., L. Lens and D. Gitau. 1997. Entomological research in the Taita Hills II: Syrphidae (Diptera) diveristy in the forest fragments, a preliminary survey. *Abstracts Int. Conference Eastern Arc Mountains.* Morogoro, Tanzania. p.32-33.

De Meyer, M. and L. Lens. 1998. Preliminary notes on the Syrphidae fauna of forest fragments in the Taita Hills*. Proceedings Fourth International Congress of Dipterology.* Oxford, UK p.149-150.

Githiru, M. 1997. Avian frugivory and seed dispersal in some fragments of the Taita Hills forests'. *Abstracts Int. Conference Eastern Arc Mountains.* Morogoro, Tanzania.

Lens, L. and M. De Meyer. 1997. The Taita Hills Project, a study on biodiversity and habitat fragmentation. *Abstracts Int. Conference Eastern Arc Mountains.* Morogoro, Tanzania. p.20.

Lens, L., E. Waiyaki, T. Brooks and M. De Meyer 1997. Ornithological research in the Taita Hills II: interspecific variation in mobility. *Abstracts Int. Conference Eastern Arc Mountains.* Morogoro, Tanzania

Oguge, N.O. and R.O. Odhiambo 1997. Small mammals research in the Taita Hills. *Abstracts Int. Conference Eastern Arc Mountains.* Morogoro, Tanzania.

Waiyaki, E. and M. Githiru 1997. Ornithological research in the Taita Hills III: case studies on behavioural ecology and frugivory. *Abstracts Int. Conference Eastern Arc Mountains.* Morogoro, Tanzania

Wilder, C., T. Brooks and L. Lens. 1997. Vegetation structure and composition of the Taita Hills forests. *Abstracts Int. Conference Eastern Arc Mountains.* Morogoro, Tanzania.

5.2.3. Peer reviewed

Brooks, T., L. Lens, J. Barnes, R. Barnes, J.K. Kihuria and C. Wilder 1998. The conservation status of the forest birds of the Taita Hills, Kenya. *Bird Conservation International* **8**: 119-139.

Brooks, T., L. Lens, M. De Meyer, E. Waiyaki and C. Wilder 1998. Avian biogeography of the Taita Hills, Kenya. *Journal of East African Natural History* **87**: 189-194.

Galbusera, P., L. Lens, T. Schenck, E. Waiyaki and E. Matthysen 2000. Genetic variability and gene flow in the globally, critically-endangered Taita thrush. *Conservation Genetics* **1**: 45-55.

Githiru, M., L.A. Bennun and L. Lens (submitted). Patterns of regeneration of some fleshy fruit - producing plants species in a fragmented afrotropical forest. *Journal of Tropical Ecology*

Githiru, M., L. Lens, L.A. Bennun and C.P.K.O. Ogol (submitted). Effects of site and fruit size on avian frugivore assemblages in a fragmented Afrotropical forest. *Oikos*

Githiru, M., L.A. Bennun, L. Lens and C.P.K.O. Ogol (submitted). Distribution and fluctuations in fruit abundance and densities of avian frugivores in a fragmented Afrotropical forest. *Biotropica*

Grichanov, I.Ya. 1998. New data on Sciapodinae (Diptera: Dolichopodidae) with a revised catalogue and keys to Afrotropical species. *Bulletin de l'Institut royal des Sciences naturelles de Belgique, Entomologie* **68**: 79-130.

Grichanov, I.Ya. 1999a. A brief review of the Afrotropical fauna of the subfamily Medeterinae (Diptera: Dolichopodidae) with descriptions of a new genus and new species. *Bulletin de L'Institut royal des Sciences naturelles de Belgique, Entomologie* **69**: 87-112.

Grichanov, I.Ya. 1999b. New species and new records of Afrotropical Sciapodinae (Diptera: Dolicopodidae). *Bulletin de L'Institut royal des Sciences naturelles de Belgique, Entomologie* **69**: 113-135.

Grichanov, I.Ya. 2000. Afrotropical Neurigoninae and notes on the diaphorine genus *Dactylonotus* Parent (Diptera Dolichopodidae). *Belgian Journal of Entomology* **2**: 257- 271.

Lens, L., F. Adriaensen and E. Matthysen 1999. Dispersal studies in recently and historically fragmented forests: a comparison between Kenya and Belgium. In: Adams N.J. *et al.* (eds.) *Proceedings of the 22nd International Ornithological Congress, Durban, Johannesburg*, BirdLife South Africa, pp. 2480-2491.

Lens, L., P. Galbusera, T. Brooks, E. Waiyaki and T. Schenck 1998. Highly skewed sex ratios in the critically endangered Taita Thrush as revealed by CHD genes. *Biodiversity and Conservation* **7**: 869-873.

Lens, L. and S. Van Dongen 1999. Evidence for organism-wide asymmetry in five bird species of a fragmented afrotropical forest. *Proceedings of the Royal Society London Series B* **266**: 1055-1060.

Lens, L. and S. Van Dongen 2000. Fluctuating and directional asymmetry in natural bird populations exposed to different levels of habitat disturbance, as revealed by mixture analysis. *Ecology Letters* **3**: 516-522.

Lens, L. and S. Van Dongen (in press). Fluctuating asymmetry as an indicator of stress: paradigm or conservation tool? *Ostrich*

Lens, L., S. Van Dongen, P. Galbusera, T. Schenck, E. Matthysen and T. Van de Casteele 2000. Developmental instability and inbreeding in natural bird populations exposed to different levels of habitat disturbance. *Journal of Evolutionary Biology* **13**: 889-896.

Lens, L., S. Van Dongen and E. Matthysen (submitted). Fluctuating asymmetry acts as an 'early warning system' in the critically-endangered Taita thrush. *Conservation Biology*

Lens, L., S. Van Dongen, C.M. Wilder, T.M. Brooks and E. Matthysen 1999. Fluctuating asymmetry increases with habitat disturbance in seven bird species of a fragmented afrotropical forest. *Proceedings of the Royal Society London Series B* **266**: 1241-1246.

Masinde, S.R. (2000) *Ceropegia verticillata* (Asclepiadaceae-Stapelieae), a new species with whorled leaves from Kenya. Cactus and Succulent Journal (U.S.) **72(3)**: 155-158.

Rogo, L.M. and N. Oguge (2000). The Taita Hills forest remnants: a disappearing Kenyan heritage. *Ambio*, **29** (8):522-523.

Vandenspiegel, D. and R.L. Hoffman 2000. A Survey of the genus *Apoctenophora* Hoffman & Howell with a description of two new species from Kenya (Diplopoda, Harpagophoridae). *Annales du Musee Royal de l'Afrique Central (Zoology)* **205**: xxx-xxx.

Vandenspiegel, D. 2000. Description de deux nouvelles espèces du genre *Stemmiulius* récoltées au Kenya (Diplopoda, Stemmiulida, Stemmiulidae). *Annales du Musee Royal de l'Afrique Central (Zoology)* **205**: xxx-xxx.

Van Dongen, S. and L. Lens 2000. The evolutionary potential of developmental instability. *Journal of Evolutionary Biology* **13**: 326-335.

Van Dongen, S. and L. Lens 2000. Symmetry, size, and stress. *Trends in Ecology and Evolution* **15**: 330.

Van Dongen, S., L. Lens and E. Matthysen (in press). Heterogeneous association between stress and developmental instability in birds and insects. *Journal of Belgian Zoology*

Van Dongen, S., L. Lens and G. Molenberghs 1999. Mixture analysis of asymmetry: modelling directional asymmetry, antisymmetry and heterogeneity in fluctuating asymmetry. *Ecology Letters* **2**: 387-396.

Van Dongen, S., L. Lens and G. Molenberghs 2001. Recent developments and shortcomings in the analysis of individual asymmetry: Can Bayesian statistics help us? In: Polak, M. (ed). *Developmental instability: causes and consequences.* Oxford University Press, Oxford.

Wilder, C.M., T.M. Brooks and L. Lens 1998. Vegetation structure and composition of the Taita Hills forests. *Journal of East African Natural History* **87**: 181-187.

Vandenspiegel, D. (submitted). *Taitastreptus flavipes*, a new genus and new species of arboreal millipede from Kenya (Dipopoda, Spirostreptidae). *Insect Systematics and Evolution*

5.2.4. In preparation

Chege, J. and B. Bytebier. (in prep). Vegetation Structure of four small Taita Hills forest fragments. For submission to the *Journal of East African Natural History*.

Chuah-Petiot, M. and B. Bytebier. (in prep). Contribution to the bryoflora of the Taita Hills, Kenya. For submission to *Tropical Bryology*.

Cooper, J. and L. Lens. (in prep). A study of avian blood parasites in the Taita Forest, Kenya.

Dall'Asta, U and S. Hanot. (in prep). Moth samples from the Taita Hills (south-east Kenya): observations on weather conditions and a first check-list of the Noctuidae (Lepidoptera, Heterocera). For submission to the *Journal of East African Natural History*

De Meyer, M. (in prep) A new *Centrioncus* species (Diptera, Centrioncidae) from Taita Hills, Kenya.

Lens, L., S. Van Dongen, S. Kark and E. Matthysen. (in prep). Fluctuating asymmetry as an indicator of fitness: can we bridge the gap between studies?

Odhiambo R. O. and N.O. Oguge. (in prep) Morphological and craniodental comparison of seven populations of *Praomys taitae* (Rodentia : Muridae) captured at different fragments in Taita Hills, Kenya.

Odhiambo R. O. and N.O. Oguge. (in prep). Cytogenetics of *Praomys taitae* Heller 1911 (Rodentia : Muridae) from Ngangao and Chawia forests of Taita Hills, Kenya.

Odhiambo R.O., N.O. Oguge, C.P.K.O. Ogol and R.O. Okelo. (in prep). Small mammals of the fragmented forest habitats of Taita Hills, Kenya: Densities and community dynamics. For submission to the *Journal of Biogeography*

Odhiambo R.O., N.O. Oguge, C.P.K.O. Ogol and R.O. Okelo. (in prep). Population dynamics of the Kenyan endemic soft-furred rat *Praomys taitae* (Rodentia : Muridae) Heller 1911, in Ngangao and Chawia forest fragments of Taita Hills, south-eastern Kenya. For submission to the *African Journal of Ecology*

Oguge, N.O. & R. Hutterer. (in prep). Notes on *Crocidura fischeri* and *C. macarthuri* in Kenya.

Oguge, N.O. and R. Hutterer. (in prep). *Crocidura jacksoni*. *The Mammals of Africa*. Kingdon, J., D. Happold & T. Butynski (Eds). Academic Press, London

Oguge, N.O., R. Hutterer, R. Odhiambo and W. Verheyen. (in prep). Distributional patterning of shrews in the montane forests of south-east Kenya.
Oguge, N.O., R. Hutterer, R. Odhiambo and W. Verheyen. (in prep). Notes on shrews (Mammalia : Insectivora) of the montane forests of south-east Kenya and the taxonomic status of *Crocidura cf. selina* and *Sancus (lixus) aequatorius* (Soricidae).

Oguge, N.O., W. Verheyen and R. Odhiambo (in prep). Diversity and distribution of murid rodents in south-east montane forests in Kenya

Oguge, N.O., W. Verheyen and E. Verheyen. (in prep). Taxonomy of *Praomys taitae* and phylogeography of the eastern African murid rodents of the genus *Praomys.*

Perkin, A., B. Agwanda, B. Bytebier, T. Butynski and S. Bearder (in prep). *Galagoides orinus*, a new primate for Kenya. For submission to the *Journal of East African Natural History*

Vandenspiegel, D. (in prep). Three new species of ammodesmid millipedes (Diplopoda, Polydesmida) from Taita Hills, Kenya.

Vandenspiegel, D. and H. Engoff (In prep). A review of the genus *Obelostreptus* (Diplopoda, Harpagophoridae) with the description of two new species from Kenya.

6. COLLABORATORS AND ACKNOWLEDGEMENTS

Prof. Walter Verheyen of the University of Antwerp (RUCA) was the THBP leader. He provided assistance, guidance and general co-ordination for the project. He also formed the direct link between the scientists involved in the THBP, the Flemish Interuniversity Council (VLIR) and the funding agency DGIS.

Dr. Luc Lens is a postdoctoral fellow of the Foundation for Scientific Research (FWO) at the University of Antwerp (UIA). He supervised the THBP ornithology research component. His input into THBP was tremendous and highly appreciated.

Dr. Nicholas Oguge is the Chairman of the Zoology Department at the Kenyatta University in Nairobi. He supervised the THBP mammalogical research component and formed the link with Kenyatta University. The co-ordinator wishes to thank him for his input and very smooth collaboration.

Dr. Marc De Meyer was the co-ordinator of THBP during the first year. He now heads the Entomology Section of the Royal Museum for Central Africa in Tervuren, Belgium. He supervised the THBP entomology research component. The co-ordinator wishes to thank him for all his efforts and the close collaboration.

Mr. Edward Waiyaki (Ornithology Department, NMK) and Mr. Kamau Wakanene Mbuthia (Centre for Biodiversity, NMK) are doing their Ph.D research projects within the THBP research framework. Mr Mwangi Githiru (Ornithology Department, NMK) and Mr Richard Odhiambo (Zoology Department, Kenyatta University) did their M.Sc. research projects within the framework of the THBP, and have since embarked on their Ph.D. studies. Mr. Ronald Mulwa (Ornithology Department, NMK) also did his research within the project and is about to finish his M.Sc. studies. Ms. Daina Samba and Mr. Paul Kariuki Ndang'ang'a started as research assistants with Mr. Waiyaki, but have since been able to attract scholarships and have started their M.Sc. studies.

Mr. Charles Lange (Invertebrate Zoology Dept., NMK), Mr. Charles Warui (Invertebrate Zoology Dept., NMK), Dr. Ugo Dall'Asta (Entomology Section, Royal Museum for Central Africa, Belgium), Dr. Rudy Jocque (Invertebrate Zoology Section, Royal Museum for Central Africa, Belgium), Dr. Didier Van den Spiegel (Invertebrate Zoology Section, Royal Museum for Central Africa, Belgium), Mr. Andrew Perkin (Nocturnal Primate Research Group, Oxford Brookes University, UK), Ms. Joyce Chege (East African Herbarium, NMK), Mr. Kenyatta Malonza (Herpetology Department, NMK), and Dr. Min Chuah (Botany Department, University of Nairobi, Kenya), are researchers associated with THBP.

Mr. David Gitau, Mr. Bernard Agwanda, Mr. Ernest Obanda, Mr. Paul Kariuki Ndanga'ng'a, Ms. Daina Samba, Mr. Bernard Amukobe, Mr Fred Barasa, Mr. Georges Eshimwata, were the THBP research assistants. They were invaluable to THBP as they gathered the baseline data. Their work, sometimes done under very harsh field conditions, is highly appreciated. They were assisted by Mr. Patrick Mwaita, Mr. Lawrence Wanjahi, Mr. Maxwell

Chovu, Mr. Rueben Mwakodi, and Mr. Samuel Kaluma Karanja, who was the THBP camp manager.

Ms. Julia Muench (Carolo-Wilhelmina Universitaet, Braunschweig, Germany) and Mr. Graham D. Fairhurst (Congers, New York, USA) were volunteers with the project and their enthusiasm to join the THBP and work for free is highly appreciated.

The co-ordinator also wishes to thank the following people for their advice, assistance and support to the project:

Mr. Kiti (District Forest Officer Taita Taveta) for allowing us unlimited access to the forest and giving us assistance whenever needed.

Mr. Mwang'ombe, Mr. Mwanyumba and Mr. Gachanja of the Taita Hills Project of the East Africa Wildlife Society for close collaboration and a continuous exchange of ideas. Special thanks goes to James Mwang'ombe for logistical assistance on numerous occasions.

The local auhorities and the people of Taita Hills for their generous hospitality.

A special word of thanks goes to Mr. David Laur (Phytochemistry, NMK) for his continued assistance and relentless efforts towards THBP.

Dr. Helida Oyieke (Assistant Director, Centre for Biodiversity, NMK), Dr. Georges Abungu (Director General, NMK), Dr. Richard Bagine (Deputy Director Research and Planning, Kenya Wildlife Service), Dr. Mohamed Isahakia (former Director General, NMK), Dr. Rashid Aman (former Director Research and Scientific Affairs, NMK), Dr. Leon Bennun (Head of Ornithology Dept, NMK), Dr. Wanja Kinuthia (Head of Invertebrate Zoology Dept, NMK), Dr. Koen Maes (former Head of Invertebrate Zoology Dept, NMK), Dr. Beatrice Khayota (East African Herbarium, NMK), Dr. Patrick Masinde (East African Herbarium, NMK), Mrs. Damaris Rotich, (Head of Herpetology Dept., NMK), Mr. Vincent Muchai (Herpetology Dept., NMK), Mr. Victor Wasonga (Herpetology Dept., NMK), Dr. Mwangi Gathua (Head of Mammalogy Dept., NMK, deceased), Mr. Erustus Kanga (formerly of Mammalogy Dept., NMK), Ms. Lydia Kigo (Mammalogy Dept., NMK), Prof. Aloys Orago (Zoology Dept., KU), Dr. C.K.P.O. Ogol, (Zoology Dept, KU), Dr. Lucie Rogo (Research Scientist, ICIPE), Dr. Scott Miller (Leader Biodiversity and Conservation Project, ICIPE), Mr. A.H. Jama (Licensing Warden, Kenya Wildlife Service), Mr. Quentin Luke (Research Scientist, Coastal Forest Conservation Unit, NMK), Dr. Thomas Butynski (Senior Conservation Biologist, Zoo Atlanta), Dr. Ron Verhagen (Biology Dept, University of Antwerp (RUCA)), Dr. Jan Hulselmans (Biology Dept, University of Antwerp (RUCA)), Dr. Erik Matthysen (Team leader Behavioural Ecology Unit at UA (UIA)), Dr. Eric Verheyen (Royal Belgian Institute for Natural History), Dr. Ian Gordon (formerly of Kipepeo), all staff members of the Kipepeo Project, Mrs. Nancy Njoroge (Physical Operations, NMK), Mrs. Jennifer Njogu (Centre for Biodiversity, NMK), Mrs. Nikki Wouters (UA (RUCA)), Mrs. Jenny Moens (UA (RUCA)), Ms. Margaret Omoto (Invertebrate Zoology Dept., NMK), Mr Daniel Karanja (Invertebrate Zoology Dept., NMK), the staff of the Nature Kenya office, Mr. Titus Waiganjo (Plant Conservation Programme, NMK), Mr. Onesmus Mwangangi (Plant Conservation Programme, NMK), Mr. Titus Imboma (Ornithology Dept., NMK), Mr. Mwavua (County Council, Taita-Taveta), Ms. Jacqueline Mwdame (Forest Dept. Wundanyi), Mr. Jonam Mwandoe, Mr. Frumence Mwakio, Mr Mwambeo, Mr. Kenneth Nyange, and all the forest

guards of Taita-Taveta District, Kenya Forestry Department, Mrs. Kiteto from Mbololo, the Chovu family from Macha, Mr. Edwin Selempo (Taita Discovery Centre), Mr. Rob Dodson (Taita Discovery Centre), the staff of the Taita Taveta Agricultural Project, Mr. William Wambugu (Botanic Garden Manager, NMK) and Mr. Daniel Odhiambo (Nursery Attendant, NMK), Mr. Thierry Geenen (Photographer)

I am pretty sure that I have forgotten to mention some people. Please accept my apologies for that. Please know that I'm very grateful for your contribution to the success of the THBP.

7. APPENDICES

7.1. Land Use GIS model of the Taita Hills

7.2. GIS model of Mount Kasigau

7.3. Some relevant publications

7.3.1. Lens, L., P. Galbusera, T. Brooks, E. Waiyaki and T. Schenck 1998. Highly skewed sex ratios in the critically endangered Taita Thrush as revealed by CHD genes. *Biodiversity and Conservation* **7**: 869-873.

7.3.2. Lens, L. and S. Van Dongen 1999. Evidence for organism-wide asymmetry in five bird species of a fragmented afrotropical forest. *Proceedings of the Royal Society London Series B* **266**: 1055-1060.

7.3.3. Lens, L., S. Van Dongen, C.M. Wilder, T.M. Brooks and E. Matthysen 1999. Fluctuating asymmetry increases with habitat disturbance in seven bird species of a fragmented afrotropical forest. *Proceedings of the Royal Society London Series B* **266**: 1241-1246.

7.3.4. Galbusera, P., L. Lens, T. Schenck, E. Waiyaki and E. Matthysen 2000. Genetic variability and gene flow in the globally, critically-endangered Taita thrush. *Conservation Genetics* **1**: 45-55.

7.3.5. Grichanov, I.Ya. 1999b. New species and new records of Afrotropical Sciapodinae (Diptera: Dolicopodidae). *Bulletin de L'Institut royal des Sciences naturelles de Belgique, Entomologie* **69**: 113-135. (Partly reproduced)

7.3.6. Grichanov, I.Ya. 2000. Afrotropical Neurigoninae and notes on the diaphorine genus *Dactylonotus* Parent (Diptera Dolichopodidae). *Belgian Journal of Entomology* **2**: 257- 271.

7.3.7. Wilder, C.M., T.M. Brooks and L. Lens 1998. Vegetation structure and composition of the Taita Hills forests. *Journal of East African Natural History* **87**: 181-187.

7.3.8. Masinde, S.R. (2000) *Ceropegia verticillata* (Asclepiadaceae-Stapelieae), a new species with whorled leaves from Kenya. Cactus and Succulent Journal (U.S.) **72(3)**: 155-158.