EFFECTS OF FOREST LOSS AND FRAGMENTATION ON THE POPULATIONS OF TWO CRITICALLY ENDANGERED PRIMATES: THE TANA RIVER RED COLOBUS (*PROCOLOBUS RUFOMITRATUS*) AND CRESTED MANGABEY (*CERCOCEBUS GALERITUS*) IN TANA RIVER KENYA

Project report to Rufford Small Grants for Nature Conservation, April 5 2005.

By
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1. INTRODUCTION AND BACKGROUND:

My project is located in Tana River area of eastern Kenya, and comprises 26 km^2 of gallery forest patches on both sides of the Tana River. These forests are unusual because they exist in an arid environment where rainfall does not exceed 400 mm a year. They are a relic of a tropical rainforest that extended from the Congo basin to the east coast of Africa during the Pliocene-Pleistocene epochs. The forests are of great conservation importance. They are part of the east African coastal forests global biodiversity hotspot and support a high diversity of rare plant and animal species, more than 57 mammals, 260 birds, and 175 woody plants. In particular, they provide the only known habitat of two endemic primates, the Tana River red colobus (*Procolobus rufomitratus*) and the crested mangabey (*Cercocebus galeritus*). In addition to the natural forest fragmentation caused by the meandering of the river in its old stage, recent human activities have further reduced and fragmented the forests causing precipitous declines in the primate populations, and extinctions in several of the fragments. Thus, the IUCN ranks both species as critically endangered and classifies them among the top 25 most endangered primates in the world.

The Tana colobus and mangabey are of similar body size but their behavioral ecology and life history strategies are quite different. The red colobus is a putative habitat specialist with limited vagility. It is almost exclusively arboreal and lives in relatively small social groups that exhibit high site fidelity. A canopy dweller, the colobus depends on a diet of mainly leaves obtained from a limited number of canopy tree species. In contrast, the mangabey is a putative habitat generalist that is mostly terrestrial and highly vagile. It lives in much larger social groups and its diet comprises seeds and ripe fruit from a variety of tree species, and substantial amounts of animal prey.

Since the early 1970's, various conservation efforts have been tried in the Tana. In 1976, the Tana River Primate National Reserve (TRPNR) was established, and detailed primate censuses conducted in 1975 and 1994 to assess the status of the primate populations. The 1994 census was the most comprehensive to date and revealed that only 37% of colobus groups and 56% of mangabey groups were resident within TRPNR, and that the populations were still declining twenty years after TRPNR was established to protect them. Colobus were found in 50% and mangabeys in 40% of the forests respectively, and only 26% of the forests had both colobus and mangabeys occuring together in the same forest. Thus, there is great need for enhanced conservation measures for both primates in all forests.

First, there is need to alleviate the forest degradation, fragmentation and loss. To do that, it is essential to identify the attributes of the human population growth that drive the forest degradation, fragmentation and loss. Second, there is need to increase the amount of forest habitat by reforesting degraded sites and by creating forest corridors between existing fragments. Thus, it is essential that we identify the key ecological factors that influence the vulnerability of these species to habitat loss and fragmentation. In addition, there is need to focus our attention to other problems that arise because of habitat loss and fragmentation and can further imperil populations of the endangered primates. The most important of these problems include increased prevalence of diseases and parasites, the loss of genetic diversity, and the disruption of gene flow between populations. **My overall aim in this project is to address these issues comprehensively by way of a long-term research project.**

2. FINDINGS OF RESEARCH SUPPORTED BY MY FIRST RUFFORD SMALL GRANT:

In the first phase of my research focused on the red colobus and supported by a **Rufford Small Grant**, I accomplished two goals. First, I found that the density and the size of colobus social groups were determined by the abundance of food trees, and that the forest composition of tree species as well as edge habitat determined whether colobus occupied a forest. Therefore, effective conservation measures may require strategies that consider factors that influence both the occurrence and the relative abundance of the primates in the forests (Mbora & Meikle 2004a). Second, I found that forests outside TRPNR were in as good a condition as those inside TRPNR, and that there were no differences in composition or size of groups among colobus in the two areas. Since the population of red colobus is in decline, then forests outside the TRPNR are very important for the conservation of the Tana River red colobus and should be conserved (Mbora & Meikle 2004b).

This research also made it clear that three further, critical questions needed be answered. First, what factors influence the distribution of the crested mangabeys in forests across their range? Second, what factors influence the concurrent occupation of the forests by both species? Third, what factors influence the rates of mortality and natality in the populations of both primates? These questions can only be answered with data from detailed temporal surveys of social groups throughout the species range to determine their distribution, age-sex composition, as well as the factors that that influence natality and mortality in the groups. Thus, I sought a second Rufford small grant to: (a) establish the project to answer the additional questions outline above, (b) to answer questions on parasite prevalence and on population genetic structure.

3. RESEARCH ACHIEVEMENTS FROM MY SECOND RUFFORD SMALL GRANT:

A **second Rufford small grant** was awarded in November 2004. Following this funding, my project has focused on establishing a program of detailed temporal surveys of representative study groups. I designed these surveys to habituate primate groups to human presence to facilitate (a) collection of good information on group age-sex composition over time, and (b) to facilitate the collection of stool samples for the analyses of parasites and population genetics. I achieved this as follows. I conducted a GIS analysis of the gallery forests using aerial photographs taken in 1994 and 1996, and selected 14 forests as study sites. I chose forests so that approximately equal areas were sampled east and west of the Tana River to capture the range of habitat conditions within the floodplain. I surveyed each study forest to determine the number of resident groups of colobus and mangabeys, and identified a subset of groups within each forest for detailed studies of group size, age and sex composition over time. I selected social groups systematically so that they were easy to locate and to identify using “marker” animals, as study groups. I continue to survey these forests and monitor the study groups with the help of field assistants recruited from the local community.

I record a range of primate population attributes and relate them to changes in habitat characteristics. I record group size and composition, collect stool samples and measure changes of forest cover. I extract DNA and diagnose parasite infections from the stool samples in the laboratory. I am using the data from the field and from the laboratory analyses to explore the questions outline above. In the paragraphs that follow below, I list the four research questions I am pursuing, state the achievements I have made to date and specify further work that is required.

Research question 1: What human population attributes are the primary drivers of habitat change?

To gain a full appreciation of how habitat changes influence the two primates, one needs a good understanding of the factors that drive the habitat change. Generally, increasing human population size is considered the driver of habitat change while changes of household size and numbers are seldom considered. Yet declines in household size and concomitant increases in the number of households typically increase the per capita consumption of natural resources by humans. I am testing the hypothesis that reductions in average household size and concomitant growth in household numbers are contributing to the effects of simple population growth as important causes of habitat change in the study area.

Achievements in answering question 1:

I have developed a GIS database of land cover changes in the area for the last 50 years, and collated data on human population structure for the same period.

Further work needed for question 1:

Data analysis is in progress and a research manuscript reporting the findings is in development. In addition, a current census of household sizes in the study area is needed.

Research question 2: How does habitat change influence the number, size, composition and distribution of primate groups over time in the study area?

I expect that increases in the per capita consumption of forest resources reduce the quality of primate habitat, which leads to reductions in the number and size of social groups. Furthermore, because when food resources decline, priority of access is limited to high-ranking animals, I expect an increase in the proportion of males among adult animals, and a reduction in juvenile recruitment rates. All these factors, taken together, lead to declines in the primate populations. I expect these changes to influence the colobus more strongly than mangabeys because colobus are habitat specialists.

Achievements in answering question 2:

1. Data on primate study group ranging patterns, as well as their age-sex compositions is now being collected on a monthly basis.
2. I am building a metapopulation model to evaluate the importance of patch size, quality and isolation, in addition to patch quality, in determining which fragments are occupied by the two primates. A research manuscript reporting these findings is in preparation for the journal of *Applied ecology* (Mbora, Ray & Bolger, in prep).

Further work needed for question 2:

1. Analysis of the data on primate study group ranging patterns, as well as changes in their age-sex compositions is in progress and a research manuscript needs to be developed.
2. A validation of the metapopulation model will be required, and the model will be used to investigate hypotheses on conservation and management scenarios such as varying the elements of the matrix and patch quality, to determine how they affect the expected behavior and population status of each species. The model will also be used to evaluate the importance of un-occupied habitat to population persistence as well as to prioritize sampling and conservation efforts.

Research question 3: What parasites infect the two primates, and how does habitat change influence the prevalence of these parasites among the primates?

Parasites and infectious disease of wildlife have emerged as a major threat to conservation of endangered species within the last two decades. This threat is in addition to the direct and well-documented threats caused by habitat loss and fragmentation. However, the interactive effects of the two threats are not well studied. I am testing the hypothesis that habitat change generally creates conditions that lead to an increase in parasite prevalence among the primates. The theoretical rationale is based on three testable postulates. First, reduction of food resources leads to poor body condition, which increases physiological stress and compromises immune responses. Second, crowding of animals in habitat fragments increases rates of parasite transfer among residents. Third, reduced quality of habitat leads to increased ranging by the primates, which increases the frequency of cross-species infections among primates, people, and domestic animals. In this study area, this theory predicts that within the same habitat patches, mangabeys should have higher parasite prevalence and harbor a higher diversity of complex life cycle parasites. These patterns are expected because mangabeys consume animal prey, are more vagile and live in larger groups, they use a larger home range, travel greater distances and encounter more parasites through contact with the environment and with more conspecific individuals.

Achievements in answering question 3:

A research manuscript has been accepted for publication in the *Journal of Parasitology* based on work completed so far (Mbora & Munene, accepted). In this manuscript, we report that we detected a higher number of different parasite species in individual mangabeys, and that the overall prevalence of parasites was higher among mangabeys.

Further work needed for question 3:

The next step in this line of research will be to relate parasite prevalence to the density of primates, to size and composition of social groups, availability of food resources and to levels of human use of the forests. This goal is complemented by the achievements outlined for question 2 above.

Research question 4: How different are the genetic structures of the two primates? How does the population structure of the red colobus, where both sexes disperse, compare to the mangabey where only males disperse? What impact is habitat change having on the demography and conservation status of the two species given their genetic population structure?

Habitat loss and fragmentation are key factors in species extinction because they lead to small and isolated populations, which have reduced genetic diversity. The loss of genetic diversity occurs by genetic drift because forest loss reduces the effective population size, while habitat fragmentation disrupts gene flow between populations via geographic isolation. Gene flow between populations is usually achieved by the dispersal of individuals. Therefore, if we understand how the pattern of dispersal influences the genetic structure of the primates, then we can gain important insights into how forest loss and fragmentation affect the two species and the extent of their vulnerability to current habitat change because of their dispersal pattern.

The population structure of the variation in the maternally inherited mitochondrial DNA can be particularly useful in understanding the effects of forest loss and fragmentation on population genetic structure of forest primates. Mitochondrial DNA is maternally inherited, lacks recombination and exhibits rapid sequence evolution. Consequently, any mtDNA lineages that differentiate in populations (e.g. in forest fragments) are independent clones that rapidly accumulate divergent sets of mutations through time. Thus, in species with male-biased dispersal, little or no variation should exist within, and much variation should exist between populations. In contrast, female dispersal leads to much differentiation within and less differentiation between populations.

I compared the population structure of the mtDNA variation of the Tana River red colobus and crested mangabey to determine how they are influenced by the pattern of dispersal and the changes in their forest habitat over time. My goal was to answer two questions by analyzing the population structure of the mtDNA variation of the two species. First, how does the population structure of the mtDNA variation in the mangabey where only males disperse compare to the red colobus where both sexes disperse? Second, what have been the long-term effects of forest loss and fragmentation on the population genetic structure of the two primates?

Achievements in answering question 4:

I have prepared a research manuscript of my findings for submission to the Journal of *Molecular ecology* (Mbora & McPeek, in preparation). In this manuscript, we report interesting and unexpected similarities in the population genetic structure of the two primates. First, both species had surprisingly high levels of genetic diversity. Second, populations of both species showed strong genetic structure, but little or no correspondence between genetic and geographic distances. These results are good news for these primate species. They show that despite the low population sizes, these primates retain high a level of genetic diversity, and that it is not yet compromised by habitat fragmentation.

Further work needed for question 4:

The results outlined above pertain to the genetic variation in the mtDNA. Because mtDNA is maternally inherited, gene flow in the population is usually mediated only by female dispersal. Thus, additional insights on the effects of forest loss and fragmentation can be gained by analyzing the population genetic structure of nuclear DNA. Therefore, further work on this question will use the variation observed at microsatellite loci of aDNA to explore levels of relatedness within and between social groups in different forests, and the relationships between levels of genetic variation in the major histocompatibility complex loci and parasite infections.

4. RESEARCH IMPACT ON THE LOCAL COMMUNITY:

An important goal of my project is to enhance the capacity of the local community to monitor their own biological resources and to implement conservation efforts. Towards this end, I have recruited and trained six young people from the local community, 3 men and 3 women. These individuals are now experienced in primate and habitat-monitoring techniques and are employed as research assistants on the project.

5. PROJECT FINANCIAL ACCOUNTING:

Table 1 below is a detailed summary of the project expenses for 2004-2005. Please note that the award of the **second Rufford small grant** helped me leverage further funding from Dartmouth College and the Margot Marsh Biodiversity foundation. These additional funds are now helping to sustain project activities at this time. However, additional funding will be required to sustain research activities beyond 2006-2007.

6. CONCLUSIONS AND PLANS FOR THE FUTURE:

My research program in the Tana River forests has generated findings that, clearly, will enhance the conservation of these two critically endangered primates. These findings, specified in sections 2 and 3 above, however, raise several further important questions, also specified in section 3 above. Thus, it is critical that the momentum of research activities generated by the two RSG grants is maintained.

Table 1: Detailed Project Expenses, 2004-2005

Budget Item	Quantity	Unit cost (GBP)	Total Cost (GBP)	Year 2004		Year 2005	
				RSG	Dartmouth	RSG	Margot Marsh, BF
<u>**Personnel Expenses**</u>							
Field assistance, person days	555.0	3.15	1748.25	-	491.3	-	1255.29
<u>**Travel and Living Expenses**</u>							
International Travel							
Air-tickets	3.0	777.00	2329.44	634.5	861.0		833.94
Transportation in Kenya							
Automobile hire, days	90.0	33.21	2988.90	2988.9			
Fuel Costs			3409.71		1,906.0		1503.73
Other Transport (boat, canoe etc.)	5.0	6.00	30.00	20.8	9.0		
Living Expenses							
Research camp use fee, days	83.0	10.00	830.00		167.3		667.53
PI subsistence, days	26.6	15.00	399.00	399			
<u>**Research Analyses**</u>							
Laboratory costs			896.96		200.8	397.0	299.12
<u>**Research materials and supplies**</u>							
Equipment			559.77	559.772	-		
Miscellaneous (phone, email, visa fee, etc.)			1005.91		484.20		521.71
Total			**14197.95**	**4602.97**	**4119.60**	**397.03**	**5081.33**

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