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An Analysis of *Pteropus livingstonii* Roost Habitat: Indicators for Forest Conservation on Anjouan and Mohéli

Elise Granek

Introduction

The rate of deforestation on the Comoros Islands of Anjouan and Mohéli has increased to a rate of 5.6% per year during the 1990s (UNDP, 1998). This change in land cover has implications for all living things, especially endemic plants and animals. In order to halt the deterioration of environmental conditions, the Global Environment Fund, in collaboration with IUCN and UNDP, has initiated a 5-year project working with the Comorian Ministry of the Environment to establish National Reserves and Protected Areas in the Comoros (UNDP unpublished report). Two of these parks will focus on tropical forest regions on the islands of Anjouan and Mohéli.

To create reserves that are sufficient to protect wildlife and are feasible in terms of community support, a suite of questions must be addressed in both the social and ecological realms. Livingstone's fruit bat (*Pteropus livingstonii*), an endangered and endemic species found only on the islands of Anjouan and Mohéli, has been chosen as a focus of these protected areas due to its endangered status and its perceived sensitivity to habitat degradation. However, if *Pteropus livingstonii* is indeed a useful indicator of the habitat type that other endemic species on these islands utilize, it becomes essential that we understand the various biotic and abiotic requirements of these bats' habitat. I studied the kind of habitat that the Livingstone's fruit bats prefer through an analysis of various biotic and abiotic factors measured at the roost site. Learning the characteristics of the habitat in which this species roosts is the first step toward conservation of *P. livingstonii.*

Using the known characteristics of existing roost sites, including approximate slope, altitude range and the presence of forest cover, I was able to locate new sites where *Pteropus livingstonii* were likely to roost. By comparing the sites where bats were found to those where they were not found, I could identify additional factors common among bat roost sites. Also, in order to determine whether dry and rainy season roost sites were the same, I measured the abundance of *Pteropus livingstonii* at the identified roost sites during both the dry and rainy seasons

At the same time, I identified villages that I felt were currently active in environmental work and would assist in the protection of designated areas. Without local environmental groups supporting the parks and protected areas, the likelihood of protecting these sites over the long-term is quite low. Work was performed with two of the most active villages that have roost sites within their territory to create village maps of land utilization and to identify sites for potential protected areas.

Background on Livingstone's Fruit Bat

Livingstone's fruit bat, a member of the order Megachiroptera, is a species of Old World Fruit Bat found only on Mohéli and Anjouan in the Comoros Islands. Other species in the genus *Pteropus* are found throughout the Western Indian Ocean, predominantly on islands, though also on the Indian subcontinent and Australia. *Pteropus livingstonii* are jet-black bats, although some individuals have rust-colored patches of fur around the genital area or on the upper back. They can reach a size of up to 2 meters in wingspan and are distinctive with their big, rounded ears. Like other *Pteropus*, Livingstone's fruit bats are tree-roosting frugivores that depend on a diet of fruit, pollen and leaves. They are found roosting during the day in groups of 6 to 160 individuals in 1 to 8 roost trees per site. Livingstone's Fruit bat is believed to be a "sequential specialist," feeding at any one time on one or a few plant species among a group of potential food plants available at that time/season (Marshall 1983). Such a diet may cause roost sites to vary, depending on the season and food availability. There is very little known about their diet, behavior, and reproductive patterns, though there is some indication that females with young move to maternity roosts while their babies are still in their first few months of life.

Livingstone's fruit bats roost predominantly on south- and east-facing slopes, suggesting that bats are sensitive to wind and sun.

Study Site

This study was conducted from August to December 1998 in the tropical forests of Anjouan and Mohéli, two of the four volcanic islands comprising the Comoros Archipelago. The habitat type is primarily steeply sloped montane tropical rainforest; however, some areas in the region have been heavily deforested. While not as species-rich as mainland tropical forests, the ecosystem is comprised of numerous endemic and native tropical tree species. Some important species are: *Khaya comorensis*, *Nuxia pseudodentata*, *Brachylaeno ramiflora*, *Anthocleista grandiflora*, *Cussonia sputata*, *Ocotea comoriensis*, *Weinmania comorensis*, *Litsea glurinosa*, *Eugenia comorensis*, *Calycophylum inophyllum*, *Tambourissa leptophylla*, unidentified single species in the *Draceana* and *Gambeya* genera, and several species of *Ficus* (Adjanahoun et al.1982, Action Comores 1997). Anjouan and Mohéli receive a maximum rainfall of 4925 mm and 3086 mm respectively, with most rainfall occurring between November and March (Adjanahoun et al. 1982)

Methods

Before this research began, there were only nine known *P. livingstonii* roost sites. All of these sites had the following three characteristics: 1) they were between 500-1100m in elevation; 2) the land was steeply sloped; 3) some native forest cover was present. I then looked for all sites on the islands of Anjouan and Mohéli that met these three criteria. (Trewhella 1998). After locating likely roost sites, I compared sites where bats were found (new sites and those previously discovered) to several sites where bats were not found.

With help from local assistants, I recorded altitude, aspect, slope, tree species growing within 75 meters of a roost tree, land cover type, proximity to water, number of roost trees, and distance of the site to the nearest human settlement. For each roost tree we recorded the species, measured the height and diameter at breast height (dbh), and counted the number of bats per tree. The island on which the site was found, the season, and the current weather conditions were also recorded to compare seasonal changes in the number of individuals. I also described the cover type on a numeric scale of 1 to 4 according to the following guidelines: 1) intact forest; 2) forest cover under-planted with fields; 3) mixed forest and fields; 4) fields with few forest trees remaining.

To test for dependence of bat presence or absence on these factors, a G-test of independence was run (Sokal & Rolff 1981). The effect of season on population size was tested using a paired t-test.

At the same time, I tried to determine which villages would successfully participate in conservation programs. I invited village environmental groups with roost sites in their territory to participate in my research in order to train them for future monitoring of *P. livingstonii*. I paid special attention to a village that had previously been identified by IUCN consultants as a probable site for a forest reserve (UNDP unpublished report).

In villages with demonstrated interest, I worked with the local environmental associations to create village maps of the territory within their villages. I then asked them to map land use across this territory. Finally, I asked them to identify areas where they would prohibit specific uses if they were given authority to do so, and what those uses would be.

Results

Abiotic factors

On Anjouan and Mohéli, I was able to locate thirteen new sites that met the three known criteria for roost sites as given in the previous section. Six of these sites were indeed roost sites, significantly increasing the number of known *P. livingstonii* roosts. In all, I counted a total of 663 bats, the largest number of individuals of this species ever found. Three of the six new roosts were large sites with more than 50 bats present during the rainy season. A g-test of independence indicated that presence of bats was positively correlated with presence of water in the same valley ($p < 0.005$) and an East- or South- facing slope ($p<0.1$ and $p<0.05$ respectively) (Table 1). All of the roost sites and 5 of the absence sites were found in 'bowls' (i.e., a valley protected by mountains on three sides). No significant effect of altitude or forest cover on bat presence was observed. However, this may be merely an artifact of choosing absence sites within the same range of altitudes and cover types as the roost sites that were chosen.

Biotic Factors

A g-test was used to analyze the effect of various tree species on bat presence or absence at a site (Table 1). Bats showed positive association with two tree species: *Gambeya* sp. and *Nuxia pseudodentata* at the $p<0.05$ level. A paired t-test revealed that *P. livingstonii* abundance was significantly higher in the rainy season than in the dry season for the seven sites at which counts had been made in both seasons ($p<0.05$).

Table 1: G-test of independence for 15 roost and 7 non-roost sites as affected by a variety of factors

	Factor	Roost site	Absence site	p-value[1]
Water Availability	Water in valley	14	2	
	Absence of water in valley	1	5	< 0.005
Aspect[2]	North-facing	2	3	
	South-facing	13	1	< 0.05
	West-facing	3	2	
	East-facing	14	1	< 0.1
Tree Species	*Nuxia pseudodentata*	9	1	
	Absence of *N. pseudodentata*	6	6	< 0.05
	Gambeya spp.	13	3	
	Absence of *Gambeya spp.*	2	4	< 0.05

[1] P-value shows level of significance for unadjusted G-value and was obtained from a chi-squared table with df=1.
[2] Numbers of roost and absence sites for aspect are not equal to 22 for several reasons: 1) Some large sites are represented by two observations if site faced two different directions; 2) Aspect was not recorded for three of the seven absence sites; 3) Aspects were one of the cardinal directions (N, S, E, W) and did not have an orthogonal component (i.e. Site facing due E has no N-S component).

Looking now specifically at roost trees, the mean roost tree dbh was 103 cm (SE = 10.7, n=43) and mean roost tree height was 24.35 m (SE = 1.02, n = 43). Of the 43 roost trees, seventeen were *Ficus* spp., six were *Nuxia pseudodentata*, and six were Gambeya sp. The remaining roost tree species were represented by four or fewer individuals. In three cases, the roost trees were growing together, entwined or fused with other tree species, generally a fig tree growing with another *Ficus* species.

Human factors

Two villages showed notable interest in participating in bat monitoring and a third village had previously been identified by IUCN consultants as a probable site for a forest reserve (UNDP unpublished report).

Both roost sites on the island of Mohéli are within the territory of the village Ouallah-Mirereni. The village environmental association had independently taken steps to ensure the protection of the previously discovered roost site by banning farming around and below the roost and relocating those farmers whose fields border on the roost site. When a new roost site was discovered in October 1998, the association forced herders from a neighboring village who had been grazing their cattle in Ouallah-Mirereni's forest to cease their herding activity in the area of the newly identified roost sites. The association denoted the roost sites as areas in which utilization would be limited to the collection of traditional medicine and non-timber forest products. The rivers were also identified as territory in which use should be limited.

On Anjouan, The village of Nindri showed notable interest in the protection of the roost. The Nindri association discovered the roost site in 1995 and members of the group visit the roost regularly to check on the status of the bats. When asked to delineate protected areas and designate usage, the roost and the Nindri River were identified as critical habitat in need of some level of protection.

Also on Anjouan, the village of Lingoni has been identified by visiting consultants (UNDP unpublished report) as an ideal site for a forest reserve because of the extent of undisturbed primary forest, the rivers in the region, and the size of the roost, which is the largest ever identified for *P. livingstonii* (with counts of 150 individuals in some years). The Lingoni environmental association was requested to draw a village map that would note land use limitations. Again the association recognizes the importance of protecting the rivers in the valley as well as the forested area in which the roost exists. In these three village environmental associations, there was an understanding of the importance of the bats as a valuable component of the ecosystem as well as a potential income-generating tourist attraction if the forests where bats reside are indeed protected.

Discussion

Livingstone's fruit bats are strongly associated with a number of habitat variables. Prominent among those was aspect, with bats found predominantly among SE facing slopes (Figure 1). In the Southern Hemisphere, these slopes receive morning sun and are shaded from noon until late afternoon when the bats are leaving their roosts to feed. Such a finding is one of the many indications that bats are sensitive to temperature. Each of the roost sites was located in a bowl, a topographic feature which moderates climate by sheltering the bats from wind and sun (Pierson and Rainey, 1992). This affinity for valleys is supported by their preference for SE facing slopes. Water was present in all 15 of the roost sites, either in the valley itself or in the form of a river running through the valley below. Their preference for valleys containing water, which are therefore more humid, may indeed be a factor of their temperature sensitivity. *P. livingstonii* are at elevations and on slopes on which forest cover is still present—above 500 meters on Anjouan and above 200 meters on Mohéli. As the population density of Anjouan is much higher, little forest remains below 500 meters altitude whereas on the southern and western sides of Mohéli, forest can be found as low as 200 meters altitude. Below these altitudes, the temperature is much warmer due both to the elevation itself and to deforestation. This corresponds to the trend of finding *P. livingstonii* at lower altitudes on Mohéli. However, two of the newly discovered sites were found in areas with forest cover type 4, which indicates that remnant populations are still present where up to 90% of the forest cover has been removed. A dependence on several native tree species is further evidence of characteristics specific to Livingstone's roost sites.

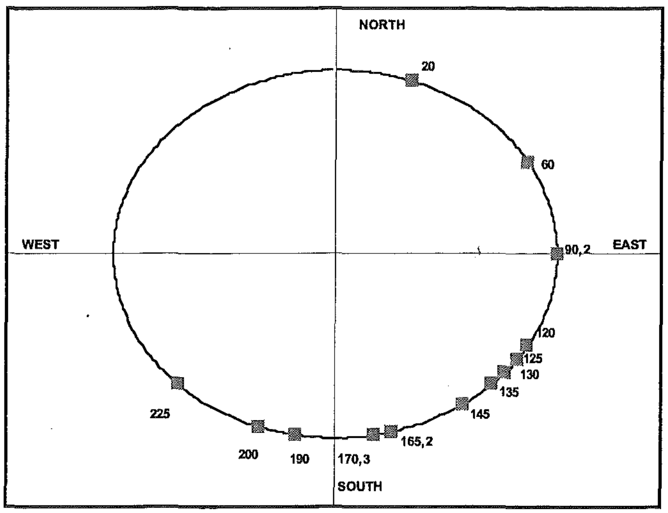

Figure 1. Aspect of Roost sites
First number is aspect angle, 2nd value is the number of sites at that aspect)
Note: Some large sites were given two values for roost site aspect if it was determined that the slope faced in two directions

Livingstone's fruit bat may be considered keystone species in the tropical rain and cloud forest of Comoros because of their essential role as forest pollinators and dispersal agents (Fujita 1988 and 1991). For this reason the United Nations Development Programme/Global Environmental Fund "Biodiversity Conservation and Sustainable Development" program has targeted *P. livingstonii* as a focal species for protected areas priority (UNDP unpublished report). My data demonstrating seasonal sensitivity to habitat characteristics supports this need and further identifies *P. livingstonii* roost sites as priority forest habitat for conservation.

Social indicators point to the village of Ouallah-Mirereni as a focal region for Mohéli and the villages of Nindri and Lingoni as foci for the forests of Anjouan. Further education and training in monitoring techniques is necessary for these three villages; however, a solid foundation of basic ecological understanding lends confidence to the possibility of success if forest reserves are overseen by these village associations. The size of roost sites located near these three villages further supports the preference for this prioritization.

Conclusion

Livingstone's fruit bats appear to prefer habitat that is protected from wind and mid-day sun yet allows morning sun. The bats seem to be attracted to certain topographic characteristics and tree species that are specific to the forest zone where these species exist. To ensure the survival of this species, roost habitat must be protected.

However, the protection of roost habitat alone is insufficient to ensure the survival of *P. livingstonii*, a species critical for forest regeneration. For example, it is known that they spend much of their time at feeding sites. Further research on dry season distribution, maternity roosts, and feeding sites is essential for the survival of the species. As the human population on the islands of Anjouan and Mohéli grows at a rate of 3.3% per year (UNDP 1998), the feeding sites, many of which are found at lower elevations, will become more threatened. This threat to feeding sites is a serious risk to the species, believed to be a "sequential specialist." As the human population moves up slope, clearing land for agriculture on increasingly steeper slopes, the need for protection of these roost sites increases.

In order to ensure the success of protected areas in the region, established community environmental groups must be involved in enforcing the restrictions on protected areas. I therefore recommend focusing on the roost sites at Ouallah-Mirereni on Mohéli and at Lingoni and Nindri on Anjouan initially, with potential for future work with other villages such as Bazmini and Mpage where large roost sites were found.

The establishment of protected areas must be accompanied by continued research on the roost site distribution, feeding ecology, roost behavior, and reproductive biology of *P. livingstonii* as well as the continued awareness-raising and training of local communities concerning the importance of the bats and methods for monitoring the forest.

Elise Granek, MESc '00, is currently working as the Ecology Specialist for an IUCN project entitled "Biodiversity Conservation and Sustainable Development in the Federal Islamic Republic of the Comoros".

Collaborator Notes

This research was conducted in Comoros with the assistance of Action Comores, a British-based NGO focused on conservation of Livingstone's fruit bats and their habitat. The Comorian Minsitry of the environment in MDE, Grande Comores and the Centre National pour la Documentation et la Recherché Scientifique (CDNRS) in Moroni, Grande Comores also facilitated this project. Ishaka Said of Anjouan served as Field Assistant, making this field work a success.

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Dietary Overlap and Relative Abundances of Two Sympatric Bat Species in Central French Guiana

Heather Peckham

Introduction

Many studies have shown that the structure and composition of Neotropical forests depend on the intricate relationships between animals and plants (Howe and Wesley, 1986; Gilbert, 1980; Leigh, 1993). Animals pollinate plants and disperse their seeds. Plants in return reward the animals with nectar or fruit. Approximately half of all mammalian species in the tropics are bats (Wilson, 1997). Consequently, their impact on plant diversity is substantial. The role of bats is especially important when they are the only vectors for a keystone plant species. If a keystone species declines from the loss of a pollinator or disperser, many other species may decline as well through what Myers (1986) describes as "cascades of linked extinctions."

Bats may have an effect on the diversity of fragmented primary forests as well as on the rehabilitation of deforested areas. The understory frugivores, such as species in the genus *Carollia*, forage on plants in natural gaps in the forest and in cleared areas. They disperse the seeds of many pioneer species that are the first trees to colonize old field environments. Bats are successful seed dispersers because, unlike most birds, bats fly away from the plant with the fruit in their mouths to a night roost. Seeds dropped farther away from the parent tree have a higher survival rate. Janzen (1981) attributed this trend to density-dependent mortality and increased predation near the parent tree. Finally, almost all of the seeds dispersed into cleared areas occur during the night, suggesting that bats are the largest seed contributors (Gorchov et al., 1993; Charles-Dominique, 1986; de Foresta, 1984). The pioneer species later provide suitable habitat for the more shade tolerant, late seral tree species.

Habitat disruption has been found to lower bat species richness (Brosett et al., 1996; Simmons & Voss, 1998), which may then affect plant diversity of remaining fragments and regenerating forests through the loss of pollinators and dispersers. Several bat inventories in French Guiana found that *Carollia brevicauda*, an important seed disperser of pioneer species, were either rare or entirely absent in more disturbed areas (Simmons & Voss, 1998, Brosett et al., 1996). On the other hand, *C. perspicillata*, a closely related species, proliferated in these same areas. The rarity of *C. brevicauda* may be related to its specialization on highly nutritious *Piper* spp. fruits.

The diet of *C. brevicauda*, the smaller bat, has been found to contain more *Piper* spp. fruit than *C. perspicillata*, the larger bat (Fleming, 1991; Gorchov et al., 1995). Larger bats can afford to eat fruits with less protein because of a lower demand for energy and protein relative to their mass. *C. brevicauda* may not be able to persist in less diverse forests where their preferred species of *Piper* may not be available. The *Piper* spp. fruits that are available in this habitat may be depleted rapidly. Only a few *Piper* fruits on an individual