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Population, diet and conservation of Malayan flying Lemurs in altered and fragmented habitats in Singapore

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Abstract. The Malayan flying lemur (*Cynocephalus variegatus*) is a nocturnal mammalian arboreal folivore that inhabits the forests of Southeast Asia. Surveys were conducted from August to November 2003 to estimate the population density of Malayan flying lemurs for the first time in the Singapore Zoological Gardens. The study area consisting of Singapore Zoo and Night Safari was located in the Central Catchment Nature Reserve, where most of Singapore's remaining natural forest is found. The Zoo consisted of 28 ha of landscaped habitat and the adjacent Night Safari consisted of 40 ha of secondary rainforest. The density estimates of flying lemurs in the Zoo and Night Safari were 15 and 24 individuals respectively. Seven plant species that were the preferred food items and an additional 10 plants that were common in the sites but not eaten by the flying lemurs were analysed to compare the mineral and phytochemical contents. Flying lemurs consumed leaves containing significantly less potassium and nitrogen but higher tannin ($p < 0.05$). The study shows that flying lemurs are able to survive in altered and fragmented landscapes. Conservation and management strategies are essential to protect the shrinking habitats in Singapore.

Introduction

Flying lemurs or colugos belong to the order Dermoptera, containing one known genus, *Cynocephalus*, with two extant species – *C. volans* found in the southern Philippines and *C. variegatus*, found in the southern parts of Thailand and Indochina, the Malay Peninsula, Sumatra, Java, Borneo and nearby islands (Lekagul and McNeeley 1977; Mendoza and Custodio 2001).

Flying lemurs inhabit both lowland and mountainous areas, and are found in primary or secondary forests, coconut groves, and rubber plantations. They are totally arboreal and nocturnal, spending their day in holes/hollows, hanging from branches or clinging to tree trunks and begin their activity around dusk (Nowak and Paradiso 1983). Due to the rapid loss of forested habitat throughout their ranges, populations of both species are thought to be rapidly declining (Wischusen 1990). Recent studies were concentrated on the *C. volans* (Wischusen and Richmond 1989, 1998; Wischusen 1990; Wischusen

et al. 1992). Previous estimates on the total number of flying lemurs in Singapore range from 200 to 3000 individuals (Medway 1983; Yang et al. 1990; Ho et al. 1994; Lim per. comm.).

This paper presents data on the population status, density and diet preferences of flying lemurs within the artificial and cultivated landscape of the Singapore Zoo and the relatively intact secondary rainforest within the Night Safari with implications for conservation.

Materials and methods

Study area

Singapore (1°22′ N, 103°48′ E) is a city-state with a total area of 682.7 km^2 . Much of the island lies within 15 m of sea level, with an elevation peak of 176 m (Foo 2003). Singapore has an equatorial climate, where the weather is tropical, hot, humid and rainy with two distinct monsoon seasons; North-eastern monsoon from December to March and South-western monsoon from June to September. The inter-monsoon, April to May is characterised by frequent afternoon and evening thunderstorms (Foo 2003).

Between 1 August and 30 November 2003, the study site received a total of 739 mm rainfall. August received the least amount of rainfall (143 mm) and November the most (252 mm). The mean maximum and minimum temperatures were 31.1 and 23.6 °C respectively. There was little monthly variation in the mean maximum and minimum temperatures recorded, with the greatest maximum temperature recorded in October and lowest recorded in November (World Meterological Organisation 2003).

Prehistoric Singapore was covered with three forest types, mangroves (13%), freshwater swamp (5%) and lowland rainforest (82%) (Corlett 1991). Progressive deforestation during the nineteenth century reduced the forest cover to isolated patches in a matrix of grassland. The Singapore Zoo and Night Safari are located in the 2000 ha Central Catchment Nature Reserve, which consists primarily of four reservoirs, surrounded by forested land. All primary forest patches outside of the nature reserve were cleared but protection within the reserve has allowed the preservation of small fragments of forest scattered amongst secondary growth (Turner et al. 1994; Chan and Corlett 1997; Turner et al. 1997).

The study area consists of the Singapore Zoo (28 ha) and the adjacent Night Safari (40 ha). The Zoo and the Night Safari are bordered by the Upper Seletar Reservoir on all sides except the western extremity that is continuous with the Upper Seletar Zone of the Central Catchment Area through a narrow corridor. The Singapore Zoo was built in 1973 and much of the natural vegetation was subsequently cleared and landscaped (Agoramoorthy and Hsu 2001a). The area now consists of 80% cultivated trees dominated by non-native tree species such as *Samanea saman, Khaya* sp., *Hevea brasiliensis*, *Lecythis ollaria* and

Spathodea campaulata and native species such as *Syzygium grande*. The Night Safari was built in 1994 and disturbance to the natural vegetation was minimal. The area consists of secondary forest characterised by species such as *Trema tomentosa, Macaranga heynei, Macaranga triloba, Ficus grossularioides, Ixonanthes reticulata*, and *Dioscorea* sp. (Boo 1996). Small patches of secondary rainforest are present in the western loop as characterised by species such as *Rhodamnia cinerea, Syzygium* sp., *Campnosperma auriculatum*, *Calamus* sp., and *Alstonia angustiloba*. Semi-cultivated areas bordered by the Upper Seletar Reservior make up much of the eastern loop.

Population surveys

Line transect surveys were conducted in the Zoo and Night Safari from 14 August to 21 November 2003. Nocturnal transect surveys were conducted along a 2 km route at the Zoo and along a 2.6 km route at the Night Safari. A total of 14 transects surveys along the Zoo transect and 5 transects along the Night Safari transect to enable pooled data analysis for increased precision (Buckland et al. 1993). Along the Zoo transects, the survey team walked slowly (1.5 km/h) on the transect route to record the occurrence of flying lemurs. Along the Night Safari transects, a motorised buggy was used due to safety concerns with the presence of free-ranging animals. Speed was maintained at 1–1.5 km/h. The surveys were standardised to time and weather conditions. Surveys were mainly conducted between 0100 to 0600 h. Census data collected on rainy days were excluded.

Halogen headlights were used to detect the red eye-shine of the flying lemurs or their silhouettes against tree trunks. As soon as a flying lemur was sighted, night vision binoculars with 2.4× magnification (Newcon^{TM} Optik, BN-5) used to observe the subject for 10 min to record data. The perpendicular distance from animal to transect line was measured using a laser rangefinder (Leica LRF 800) for >14 m or with a measuring tape (<14 m). A pair of Zeiss (8×30) binoculars aided scanning at further distances and confirmation of sightings.

Data for each of the study sites were pooled and used to calculate population density estimates using DISTANCE 4.0 software (Buckland et al. 1993). Unweaned individuals were excluded due to their lesser role in the ecological competition of resources as well as variability in sighting efficiency as they may be hidden under the patagium of the adult. In accordance with recommendations of Buckland et al. (1993), the largest 5% of the data sets were truncated to reduce outliers and to improve the robustness of the detection model. Five recommended models were selected to fit the distance histograms: uniform with cosine expansions, half-normal with cosine or hermite expansions, and hazard rate with either cosine or simple polynomial expansions. The best-fit model was selected based on minimum Akaike information Criterion (AIC) values to estimate w, goodness of fit near zero distance in the detection histogram and

the presence of a 'shoulder' in the histogram meeting the shape criterion (Buckland et al. 1993).

Food plants analysis

Seven preferred plant samples including young and mature leaves were collected after observations for nutritional analysis. An additional 10 plants that were common in the sites but not eaten by the flying lemurs were analysed to compare the mineral and phytochemical contents. Samples were dried to a constant weight in an oven (60 °C) to determine total dry matter. They were then ashed in a muffle furnace overnight to obtain total ash (inorganic constituents) content. Samples were analysed in duplicate for total nitrogen (N) content using a macro-Kjeldahl (Williams 1984). Crude protein levels were calculated as $N \times 6.25$ using the standard formula (Williams 1984). Fiber analysis was done following van Soest et al. (1991). Analysis of minerals such as calcium (Ca), iron (Fe), magnesium (Mg), manganese (Mn), phosphorous (P), sodium (Na), zinc (Zn), and potassium (K) were done by multi-element inductivity coupled plasma spectroscopy. Wilcoxon Rank Nonparametric Test (SAS Institute 1993) was used to test the difference between percentage of ash, nitrogen, water, crude fiber and seven elements (Ca, Fe, K, Mg, Mn, Na, Zn) and Tanin in plant species that were eaten with other plant species that were not eaten by the flying lemurs.

Results

The population density of flying lemurs was 55.0 ± 7.8 individuals/km^2 at the Zoo site and 60.1 ± 7.8 individuals/km^2 at the Night Safari site. Both estimates were of reasonable accuracy with coefficient of variance $< 20\%$ (Buckland et al. 1993). Out of the total 66 flying lemurs that were recorded during the study, 21 were males, 1 unknown and 44 were females including 8 carrying unweaned young. At the Zoo site, the male to female ratio was 16:25, corresponding to 39.0% and 61.0% respectively. There were four juveniles (13.0%), two males and two females, evident from their smaller body sizes. Adults constituted 76.1% while unweaned young comprised of 10.9%. At the Night Safari, the male to female ratio was 6:18 with adults (70.4%), juveniles (18.5%), and un-weaned young (11.1%).

The flying lemur sightings along transect lines were plotted on a field map (Figure 1) to analyse the distributions and habitat preferences. At the Zoo, sightings were spread across with spatial distributions concentrated in the southern region. At the Night Safari site, sightings were evidently skewed, with the population concentrated in the west loop with fewer sightings in the east loop.

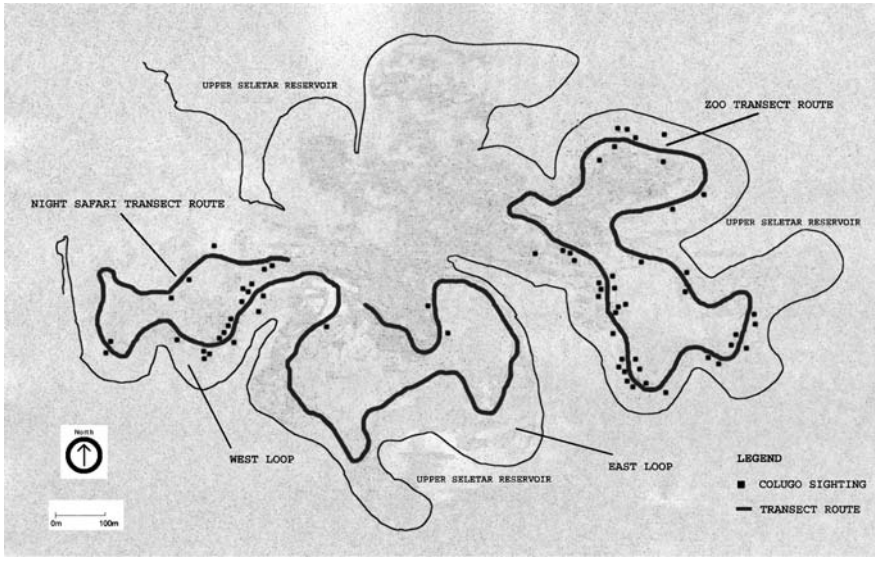

Figure 1. Malayan flying lemur sightings along transects in Singapore Zoo and Night Safari.

During this study, the flying lemurs were observed to feed on 7 plant species (Table 1). At the Zoo site, species such as *Syzygium grande*, *Seraca cauliflora*, *Rhodamnia cinera* and *Peltophorum pterocarpus* were eaten. At the Night Safari, species such as *Syzygium pachyphyllum, Syzygium palembanicum* and *Campnosperma auriculata* were fed respectively. All feeding activities observed were on leaves with a single instance of feeding on fruit of *Syzygium pachyphyllum*.

We tested the difference in the nutritional contents of the 7 plant species that were preferred as food with 10 other plant species that were not eaten by the flying lemurs, but were common in the study sites (Table 2). Flying lemurs

Table 1. Plant food items consumed by the Malayan flying lemurs in Singapore.

Plant species name	Family name	Relative abundance[a]	Preference of food items
Campnosperma auriculata	Anacardiaceae	Not abundant	Leaves
Peltophorum pterocarpus	Leguminosae	Not abundant	Young leaves
Rhodamnia cinera	Myrtaceae	Not abundant	Leaves
Saraca cauliflora	Leguminosae	Not abundant	Young leaves
Syzygium pachyphyllum	Myrtaceae	Unknown	Leaves & fruits
S. grande	Myrtaceae	Abundant	Mature & young leaves
S. palembanicum	Myrtaceae	Unknown	Leaves

[a]Relative abundance of foraged tree species in the Zoo along transect line and within maximum strip width = 30 m was estimated by tree count of trees greater than 60 cm girth at diameter breast height (1.5 m). Individual tree species were then expressed as a percentage of total trees. > 15% was considered abundant, < 5% was considered not abundant.

Table 2. A comparison of the nutrient content of plants eaten and not eaten by the flying lemurs in Singapore.

Nutrient composition of food plants	Plants eaten (7)				Plants not eaten (10)				Wilcoxon test p value
	Mean	Sd	Min.	Max.	Mean	SD	Min.	Max.	
Nitrogen (%)	0.73	± 0.17	0.5	1.0	1.33	± 0.46	0.7	2.1	$p < 0.01$*
Crude fibre (%)	9.45	± 2.45	5.1	13.3	8.97	± 4.35	2.0	14.5	$p > 0.88$
Moisture (%)	57.96	± 5.25	50.7	64.4	60.90	± 11.60	45.5	79.0	$p > 0.84$
Ash (%)	1.79	± 0.55	1.2	2.9	2.72	± 1.32	1.5	5.5	$p > 0.08$
Calcium (mg/kg)	3093.57	± 1453.03	1190.5	5844.0	5295.75	± 4552.82	1542.0	13636.0	$p > 0.52$
Iron (mg/kg)	30.09	± 7.03	22.5	43.5	40.31	± 20.31	13.2	85.8	$p > 0.26$
Potassium (mg/kg)	4726.93	± 2652.94	2479.5	10437.0	6486.60	± 1410.12	4101.0	8249.0	$p < 0.04$*
Magnesium (mg/kg)	733.57	± 182.16	579.0	1073.0	800.45	± 331.73	355.0	1449.0	$p > 0.66$
Manganese (mg/kg)	21.44	± 19.52	2.2	54.5	22.98	± 38.77	1.4	130.0	$p > 0.46$
Sodium (mg/kg)	32.43	± 14.82	17.9	61.8	27.68	± 14.77	10.6	63.1	$p > 0.96$
Zinc (mg/kg)	5.41	± 2.93	2.5	10.5	10.02	± 6.96	5.0	27.9	$p > 0.05$
Tannin (%)	4.06	± 2.08	1.7	6.7	1.74	± 1.10	0.5	3.3	$p < 0.02$*

*Statistically significant; % As to dried weight

consumed significantly less potassium and nitrogen but higher tannin from their diet ($p < 0.05$). The tannin content in the diet that was consumed by the flying lemurs averaged 4.06 ± 2.08 while in the other plants that were not consumed was 1.74 ± 1.10. The percentage of nitrogen in the diet consumed was 0.73 (± 0.17) while in the other plants it was 1.33 ± 0.46 (Table 2).

Discussion

Flying lemurs fed on *Syzygium* spp. at both Zoo and Night Safari sites, constituting 50% of total observed feeding. Family Leguminosae consisted mainly of introduced species such as *Samanea saman, Seraca cauliflora and Peltophorum pterocarpus* found at the Zoo site but not at the Night Safari. There was a marked preference for *Seraca cauliflora* at the Zoo which is unusual given this species relative low abundance on the site. Its regular production of young leaves may be a reason for the preference. Young leaves were preferred in the Philippines species due to higher nutritional value and bulkiness (Wischusen and Richmond 1998).

This study found more females ($n = 44$) than males ($n = 21$); 8 of the females had dependant offspring. The flying lemurs consumed plants that had higher tannin contents. This is similar to sifaka in Madagascar where lactating and pregnant females tend to eat plants that had high tannin contents (Carrai et al. 2003). Tannins are known for their protein-binding properties; protein demands are also high in pregnant and lactating females. Tannin consumption has been reported to be associated with increase in body weight and to stimulate milk secretion in the wild sifakas (Carrai et al. 2003).

At the Night Safari site, flying lemurs were concentrated at the western loop, with fewer sightings in the eastern loop. The eastern loop of the Night Safari consists of large tracts of dense secondary vegetation colonised by lianas, exotic vines and climbers, which might have contributed for the incompatibility as a suitable habitat. Emmons and Gentr (1983) observed that gliding vertebrates predominates in regions where the forests had low vine density. Wischusen (1990) supported this assertion with observations that flying lemurs often have difficulty climbing up trees covered with vines.

Disturbance to the forest area adjoining Seletar Reservoir where the Zoo and Night Safari are situated could be dated to as early as the 1960s. Subsequent isolation from larger tracts of continuous forest began three decades ago when construction of the Zoo commenced. Development of the Night Safari is relatively recent, dating back to a decade. Different species vary in the way they respond to habitat fragmentation and changes in habitat structure (Mabry et al. 2002). The populations of Malayan flying lemurs in the Zoo and the Night Safari may reflect its adaptability to survival in altered and fragmented habitats. Lack of natural predators and hunting combined with the round the clock security at the Zoo and Night Safari provide an opportunity for protecting the remaining small population of the flying lemurs.

Given the fact that only limited natural forests remain in Singapore (Agoramoorthy and Hsu 2001b), proper management of fragmented and landscaped habitats where viable populations of flying lemurs exist may have equal importance for conservation. Habitat conservation and management at the Zoo and Night Safari should be aided by apt horticultural practices attuned to the protection of the species. Tree pruning/cutting practices as well as collection of food plants for the zoo animals has to be carefully managed to prevent major disruptions to the flying lemurs' ecosystem. Conserving the dwindling natural habitats and its vanishing native fauna such as the fascinating flying lemurs is certainly crucial for the city-state, Singapore (Agoramoorthy and Hsu 2001b).

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