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Research Article

ECOLOGY OF SMALL MAMMALS IN OLOOLUA FOREST IN NAIROBI, KENYA

***[1]Ben N. Meroka, [2]Nathaniel N. Gichuki and [3]Samuel K. Kiboi**

[1]Zoology Department, National Museums of Kenya, P.O Box 40658-00100, Nairobi, Kenya

[2]School of Biological Sciences, University of Nairobi, P.O Box 30197-00100, Nairobi, Kenya

[3]School of Biological Sciences, University of Nairobi, P.O Box 30197-00100, Nairobi, Kenya

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ABSTRACT

Rapid growth of Nairobi as an urban centre has had numerous negative effects on biodiversity greatly jeopardizing the future of small mammals due to habitat alteration and destruction. In this study we assessed the abundance, diversity, distribution and seasonal variation of small mammals in Oloolua forest. Four habitats were sampled for 90 days during the dry and wet seasons of the year 2017. Rodents and shrews were captured using a mixture of traps i.e. Sherman traps, museum special and victor snap traps and pitfalls. Small carnivores were sampled using tomahawk cage traps whereas bats were captured using mist nets. A total of 12,938 corrected trap nights and 2,160 net hours realised 101 rodents & shrews and 116 bats respectively belonging to orders Rodentia (43.78%); Soricomorpha (2.76%) and Chiroptera (53.46%). Diversity indices across habitats and seasons showed no significant difference. A one-way analysis of variance on the abundances across the habitats yielded $F_{(3, 35)} = 0.5209$ $P > 0.05$ indicating no significant difference in the abundance of small mammals among the habitats sampled meaning the difference in abundance numbers is mere chance. Oloolua forest is an important small mammals' refuge within the urban city of Nairobi offering unparalleled opportunities to study the ecology of sympatric small mammal species in an urban context and therefore deserves conservation.

Keywords: Abundance, Distribution, Diversity, Habitat alteration.

INTRODUCTION

More than 70% of all terrestrial biodiversity is hosted in forests (Schmitt *et al*., 2009) that may either be rural or urban. Due to increasing human population, climate change effects and unreasonably high forest product demands (Slingenberg *et al*., 2009) forests are under increased pressure to provide for their biodiversity (Young *et al*., 2005). Many assume that urban areas are deprived of biodiversity and therefore do not deserve conservation attention. On the contrary, several authors point out that they harbor many native as well as non-native species. It has been documented that urban areas harbour species of conservation concern regionally or globally, as well as endemic species. .Because of this, there is greater appreciation by the day in the field of ecology of what can be termed as 'Urban ecology' (Grimm *et al*., 2013). According to (Godefroid, 2001), cities that harbor high quality green spaces will most definitely promote wildlife numbers. Urbanization seems to be slowing down in developed countries whereas in developing countries which harbor numerous biodiversity hotspots (Myers *et al*., 2000), it seems to be increasing. McKinney notes some species are able to persist and even thrive in urban landscapes. This is despite the negative effects of urbanization such as habitat fragmentation, habitat loss, pollution, as well as introduction of human induced stressors in the ecosystem (Grimm *et al*., 2013). McKinney & Lockwood, (1999). Specifically points out that urbanization directly affects mammals, clearly seen in their abundance and diversity, as a possible consequence of habitat destruction and fragmentation. Animals may be extirpated in urban areas due to a lack of those landscape features they rely on (Gilbert, 1989).

Studies have shown that urban landscapes provide opportunities in the conservation of species which otherwise would be lost (Frankie & Ehler, 1978). Due to

*Corresponding Author: Mr. Ben N. Meroka, Assistant Research Scientist, Zoology Department, National Museums of Kenya, P.O Box 40658-00100, Nairobi, Kenya, Email: bnmeroka@gmail.com, Mobile: +254721381687

urban green spaces and the high importance of forests in biodiversity conservation (Jones & Leather, 2012) they have continually received attention and are being included in global action plans related to biodiversity conservation (Convention on Biological Diversity. 2012). After the 1992 Rio Earth Summit on Convention on Biological Diversity, urban areas have gained focus when it comes to biodiversity conservation (Cilliers *et al*., 2004).

The degree of fragmentation impacts the structure of forests and this impacts species occurrence (Tews *et al*., 2004). Small mammals respond differently to fragmentation; some remain in the isolated patches of non-native vegetation where there is forest transformation whereas others will be limited to the expansive and interlinked forest stands (Pardini *et al*., 2005; Pires *et al*., 2002). Habitat loss has negative impact on species richness (Findlay & Houlahan, 1997) as well as the restricted distribution and abundance of organisms (Gibbs, 1998). Bats as well as rodents provide reliable ecological feedback on impacts of forest management processes at regional levels (Kaminski *et al*., 2007).

Vegetation cover affects the distribution of terrestrial small mammals as well as their densities (Ajayi & Tewe, 1978). Bats are affected by roost structure and availability (Humphrey, 1975; Li *et al*., 2005); temperature (Yom Tov & Kadmon, 1998); precipitation (Yom Tov & Kadmon, 1998); vegetation types and vegetation clutter (Peters *et al*., 2006). Rodents have been shown to be affected by the presence of large mammals (Hoffman & Zeller, 2005); altitude (Mulungu *et al*., 2008); vegetation type (Prakash & Singh, 2001); human disturbance (Jing yuan *et al*., 2008) and precipitation (Lesinski *et al*., 2000). Due to their cryptic nature, small mammals have been less studied and information on their diversity, natural history and distribution remains scanty in East Africa (Oguge *et al*., 2004). This is despite the fact that they represent over 60% of global mammalian diversity (Schipper *et al*., 2008). Kenya boasts of more than 100 species of bats (Patterson & Webala, 2012).

Oloolua acts as a vital wildlife corridor between the Nairobi National Park and the Ngong hills which are important wildlife refuges themselves. The forest is part of the northern belt composite of dry forest fragments namely Karura, Muguga, Lang'ata, City Park, Kamiti and Dagoretti which occur in the peri-urban centres around Nairobi and are important as they harbor important wild flora and fauna (Gichuki *et al*., 2006). Though the forest bears potential as a biodiversity hub, it has in the recent past faced serious threats through intense stone quarrying, pollution caused by dumping from picnicking visitors and nearby settlements as well as over-harvesting of forest products including medicinal plants and firewood. Local livestock herders trespass and graze their livestock in the forest. Due to there being no published work of its small mammal biodiversity, small mammal conservation efforts have also been lacking. Lack of basic ecological data as regards urban and rural green spaces is the greatest obstacle to biodiversity conservation (Hong *et al*., 2005). This influenced this survey into the documentation of what Oloolua forest harbors with the hope that it will inform appropriate conservation and protection of this and other invaluable private as well as public green spaces. Our aims were: (1) document a current check list of small mammal species found in Oloolua forest (2) to determine the abundance and distribution of small mammal species in the various habitats of Oloolua forest (3) investigate the seasonal changes in small mammals' abundance in the forest.

MATERIALS AND METHODS

Study Area

This study was conducted in Oloolua forest (S1º22'0.12", E 36º42' 0") situated approximately 20 kilometers south west of Nairobi in the peri-urban area of Karen.It is surrounded by Bulbul location to the north, Rongai Township to the south and Olepolos to the west. The forest reserve has a variety of habitats that can be clustered broadly into four- the indigenous forest, the plantation forest, the quarry as well as the woodland forest. The four fall into two major classifications- less disturbed (indigenous and woodland) and disturbed (quarry and plantation habitats). The less disturbed forest covers a total of 479.6 hectares whereas 182 hectares are disturbed. Indigenous forest habitat is characterised with trees like *Vepris simplicifolia, Maytenus heterophylla* and *Elaeodendron buchananii* with the first species being the most populous in the zone. The woodland habitat is characterised with trees such as *Strychnos henningsii*, *Vepris simplicifolia* and *Ochna ovata*. The quarry habitat is an old quarry that has really regenerated and it bears several tall trees as well. It was dominated with *Olea africana, Strychnos henningsii* and *Vepris simplicifolia* trees. The plantation forest habitat has one tree species (*Eucalyptus botryoides*) being most dominant but other two tree species that occur in the habitat are *Olea africana* and *Croton megalocarpus.*

Rodents, shrews and small carnivore survey

Stratified random sampling was used to establish transects in the various habitat types in the forest. A 100 m long transect was established in each vegetation type and was maintained throughout the sampling period. Trap stations targeting rodents and shrews were positioned at intervals of 10 m in the various habitats (Gurnell & Flowerdew, 2006). In each trap station, different types of traps were used to increase animal captures (O'Farrell *et al*., 1977). A mixture 10 collapsible aluminium Sherman traps (medium sized 23*9.5*8 cm), 20 snap traps (Victor snaps measuring 17.5*8.5 and museum specials 14*7 cm), 5 pitfalls (5 litre buckets buried in the ground such that the top of the bucket was flush with the ground) and 1 live wire tomahawk were used in each transect to facilitate rodents and shrews' sampling. A total of 36 traps were therefore placed in each transect to facilitate capture. Sherman and snap traps were baited using a mixture of peanut and oats whereas tomahawks had sardines (Rosatte *et al*., 2011). Traps were checked twice a day, early in the morning (0730-0830 hours) and in the evening (1730-1830 hours).We sampled rodents, shrews and small carnivores for a total of 90 nights

(45 nights in the dry season followed by 45 nights in the wet season) in each transect. Opportunistic sightings were also employed and any species sighted was recorded and categorized in relation to the habitat where it was seen.

Bat survey

We used identical protocols in each habitat to capture bats (O'Farrell *et al*., 1977):1 mist net (3*12 m) was placed in each habitat along flyways and forest trails (Kunz & Kurta, 1988), open for 9 hours each night for four nights (36 net hours per habitat) resulting in a total effort of 2160 net hours. During the rainy season sampling continued unless the rains were very heavy and persisted for more than an hour. In that case sampling was halted and resumed when the rains had subsided. The captured bats were identified morphologically in the field using Identification keys (Setzer, 1971) and field guides (Kingdon, 2015; Monadjem *et al.*, 2010; Patterson & Webala, 2012). All animal captures and handling was done following protocols recommended by the American Society of Mammalogists (Sikes *et al*., 2011). Species which could not be identified in the field were collected as vouchers and fixed in 10% formalin, then later deposited with Mammalogy Section of National Museums of Kenya for further identification. After the necessary identification at the museum they were preserved in 70% ethanol.

Statistical Analyses

We used the method described by Nelson and Clark to account for both sprung traps as well as those predated upon. The formula CE=A×100/(TU-IS/2), where CE= catch per effort, A= number of animals captured of the desired species, P= number of trapping intervals, I= length of trapping interval, N = number of traps, S= total traps sprung by all causes and TU= P×I×N (number of trapping units). We estimated species richness as the number of species caught in each habitat type. Data was checked for normality and homogeneity (Zuur *et al*., 2010) and wherever necessary, log transformed to achieve normality (Axelsson *et al*., 2011). Data collected included number of species encountered in the forest and in the various habitat types, abundance of the small mammals, and captures across the wet and dry seasons. Data on species opportunistically sighted was not subjected to data analysis. Relative abundance of species captured was calculated as the number of individuals captured for a particular species divided by the total number of individuals of all species captured. Analyses were performed using Paleontological Statistics PAST (version 3.1). Species diversity was determined using the Shannon-Weiner index given by the formula $H' = -\sum (P_i * \ln P_i)$ where H' is the diversity index; P_i is the proportion of representation by species *i* and ln is the natural logarithm. A two tailed student's t-test was used to test if there was a significant statistical difference in the captures across the two seasons whereas a one way ANOVA was used to test for overall differences in captures amongst the four different habitats. Levels of significance (α) were determined at P=0.05.

RESULTS AND DISCUSSION

Species composition of small mammals

A total of twelve small mammals species were recorded in Oloolua forest during the 90 day sampling period (Table 1).

The 12 species included 9 from standard trapping techniques and 3 from opportunistic observations. Those from standard trapping techniques belonged to 3 orders, viz. Rodentia - 43.78%; Soricomorpha - 2.76%; Chiroptera - 53.46% (Table 2).

Table 1. Updated checklist of small mammals in Oloolua Forest.

Order	Family	Species	Common name
Rodentia	Sciuridae	*Paraxerus ochraceus*	Ochre bush squirrel
	Nesomyidae	*Cricetomys ansorgei*	Southern giant pouched rat
	Muridae	*Gerbiliscus boehmi*	Robust gerbil
		Lemniscomys striatus	Zebra mouse
		Mus spp.	Common mouse
Soricomorpha	Soricidae	*Crocidura spp.*	White toothed shrew
Chiroptera	Pteropodidae	*Epomophorus wahlbergi*	Epauletted fruit bat
	Nycteridae	*Nycteris thebaica*	Slit faced bat
	Vespertilionidae	*Neoromicia nana*	Pipistrelle bat
Primates	Galagidae	*Otolemur garnetti kikuyuensis*	Small eared galago
Carnivora	Herpestidae	*Herpestes sanguineus*	Slender mongoose
		Ichneumia albicauda	White tailed mongoose

Table 2. Species composition and relative abundance (%) of live trapped small mammals in study area.

Order	Family	Species	Abundance	Rel. Abundance %
Rodentia	Sciuridae	*Paraxerus ochraceus*	32	14.75
	Nesomyidae	*Cricetomys ansorgei*	47	21.66
	Muridae	*Gerbilliscus boehmi*	6	2.76
		Lemniscomys striatus	7	3.23
		Mus spp.	3	1.38
Soricomorpha	Soricidae	*Crocidura spp.*	6	2.76
Chiroptera	Pteropodidae	*Epomophorus wahlbergi*	108	49.77
	Nycteridae	*Nycteris thebaica*	1	0.46
	Vespertilionidae	*Neoromicia nana*	7	3.23
Primates	Galagidae	*Otolemur garnetti kikuyuensis* [φ]	[φ]	[φ]
Carnivora	Herpestidae	*Herpestes sanguineus* [φ]	[φ]	[φ]
		Ichneumia albicauda [φ]	[φ]	[φ]
Total			217	100

[φ]Observed species from opportunistic method

A total of 12,938 corrected trap nights (12960 totals trap nights) and 2160 net hours' realised 101 rodents/shrews and 116 bats respectively recording a mean trap success of 0.781% for rodents and shrews and 5.417% for bats. 7 species were encountered and recorded in two habitats (indigenous and eucalyptus), 5 were recorded in the quarry habitat and 8 were found in the woodland region.

The most dominant volant species was the epauletted fruit bat (*Epomophorus wahlbergi*), whereas amongst the non-volant, the southern giant pouched rat (*Cricetomys ansorgei*) was the most dominant. Zebra mice (*Lemniscomys striatus*) were not captured in the indigenous and quarry habitats, whereas mice (*Mus spp.*) were captured in all other habitats except indigenous habitat. The slit-faced bat (*Nycteris thebaica*) was not captured in the woodland. It was also observed that the slit-faced bat (*N. thebaica*), the pipistrelle (*Neoromicia nana*), the robust gerbil (*Gerbilliscus boehmi*) and the zebra mice (*L. striatus*) were not caught in the quarry habitat; whereas *N. thebaica* and *N. nana* were not captured in the eucalyptus habitat. *N. thebaica* was exclusively captured in the indigenous habitat.

Abundances of small mammals across habitats

The results indicate that *E. wahlbergi* was the most numerous species from the Chiropteran order in Oloolua, whereas *C. ansorgei* was the most numerous amongst the rodents and shrews, during the sampling period. *P. ochraceous* was second amongst the rodents and shrews category. Two pairs of species (*G. boehmi* & *Crocidura spp.*; and *L. striatus* & *N. nana*) had equal abundances of six and seven respectively. One species (*N. thebaica*) had a very low capture of only one individual. We pooled the habitats to have just two groups- less disturbed and disturbed habitats, and the Shannon Weiner diversity indices were 1.477 and 1.594 respectively.

Across the habitats, indigenous habitat recorded the highest number of captures (78), followed by eucalyptus (67), woodland (38) and lastly quarry (34). There was no significant difference between species captured in the four habitats during the sampling period, $F_{(3, 35)} = 0.5209$ with $P>0.05$. A trap success range of between 0.43-1.269% (with an average of 0.7805) for rodents and shrews and 3.519-8.704% (with an average of 5.3705) for bats was recorded during the trapping period (Table 3).

Table 3. Trap success of small mammals in the various habitats.

Habitat	Captures: Rodents & shrews	Corrected trap nights	Trap success (%)	Captures: Bats	Net hours	Trap success (%)
Indigenous	31	3238	0.957	47	540	8.704
Woodland	14	3232	0.433	24	540	4.444
Quarry	15	3237	0.463	19	540	3.519
Eucalyptus	41	3231	1.269	26	540	4.815
Totals	101			116		
Average			0.7805			5.3705

Seasonal variations of small mammals

It was noted that there were zero captures in both dry and wet seasons for several species: *Mus spp.* and *L. striatus* in the indigenous habitat; *N. thebaica* in the woodland; *G. boehmi*, *N. thebaica* and *N. nana* in the quarry habitat; and both *N. thebaica* and *N. nana* in the eucalyptus habitats. Those species which were captured only in the dry season are *P. ochraceus*, *G. boehmi*, *Crocidura spp.*, *N. thebaica* and *N. nana* in the indigenous habitat; *Mus spp.* and *Crocidura spp.* in the woodland habitat and *Crocidura spp.* in the eucalyptus habitat. Species not captured during the dry season but were captured during the wet are *G. boehmi* (woodland habitat) and *Mus spp.* (quarry and eucalyptus habitats). A comparison of total captures of all species in the two seasons using a student's t test gave t (9) = -0.03939 with P= 0.96907 >0.05, indicating that there was no significant statistical difference between individuals captured in the two seasons.

Surveys of small mammals' abundance and distribution in urban forests have indicated that several species actually thrive well there. In north-western Ethiopia, a study in Arditsy Forest, an urban forest recorded 8 species- 7 rodents and 1 insectivore (Bantihun & Bekele, 2015). The same study revealed that the seven rodents were all from the Muridae family, and the one insectivore was a shrew of the Soricidae family. This is consistent with our study too, in terms of the families' representation, where we recorded both Muridae and Soricidae, besides the bat families which were not captured in the Ethiopia study. Nevertheless, this is relatively low compared to the results of (Li *et al*., 2005) who realised 17 species of the order rodentia and 7 of insectivore in a study in the eastern part of the Wuling mountains in central China. This may be attributed to a longer sampling period (five years) as well as the fact that it was conducted in forest ecosystems different from Oloolua (evergreen). However, it is worth noting that it is possible this study may have under-estimated some rare species probably due to the length of the sampling period or the method(s) used. Further chiropteran survey work in the forest ought to consider the use of harp traps which have been shown to be more efficient (Findlay & Houlahan, 1997); or a combination of all the methods which eliminates the challenge of each (Oguge *et al*., 2004).

Pedersen (2001) in a study in Ngong forest (approximately 13 kilometres from Oloolua) registered 8 species of rodents and shrews. Three of these species (*Mus spp*. *L. striatus* and *Crocidura spp.*) were also captured in my study. This may be attributable to the fact that these stands of forests were at one time sections of the same large continuum of urban forests block that have since been delinked due to human activities resulting in deforestation and habitat destruction.

Species diversities (Shannon Weiner) comparison between less disturbed and disturbed pooled habitats show that the disturbed habitats had a slightly higher figure (though difference was not statistically significant). This is not strange as it is consistent with studies by Vera y Conde & Rocha, (2006) in an Atlantic rainforest of Ilha Grande in southeastern Brazil. One possible reason for higher diversities in the disturbed habitats of Oloolua would be the fact that many years have elapsed since the quarrying stopped in the area, and reclamation of the quarried area done. The long period of time may have allowed considerable regeneration to take place. The old quarry area is presently characterised by huge trees and does not bear large expanses of bare ground. This may advertently have assisted the small mammals to colonise the habitats yet again. It has been noted that previously disturbed but regenerating forests also exhibit high diversities of some small mammal species (Ricart *et al*., 2008). *C. ansorgei* and *P. ochraceus* have also been encountered in other environs of Nairobi e.g. Kahawa, by Martin & Dickinson, (1985). The species that had the lowest abundance (*N. thebaika*) seems to be a resource specialist, and its population seems to have declined as a response to urbanisation (McKinney, 2008).

Generally, the captures were relatively low as compared to studies done in comparable areas. Low trap success realised in the area may be attributable to a number of factors. Disturbance from non-target species (birds and monkeys) was evidenced, as well as other animals like livestock, evidenced also by (Bantihun & Bekele, 2015). Disturbance from the latter sources was quite prevalent affecting the overall capture rates. There was a case of theft of traps but replacement of the stolen traps was done a day after realisation. The low trap success may also have been due to disturbance and pollution caused by the increasing number of people visiting the reserve which was witnessed during our stay there. The presence of a nature trail, several camping sites and a waterfall in the area has attracted visitors from far and wide.

The higher abundance of bats in the less disturbed areas as compared to the disturbed (combined abundance of 68 against 50 in our study) has also been noted in Michigan (USA) and Poland, where it was noted that bats' species richness tends to be highest in the least altered areas and lessens as levels of urbanization increased (Kurta & Teramino, 1992; Linzey & Kesner, 1997). This connotes that bats are sensitive to human disturbance and habitat alteration. It may also be attributed to availability of roost sites and variety of food resources in the less disturbed habitats. Undisturbed native tree dominated forests are known to provide higher diversities of fruit trees ensuring availability of fruits almost all year round (Opler *et al*., 1980).

The abundance of two bat species i.e. *N. nana* and *N. thebaica*, was relatively low compared to that of *E. wahlbergi*. Populations that are isolated may end up realizing decreased genetic heterozygosity, and are highly likely to face extirpation. According to a number of species may exhibit habitat specificity which often restricts their abundance and distribution. This may be the case with the two rare species aforementioned. What is not known is if these two species may have highly specific habitat requirements and still suffer from impeded migration ability to other favourable habitat patches. The United Nations National Bat Survey notes that bats of the family Vespertilionidae (in our case the species *N. nana*) strongly avoid searching for food in habitats that have been altered through various anthropogenic activities including cultivation. Areas around the study site had farming being practiced by the locals, possibly impacting *N. nana* negatively. Loss of foraging habitats and reduction in its quality as well as fragmentation are rapidly becoming serious threats to bat assemblages. These have come about due to increased food demands to cater for the ever rising human population with the end results being fragmentation and habitat loss in a global scale. Working in the same study site recorded 9 small mammal species. The lower species richness is probably due to the fact that he did not purpose to capture any volant species. On the contrary, our study focussed on both volant and non-volant species, giving a more exhaustive and complete small mammal diversity account. Possible absence from our captures could be the effect of continued development in the forest through the erection of several new buildings in the past nine years since the earlier study. It may also be attributed to the difference in the sampling sites location, given that the forest is hundreds of hectares big.

Two species were captured in all the habitats in our study possibly due to structural homogenization, which is responsible for communities of small mammals that are characterised by generalists. Kelt *et al*. (2013) argues that heterogeneous ecosystems that are prone to anthropogenic disturbance will be dominated by generalists. These two species *C.ansorgei* and *P. ochraceus* behave like generalists since they do not exhibit any distinct habitat preference. It was noted that there was no significant statistical difference between individuals captured in the dry and wet seasons. It is more common for captures to be higher during the wet season but this was not the case in my study. A possible reason may be availability of alternative food resources right in the individual species' natural habitats which may translate to lower than expected captures. With greater food availability during the wet season there is possibility of seasonal diet change by some species. Other studies have indicated that this seasonal availability of food may bring about reduced captures and trap success (Kelt *et al*., 2013).

It is worth noting that Oloolua forest reserve is an important small mammals' refuge within the urban city of Nairobi. This therefore calls for committed and persistent protection of the reserve as well as the adjacent areas from any anthropogenic disturbance. Maintenance of corridors that will ensure linkages across adjacent habitats and forest patches will be critical if the fauna in this urban forest will move freely. Construction of additional roads and other structural developments should not be prioritised at the expense of possible biodiversity loss. The forests proximity to Nairobi town offers unparalleled opportunities to study the ecology of sympatric small mammal species in an urban context.

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