Kitobo Forest of Kenya, a unique hotspot of herpetofaunal diversity

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Abstract. Herpetologically, the remoteness of Kitobo forest in south-eastern Kenya has partly contributed to it remaining virtually un-explored until 2007. Three surveys were conducted in December 2007, December 2009 and April 2010 aimed at generating a comprehensive list of the forest amphibians and reptiles. Using largely timed-species count method, 13 species of amphibians representing eight families and 32 reptiles belonging to 11 families were recorded. Overall species diversity was highest during the 2007 sampling. The richness and abundance of amphibians was highest during the April 2010 sampling period when the amount of rainfall was also highest. The results of species accumulation curves of the three sampling periods did not plateau demonstrating that more species occur in this forest. Pressure on this forest fragment from the adjacent local people is high which in addition to the annual floods threatens its long-term survival. For example the distribution and abundance of some forest associated species such as the tree frogs *Leptopelis flavomaculatus* and *Hyperolius puncticulatus* appear to fluctuate with flood events and may decline in future. Considering the forest associated herpetofanua recorded, Kitobo forest is zoogeographically assignable to the East African coastal forest biodiversity hotspot. The documentation of high species richness and diversity in this small forest fragment strongly highlight its biodiversity importance and place it among the most important sites for the conservation of reptiles and amphibians in Kenya.

Keywords. Herpetofaunal diversity, lowland forest, rainfall, floods, zoogeography.

INTRODUCTION

In the last decade in Kenya there has been increased interest in exploration of reptiles and amphibians in forests. This has resulted to production of species lists e.g. lower Tana River forests (Malonza et al., 2006), Kakamega forest (Schick et al., 2005, Lötters et al., 2007; Wagner and Böhme, 2007; Wagner et al., 2008) and the Taita Hills (Malonza et al., 2010). What is evident from these recent studies is that they are all from the well

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known world biodiversity hotspots namely the Guineo-congolian rainforest, Eastern Arc and coastal forests of East Africa (Mittermeier et al., 2004).

Kitobo forest is one of the little known arid land forest which possibly due to its remoteness has escaped the attention of biodiversity surveyors. No past biodiversity work has ever been done in this forest despite being a government gazetted community trust forest. We here present the first ever baseline data on its reptiles and amphibians diversity across three sampling wet seasons of varying rainfall intensity. From the results we try to assess the biogeographical affinity of the Kitobo forest using herpetofauna as indicator species. While highlighting its herpetofaunal diversity we briefly discuss the observed threats and their implications for sustainable conservation of the forest.

STUDY AREA

The Kitobo Forest is a ground water forest located about 10 km South-East of Taveta town in the Taita-Taveta County, south-eastern Kenya (Fig. 1). It is approximately 250 km inland from the coast and on the extreme lowland North-East of the Tanzanian Eastern Arc Mountain block of North Pare Mountains (Newmark, 2002), near the Kenya-Tanzania border (3°25.777'S; 37°36.660'E). It covers an area of ca. 160 ha at an altitude of about 730 m above sea level. It is a gazetted community Trust forest. It is largely an evergreen indigenous forest surrounded by arid lands of Acacia bushes. It owes its existence to the eruption on its edge of a large Njoro spring and other small ones inside the forest originating from the volcanic Mt. Kilimanjaro. The springs then develop into a permanent river that flow through the forest dividing it into two major blocks. Floods of varying intensity from rains in Mt. Kilimanjaro highlands in the north seasonally covers parts of the forest with some water stagnating throughout in some parts of the forest that has resulted in drying of trees. Otherwise rainfall in the area is low, unreliable and erratic. The estimated annual mean rainfall and temperature is 530 mm and 22 °C respectively (Jätzold and Schmidt 1983). Majority of the local multiethnic people depend on agriculture for their livelihood. Through irrigation they grow a wide range of crops such as bananas, onions, kales, cabbages, tomatoes, cucumbers, maize, citrus, pepper, mangoes, and coconuts mostly for outside market.

MATERIALS AND METHODS

Surveys were conducted on three occasions (December 2007, December 2009 and April 2010 each covering about two weeks. All these three periods fall within the ordinary wet season for the area but the weather conditions varied from very low rains to high, from the first to the third sampling occasion respectively. Similarly flooding events and intensity also increased from the first to the last sampling period.

Counting of amphibians and reptiles was done by using a timed species count method similar to those described by Karns (1986); Heyer et al. (1994); Sutherland (1996). This entails quietly walking and intensively searching within all possible herpetofaunal microhabitats such as under leaves, debris, decomposing tree stumps and logs , on tree, shrubs, bushes, wetlands including digging for burrowing species. This was done for one person hour both day and night by two observers. Opportunistic day and night visual and acoustic encounter surveys were made (Rödel and Ernst, 2004; Veith et al., 2004). Trapping using X-shaped drift fence with pitfall traps, a modification of that used by Corn (1994) with segments of 5 m length upright plastic sheet (drift fence) stretching between

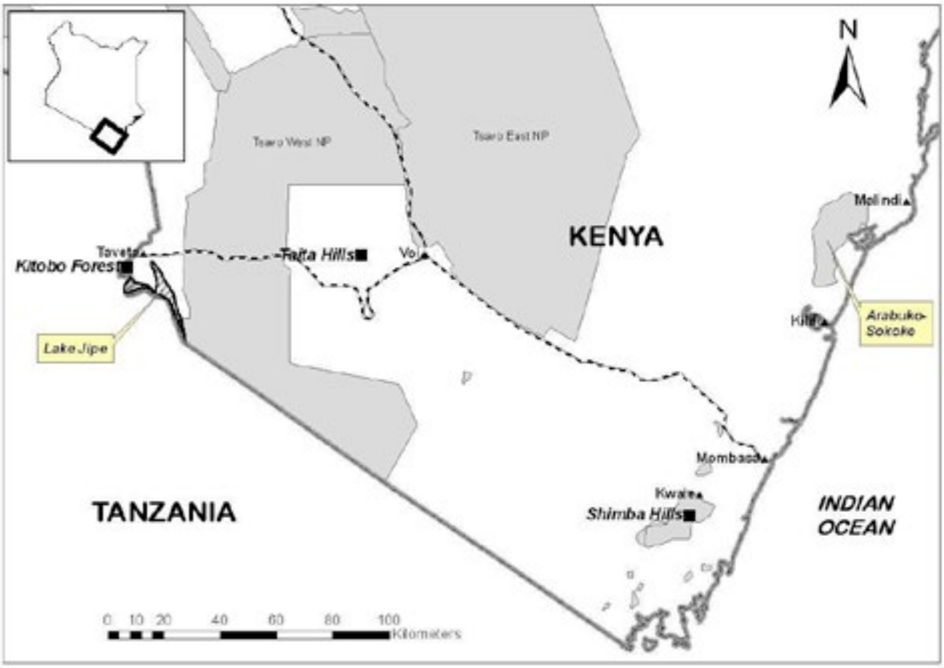

Fig. 1. Map showing the location of Kitobo forest. Inset: Map of Kenya showing the location of the study area.

the buckets was used. The pitfall traps consisted of 10 litre plastic buckets flush with the ground; in total every trap array had five buckets. Two trap sets were established in the forest interior for five days in the first occasion, seven days in the second and third sampling. Traps were used for detection of small primarily nocturnal crawling herpetofauna not easily detected through other methods.

The use of a combination of methods was to ensure detection of as many species as possible. Quantitative data analysis used data generated from timed species count only as the others either yielded less data like the traps or were un-standardized such as opportunistic visual encounter surveys (VES). Voucher specimens collected except amphibian larvae were fixed in 10% formalin (after euthanasia). Tissues of selected specimens were preserved in absolute alcohol for the possibility of later molecular analyses. Tadpoles were fixed in 95% ethanol. Colour photos of selected species and their habitats were taken. Frog calls where possible were recorded by means of an analogue Marantz PMD-222 audio cassette recorder and a Sennheiser K6-ME66 directional microphone or a Sony D20 digital camera. GPS data were determined using a 12 Channel Garmin receiver. All these data are deposited in the National Museums of Kenya (NMK), Nairobi.

Species richness and diversity analysis

In the context of this study species richness and diversity refer to the number of different species and abundance in the number of individuals of each species observed (Magurran, 1988).

The observed species richness was estimated using the EstimateS 8.2 program (Colwell, 2009). Herpetofaunal species diversity was measured with Shannon Index (*H*'). A number of species richness estimators were used: – Chao 1, ACE, and Jacknife 1. Species accumulation curves were calculated and generated using the software programme EstimateS using 1000 randomizations. These were compared to the observed species.

The taxonomy for amphibians followed Frost et al. (2006) and Frost (2007) while that of reptiles follows Spawls et al. (2002) except for scincid lizards that follows Brandley et al. (2005). Selected individuals of underrepresented species were kept as voucher specimens and deposited in National Museums of Kenya (NMK).

Statistical analyses

The variation in mean species diversity over the three sampling occasions (year or season) was quantified using the non-parametric Kruskal-Wallis H test. Data was analyzed with STATISTICA 6.0 software (StatSoft, 2001) at 5% significance level.

RESULTS

Species richness, diversity and composition

A total of 13 amphibian species representing eight families and 32 reptile species representing 11 families were recorded excluding one snake species (*Atractaspis bibronii* A. Smith, 1849) recorded only during a one day reconnaissance survey in 2006 (Appendix 1). Majority of the species were lizards with terrestrial/arboreal *Trachylepis maculilabris* (Gray, 1845) and the burrowing *Melanoseps loveridgei* Brygoo & Roux-Estève, 1981 being the most abundant especially during the dry periods (appendix). More species were recorded on the forest edge than the interior. Some species such as *Leptopelis flavomaculatus* **(**Günther, 1864) and *Hyperolius puncticulatus* (Pfeffer, 1893) were restricted to the forest interior. *Hemisus marmoratus* (Peters, 1854) and *Amietophrynus gutturalis* (Power, 1927) were the two most abundant species caught in traps. Using data from timed species counts (TSC), the total number of species recorded during the sampling periods was almost the same with amphibians increasing with increasing rainfall intensity from 2007 through 2009 to 2010. However, the mean species diversity of hereptofauna per sampling was highly significant and different (Kruskal-Wallis $H = 24.55$, $df = 2$, $n = 117$, $P < 0.001$) and highest in 2007 (Table 1).

The non-parametric species richness accumulation curves did not reach an asymptote (Figure 2). The mean number of species plus or minus the standard deviation (SD) per sampling by the other estimators was always higher than the observed species (Sobs) (Table 1).

Natural history notes

During our surveys we observed biological information of some species previously unknown. While the advertisement call of *Leptopelis flavomaculatus* is known, the species breeding and tadpoles were largely unknown. We managed to collect three tadpoles within water spring puddles inside the forest and they had a labial tooth row formula (LTRF)

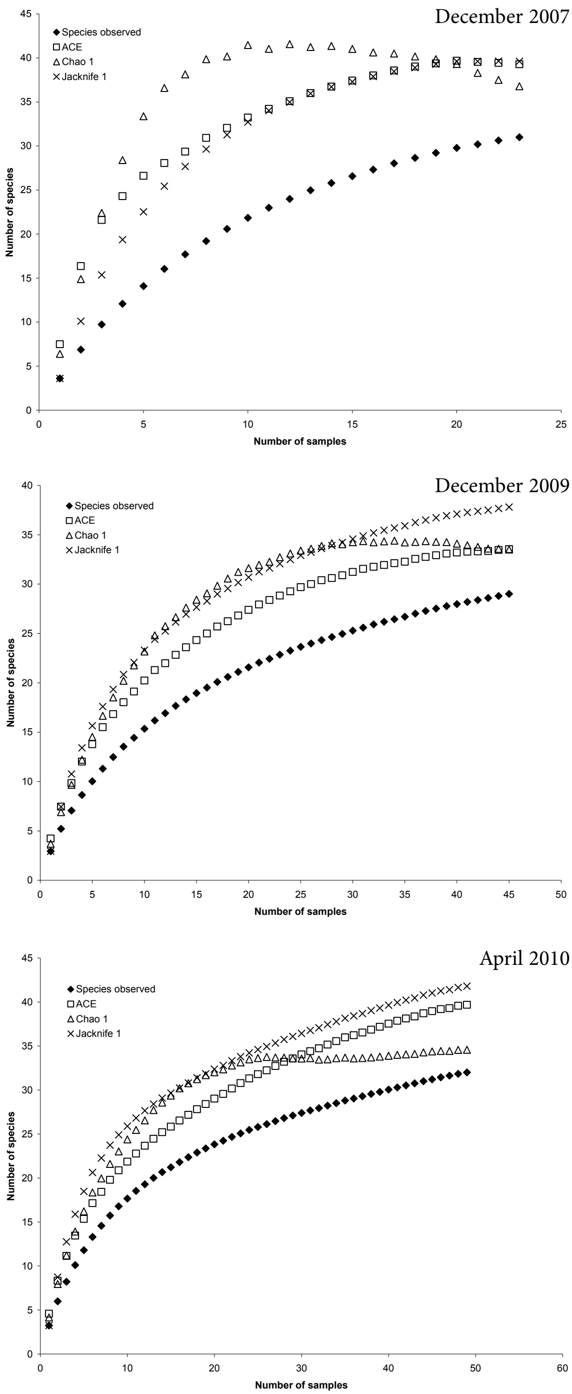

Fig. 2. Species accumulation curves of the timed species count samples showing species observed and other species richness estimators during the three sampling periods.

Table 1. The mean species richness, diversity and richness estimators±1SD for the three sampling periods

Species richness index	December 2007	December 2009	April 2010
Species observed (Sobs)	31 ± 8.07	29 ± 6.95	32 ± 7.30
Abundance based cover estimate (ACE)	39.28 ± 8.41	33.54 ± 7.77	39.68 ± 8.93
Chao 1	36.79 ± 9.21	33.50 ± 8.30	34.57 ± 7.61
Jacknife 1	39.61 ± 10.31	37.80 ± 8.73	41.80 ± 8.95
Shannon	3.0	2.65	2.75

of 4(2-4)/3. The other biological notes were of the species of the limbless burrowing skink, *Melanoseps loveridgei* which like the other *Melanoseps* species was assumed to lay eggs. During our sampling a gravid female was dug-out within a decomposing log and while being handled gave birth into a young one of about 60 mm total length.

Species range extensions

This study extended the distribution records for a number of species in Kenya. These are *Leptopelis flavomaculatus*, *Hyperolius puncticulatus* (Pfeffer, 1893), *Hyperolius tuberilinguis* Smith, 1849, *Xenopus muelleri* (Peters, 1844), *Hyperolius glandicolor* (Peters, 1879), *Cnemaspis africana* (Werner, 1895), *Lygodactylus luteopicturatus* Pasteur, 1964, *Melanoseps loveridgei*, *Trachylepis maculilabris, Thelotornis mossambicanus* (Bocage, 1895), *Dasypeltis medici* (Bianconi, 1859), and *Dendroaspis angusticeps* (A. Smith, 1849) see appendix.

Zoogeographical affinity

The findings of this study demonstrate that Kitobo forest consists of a combination of species found in the East African coastal forests, Eastern Arc Mountains and widespread African savanna species. However, considering forest associated species most of them are affiliated to the lowland coastal forest. Examples are *Leptopelis flavomaculatus*, *Hyperolius puncticulatus*, *Hyperolius tuberilinguis*, *Xenopus muelleri*, *Lygodactylus luteopicturatus*, *Dendroaspis angusticeps* among others (see appendix).

DISCUSSION

The results presented here show that Kitobo forest has a very rich and diverse herpetofauna. The results on local amphibian and reptile species richness in the forest show that there are more species than observed in this lowland forest as evident from the species accumulation curves that did not plateau. This is particularly due to the influx of species from the surrounding arid lands that use the evergreen forest as a refuge. In particular we expect more reptiles especially snakes than recorded because these are normally very cryptic and detect the presence of an observer and then disappear before being spotted. The higher species diversity in 2007 than 2009 and 2010 was due to the increase in abundance of open water breeding amphibians with increasing amount of rainfall.

The presence of high species richness and diversity in Kitobo forest concurs with other studies elsewhere. These have found that high species richness in lowland ecosystems is associated with high energy and productivity (see Hawkins et al., 2003; Willig et al., 2003). Energy in form of temperature and water are known indirect measures of net primary productivity which in turn results to high species richness (e.g. van Rensburg et al., 2002; Sanders et al., 2003). In Kitobo forest there is substantial ground water from springs much of the year and optimum temperatures (Jätzold and Schmidt, 1983) favourable for high habitat productivity and in turn species diversity. The high species richness along the forest edge was due the presence of basking sites for reptiles and open water breeding sites for amphibians (Duellman and Trueb, 1994; Zug et al., 2001). This high species richness and diversity follows the phenomenon of edge effects that provide more habitat niches for species co-existence (Fagan, 1999).

Zoogeographically, the presence of *Leptopelis flavomaculatus, Hyperolius puncticulatus, Xenopus muelleri, Lygodactylus luteopicturatus* and *Dendroaspis angusticeps* which are mostly associated with East African coastal forests (see Howell, 1993; Schiøtz, 1999; Spawls et al., 2002; Channing and Howell, 2006; Burgess et al., 2007) clearly shows the close affinity of Kitobo forest to this biodiversity hotspot.

The key threat to Kitobo forest herpetofauna is floods resulting from rainfall in the highlands of Mt. Kilimanjaro. Floods are one of the results of global climate change. Elsewhere studies have found varying direct and indirect effects of floods on amphibian and reptile communities (Borczyk, 2001; Maltchick et al., 2007; Moreira et al., 2008; Furlani et al., 2009). The direct effects include affecting the species breeding phenology while indirectly they destroy the breeding and foraging sites. These effects are species specific resulting in either population decline, fluctuation, increase or no change. Less affected are the arboreal ones because of their ability to climb on trees (Borczyk, 2001). In Kitobo forest floods have resulted in destruction of the habitat with part of the forest where stagnant water remains resulting to drying of plants. This was observed to result's in shifts in the abundance of certain forest associated species. For example with increasing flood events from 2007 through 2009 to 2010 the abundance of the tree frog *Leptopelis flavomaculatus* fluctuated by avoiding recently flooded sites and establishing new populations in un-flooded sites of the forest. Apart from floods there high human population adjacent to the forest due to the intensive agriculture (irrigation schemes) relies on the forest for fire wood, palm tree material and plant poles that continue to open-up the forest. Kitobo forest is an island in a 'sea' of intensive agricultural development, and concern is raised here for its continued protection so as to remain a species refuge. More work on herpetofauna including other forms of biodiversity is needed covering different times of the year to come up with a comprehensive species list of this forest refuge and get a clear picture of its biogeographical assignment.

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Appendix. The distribution and abundance of the 32 reptile and 13 amphibian species in Kitobo forest during the three sampling occasions using timed species count method

Species	2007	2009	2010	Habitat	Habits
AMPHIBIANS					
Pipidae					
Xenopus muelleri (Peters, 1844)	0	0	9	Interior/Edge	Aquatic
Bufonidae					
Amietophrynus gutturalis (Power, 1927)	16	4	22	Interior/Edge	Terrestrial
Hemisotidae					
Hemisus marmoratus (Peters, 1854)	2	9	10	Interior/Edge	Fossorial
Arthroleptidae					
Leptopelis flavomaculatus (Günther, 1864)	3	18	53	Interior	Arboreal
Hyeproliidae					
Hyperolius glandicolor (Peters, 1879)	16	42	66	Interior/Edge	Arboreal
Hyperolius puncticulatus (Pfeffer, 1893)	5	18	10	Interior	Arboreal
Hyperolius tuberilinguis Smith, 1849	10	2	34	Interior/Edge	
Kassina senegalensis (Duméril & Bibron, 1841)	0	0	1	Edge	Terrestrial

Species	2007	2009	2010	Habitat	Habits
Ptychadinidae					
Ptychadena anchietae (Bocage, 1867)	6	4	25	Interior/Edge	Fossorial
Ptychadena mascareniensis (Duméril & Bibron, 1841)	19	33	94	Interior/Edge	Terrestrial
Phrynobatrachidae					
Phrynobatrachus acridoides (Cope,1867)	14	51	30	Interior/Edge	Arboreal
Phrynobatrachus natalensis (Smith, 1849)	0	0	3	Edge	Arboreal
Pyxicephalidae					
Tomopterna cryptotis (Boulenger, 1907)	0	0	2	Edge	Terrestrial
Sub-total number of species	9	9	13		
REPTILES					
Gekkonidae					
Lygodactylus cf *scheffleri* Sternfeld, 1912	0	1	1	Edge	Arboreal
Lygodactylus luteopicturatus Pasteur, 1964	2	15	15	Interior/Edge	Arboreal
Hemidactylus platycephalus Peters, 1854	7	7	11	Interior/Edge	Arboreal
Hemidactylus mabouia (Moreau de Jonnés, 1818)	4	16	23	Interior/Edge	Arboreal
Hemidactylus squamulatus Tornier, 1896	1	0	0	Edge	Terrestrial
Cnemaspis africana (Werner, 1895)	2	0	0	Interior	Arboreal
Chamaeleonidae					
Chamaeleo dilepis Leach, 1819	7	9	1	Edge	Arboreal
Scincidae					
Melanoseps loveridgei Brygoo & Roux-Estève, 1981	14	2	1	Interior	Fossorial
Lygosoma sundevalli (A. Smith, 1849)	5	2	2	Interior/Edge	Fossorial
Panaspis wahlbergii (A. Smith, 1849)	1	0	0	Edge	Terrestrial
Trachylepis maculilabris (Gray, 1845)	8	74	15	Interior/Edge	Arboreal
Trachylepis striata (Peters, 1854)	2	14	29	Interior/Edge	Arboreal
Trachylepis planifrons (Peters, 1878)	0	1	2	Edge	Arboreal
Trachylepis brevicollis (Weigmann, 1837)	0	5	3	Edge	Terrestrial
Lacertidae					
Latastia longicaudata (Reuss, 1834)	1	4	2	Edge	Terrestrial
Heliobolus spekii Günther, 1872	0	0	2	Interior/Edge	Terrestrial
Agamidae					
Agama lionotus Boulenger, 1896	1	2	19	Edge	Arboreal
Gerrhosauridae					
Gerrhosaurus major Duméril, 1851	1	1	3	Edge	Terrestrial
Gerrhosaurus flavigularis Wiegmann, 1828	0	4	0	Edge	Terrestrial
Varanidae					
Varanus niloticus (Linnaeus, 1766)	2	4	0	Interior/Edge	Terrestrial
Varanus albigularis (Daudin, 1802)	0	1	0	Edge	Terrestrial
Leptotyphlopidae					
Leptotyphlops scutifrons merkeri (Werner, 1909)	2	0	0	Interior	Fossorial
Pythonidae					
Python natalensis A. Smith, 1840	0	0	2	Interior	Terrestrial
Colubridae					
Lycophidion capense (A. Smith, 1831)	1	0	0	Interior	Fossorial
Philothamnus battersbyi Loveridge, 1951	6	3	2	Edge	Arboreal

Species	2007	2009	2010	Habitat	Habits
Philothamnus punctatus Peters, 1866	0	1	1	Interior	Arboreal
Thelotornis mossambicanus (Bocage, 1895)	1	0	0	Edge	Arboreal
Dasypeltis medici medici (Bianconi, 1859)	2	0	0	Interior	Terrestrial
Prosymna stuhlmanni (Pfeffer, 1893)	0	1	0	Edge	Terrestrial
Elapidae					
Naja melanoleuca Hallowell, 1857	0	0	1	Interior	Terrestrial
Dendroaspis angusticeps (A. Smith, 1849)	1			Interior	Arboreal
Crocodylidae					
Crocodylus niloticus Laurenti, 1768 Nile	1	0	0	Interior	Aquatic
Sub-total number of species	22	20	19		