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HERPETOFAUNA DIVERSITY IN KITOBO FOREST, KENYA

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Abstract: We evaluated the changes in amphibian and reptile diversity along the edge to interior forest of the arid land insularized Kitobo forest, Kenya. Sampling was done in two occasions, in December 2007 and December 2009, using time-limited searches and traps associated with drift fences at forest edge and forest interior habitats. We aimed to test the hypotheses that there is difference in species richness and composition between habitats. After sampling 37 time-limited searches at forest edge and 46 in the forest interior, we recorded a total of 11 amphibians species (edge: 10 and interior: 9), and 29 reptiles (edge: 22 and interior: 16). There was a difference in species diversity between the forest edge and interior but not in the total number of species and individuals per species recorded during every sampling. Amphibians and reptiles appear to use the forest as a refuge. Hence those on the forest edge and the surrounding matrix cannot survive without the evergreen forest. From the forest associated species recorded, Kitobo forest seems to have close biogeographical affinities with the East African coastal forests, despite its long distance inland from the coast. We strongly support all efforts to protect this forest to continue as a species refuge and due to its potential for establishment of sustainable community-based biodiversity ecotourism projects.

Key words: Afrotropics, amphibians, biodiversity, East African coastal forests, edge effects, reptiles, species composition and richness.

Resumen: **P.K. Malonza y B.A. Bwong. "Diversidad de herpetofauna en la Selva Kitobo, Kenia"**. Evaluamos los cambios en la diversidad de anfibios y reptiles desde el borde al interior boscoso de la selva Kitobo, Kenya. El muestreo fue llevado a cabo en dos ocasiones, en diciembre 2007 y diciembre 2009, realizando búsquedas limitadas en tiempo y trampas asociadas con cercas de desvío en el borde y en el interior de la selva. Nos propusimos poner a prueba la hipótesis que hay diferencias en la riqueza y composición de especies entre hábitats. Después de realizar 37 muestreos limitados por tiempo en el borde de selva y 46 en el interior de l selva, registramos un total de 11 especies de anfibios (borde: 10 e interior: 9), y 29 reptiles (borde: 22 e interior: 16). Hubo una diferencia en diversidad de especies entre el borde y el interior de la selva pero no en el número total de especies e individuos por especie registrados durante cada muestreo. Anfibios y reptiles parecen usar la selva como un refugio. Por consiguiente, aquellos en el borde de la selva y la matriz adyacente no pueden sobrevivir sin la selva siempreverde. De las especies registradas asociadas con la selva, la selva Kitobo parece tener afinidades biogeográficas cercanas con las selvas costeras del Este de África, a pesar de su larga distancia desde la costa. Apoyamos decididamente todos los esfuerzos para proteger esta selva para que continúe como un refugio de especies y debido a su potencial para el establecimiento de proyectos ecoturísticos de biodiversidad sustentables de base comunitaria.

Palabras clave: Afrotrópicos, anfibios, biodiversidad, selvas costeras del Este de África, efectos de borde, reptiles, composición y riqueza de especies.

INTRODUCTION

Understanding species distribution is very crucial if the conservation of the species and their habitats is to be realized. Threats to biological resources are highest in the tropics where biodiversity is as well highest (Myers 2003). The need to conserve biodiversity is now more urgent than ever as unsustainable use of natural resources escalates.

The East African region presents very complex terrestrial ecological zones ranging from lowland coastal forest, deserts, dry woodland, grasslands to rainforest habitats. The diverse terrestrial habitats also support a very complex diversity of floral and faunal species many of which are endemic. In East Africa the need to understand herpetofaunal species distribution has been ongoing for years (see Loveridge 1957) and in different areas, e.g. tropical rainforest (Schick *et al*. 2005, Lötters *et al*. 2007, Wagner and Böhme 2007, Wagner *et al*. 2008); coastal forests (Drewes 1992, Chira 1993, Howell 1993, Malonza *et al*. 2006a); highland forests (Lötters *et al*. 2006); dryland areas (Malonza *et al*. 2006b, Wasonga *et al*. 2006) and Eastern Arc Mountains (Barbour and Loveridge 1928, Poynton 2003, Loader *et al*. 2004, Doggart *et al*. 2006, Burgess *et al*. 2007, Poynton *et al*. 2007, Menegon *et al*. 2008, Malonza 2008).

From the above studies it is evident that a lot has been done within the Eastern Arc Mountains and the coastal forests of Tanzania and Kenya, which are well-known world biodiversity hotpots (Myers *et al*. 2000, Mittermeier *et al*. 2004). However, species diversity in certain areas still remains largely unknown making their biogeographical affinity uncertain. One such area is the ground water Kitobo forest in southern Kenya. This is an island in a sea of arid lands and acts as species refugia. Therefore species composition in this forest could be very interesting due to edge effects from the surrounding arid matrix (Fagan *et al*. 1999, Urbina-Cardona *et al*. 2006). Whenever ecological aspects of edge have been studied, many have observed patterns of increased species richness at habitat edges (Fagan 1999). What is

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more important is to understand the links between habitat edge and community dynamics. To understand how the habitat edges affect the diversity of amphibians and reptiles, it is important to determine the changes in species composition along the gradient from the edge to the interior of the forest. Studies have shown that amphibians and reptiles found in the forest interior, which tend to avoid the edges, are more susceptible to extinction (Urbina-Cardona *et al*. 2006). Understanding the amphibian and reptile species response to microhabitat disturbance in arid land insuralized forest habitats is vital in designing their conservation strategies. In this study, we evaluated changes in amphibian and reptile diversity along the edge to interior forest. Species were grouped into assemblages based on their affinities for forest edge and forest interior habitats. We tested specific research questions such as: (1) is there any difference in species composition between habitats? (2) is there any difference in species richness between habitats?

MATERIALS AND METHODS

Study Area

The Kitobo Forest is a ground water forest located about 10 Km South-East of Taveta town in the Taita-Taveta district, Coast Province, 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 near the Kenya-Tanzania border (UTM: 9619706, 346407; 9618900, 345790). It covers an area of ca. 160 ha at an altitude of about 750 m above sea level. 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 plus other small ones inside the forest originating from the volcanic Mt. Kilimanjaro. The springs then develop into a permanent stream that flow through the forest. Bordering the forest on the southern and eastern parts are irrigation schemes that utilize water from these springs and other water canals growing rice, onions, maize, bananas, tomatoes, mangoes and citrus (Fig. 2).

Definition of the sampling habitats

1) **Forest edge**

In this study the edge refers to the transition habitat between natural evergreen forest and the bush land habitat. This was an interface belt comprising bush and wetland habitats along the forest border.

2) **Forest interior**

This is the evergreen forest within which occur natural swamps, springs, streams and ponds.

Herpetofaunal sampling

Surveys were conducted on three occasions: from 7 to 11 December 2007, from 5 to 13 December 2009, and from 00 to 00 April 2010.

Methods used for recording amphibians and reptiles (day and night) included standardized time-limited searches and pitfall traps associated with drift fences.

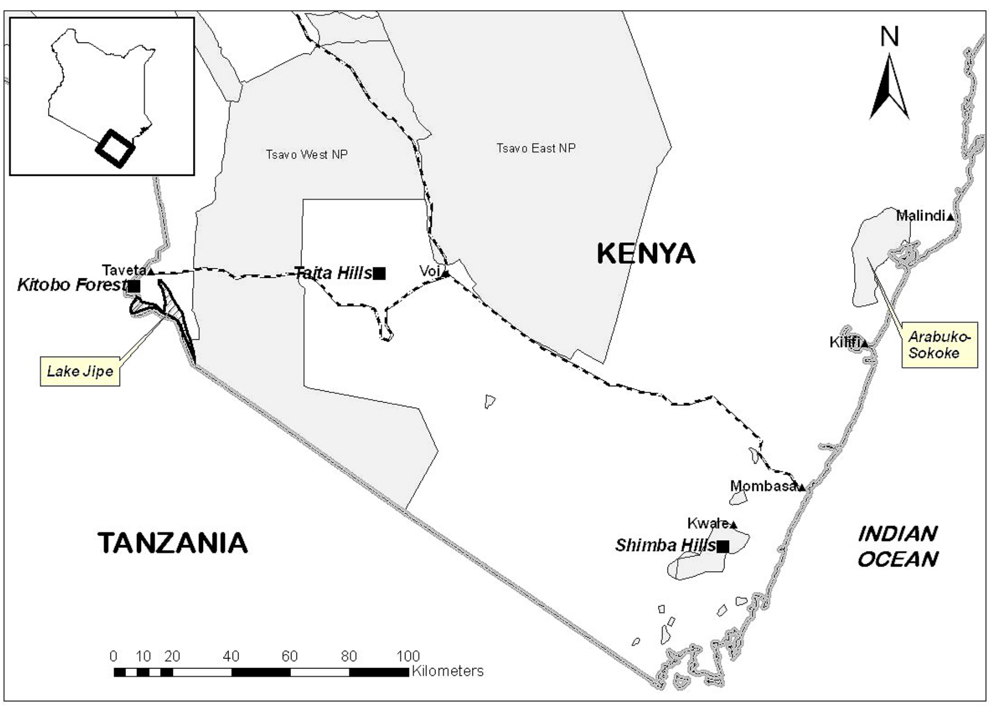

FIG. 1. Map showing the location of Kitobo forest and the comparative Arabuko-Sokoke forest, Taita Hills and Shimba Hills. Inset: Map of Kenya showing the relative location of this region.

Mapa de ubicación de selva Kitobo y, para comparación, selva Arabuko-Sokoke , Taita Hills y Shimba Hills. Inserto: Mapa de Kenia que muestra la ubicación relativa de esta región.

FIG. 2. Kitobo forest showing the sharp forest border with farmlands. *Selva Kitobo con marcado borde selvático que limita las tierras de cultivo.*

Time limited searches (TLS) method as described by Karns (1986), Heyer *et al*. (1994), Sutherland (1996) was used. It was done within the forest edge and interior habitats for one person hour both day and night. During the searches all possible microhabitats such as under leaves, debris, decomposing tree stumps, on tree, shrubs, bushes and logs, including digging were intensively searched. Quantitative species data analysis used TLS data.

X-shaped drift fence with pitfall traps, a modification of that used by Corn (1994) with segments of 5 m length were used. The pitfall traps consisted of 10 l 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 and seven days in the second. Traps were used for detection of small primarily nocturnal crawling herpetofauna not easily detected through other methods.

Species richness and diversity analysis

Herpetofaunal species diversity was measured using the Shannon Index (*H*'). The observed species richness was estimated using

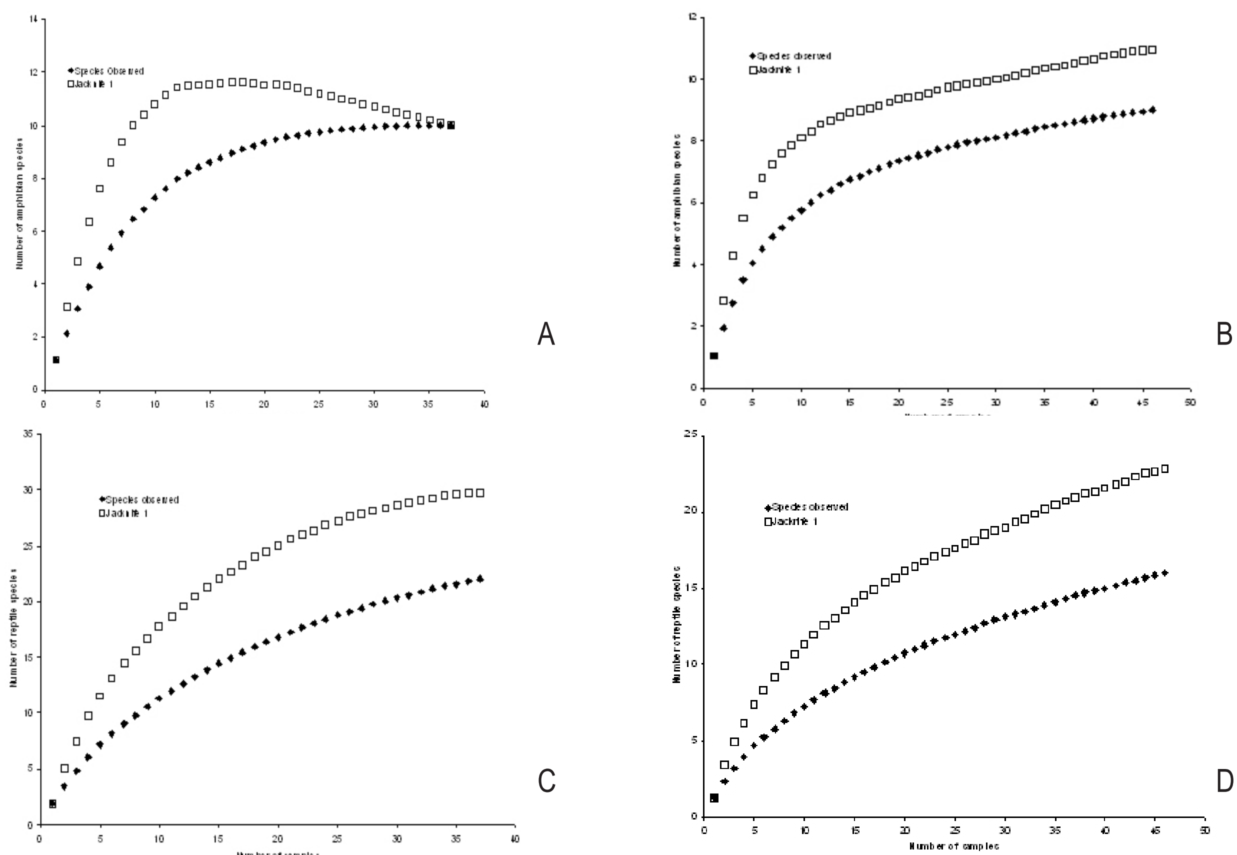

FIG. 3. Species accumulation curves from the time-limited search samples showing species observed species and Jacknife 1 species richness estimator for forest edge and forest interior habitats. A,B) Amphibians, C,D) Reptiles.

Curvas de acumulación de especies de las búsquedas con tiempo restringido, que muestran especies observadas y el estimador de riqueza de especies Jacknife 1 para hábitats del borde y el interior de selva. A,B) Anfibios, C,D) Reptiles.

the EstimateS 7.5.1 program (Colwell, 2006). Jacknife 1 species richness estimator was compared with observed species richness (*Sobs*). Species accumulation curves were calculated and generated using the software programme EstimateS using 1000 randomizations (Fig. 3). The species richness was plotted as a function of the accumulated number of samples (time-limited-searches).

Identification of the specimens was made using published taxonomic keys (Spawls *et al*. 2002, Channing and Howell 2006) and taxonomy for amphibians followed by Frost *et al.* (2006) and Frost (2007). Selected individuals of underrepresented species were kept as voucher specimens and deposited in National Museums of Kenya (NMK).

Voucher specimens 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. All specimens collected are deposited at NMK. Colour photos of selected species and their habitats were taken. GPS data were determined using a 12 Channel Garmin® receiver.

Statistical analyses

Two sample t-tests (independent samples) were used to compare species abundance and species richness between forest edge and forest interior. Data was analyzed with STATISTICA 6.0 software (StatSoft, 2001) at 5% significance level.

RESULTS

Species diversity and composition patterns

After 37 time-limited searches (TLS) at the forest edge, 180 individuals of 10 amphibian species and 104 individuals of 22 reptile species were recorded. After 46 TLS samples in the forest interior, 165 individuals of nine amphibian species and 132 individuals of 16 reptile species were recorded. After 12 days of trapping, six species (five amphibians, one reptile) were captured with the amphibians *Hemisus marmoratus* (Peters, 1854) being the most abundant. More important was that it was only through traps that the aquatic frog *Xenopus muelleri* (Peters, 1844) was detected (Table 1).

The species diversity per sampling effort (TLS) was significantly higher in the forest edge than in the forest interior (t-test independent samples: Amphibians; $t = 3.37$, $df = 81$, $n_1 = 37$, $n_2 = 46$, $P = 0.001$: Reptiles; $t = 6.65$, $P < 0.001$). However, the number of species detected per TLS sample was not significantly different between the two habitats (Amphibians; $t = 0.146$, $df = 81$, $n_1 = 37$, $n_2 = 46$, $P = 0.88$: Reptiles; $t = -0.166$, $P = 0.87$). Again, the number of individuals per species detected was also not significantly different between forest edge and forest interior (Amphibians; $t = -0.047$, $df = 17$, $n_1 = 10$, $n_2 = 9$, $P = 0.96$: Reptiles; $t = 1.72$, $df = 136$, $n_1 = 22$, $n_2 = 16$, $P = 0.088$). Both the forest interior and forest edge were dominated by the lizard *Trachylepis maculilabris* (Gray, 1845) while for amphibians the forest interior was dominated by the frog *Phrynobatrachus acridoides* (Cope, 1867) and the reed frog *Hyperolius glandicolor* (Peters, 1879), in the forest edge aquatic swamps. At night on the forest edge, the Flap-necked Chameleon *Chamaeleo dilepis* Leach, 1819 was the most dominant (Table 1).

From species accumulation curves, the number of reptile species observed in both the forest edge and forest interior increased with increasing sampling effort. Amphibian species observed seemed to plateau with additional sampling, especially on the forest edge (Fig. 3). The species richness estimator, Jacknife 1, was in many cases always higher than observed species (*Sobs*).

The Bibron's burrowing asp *Atractaspis bibronii* A. Smith, 1849, was detected through opportunistic visual encounter survey inside the forest. The local people reported the presence of spectacular large snakes like Puff-Adder *Bitis arietans* (Merrem, 1820), Southern African rock python (*Python natalensis* A. Smith, 1840), Black-necked spitting cobra (*Naja nigricollis* Reinhardt, 1843) and *Dendroaspis polylepis* (Günther, 1864).

Discussion

Our results demonstrate that the number of species and the total number of individuals per species was not different at forest edge and forest interior. This is attributable to the fact that the forest edge and the forest interior had almost similar micro-habitats. Therefore most of the species detected at the forest edges came from inside the forest for thermoregulation (Zug 2001). However, the species diversity per sample was significantly higher at the forest edge habitat. This concurs with the well known phenomenon of edge effects (Fagan 1999).

In general, the species accumulation curves did not reach an asymptote, indicating that more species could be detected with additional sampling. This is particularly so for reptiles due to the influx of species from the surrounding arid lands using the evergreen forest as refuge.

The forest edge was expected to harbour more species of amphibians that breed on open water due to the presence of diverse wetlands. However, our results demonstrated that the forest edge matrix was not necessarily an ideal habitat for the reproduction and maintenance of all amphibians. This could be due to the continuous disturbance of these micro-habitats by farmers, e.g. on the rice fields. Notable was the tree frog, *Leptopelis flavomaculatus,* which avoided habitats outside the evergreen forest. Therefore it is clear that the evergreen forest is a refuge for all the species that occur on the forest edge and the surrounding matrix and more so during the dry season.

Biogeographically, the presence of species such as *Leptopelis flavomaculatus, Hyperolius puncticulatus* (Pfeffer, 1893) and *Thelotornis mossambicanus* (Bocage, 1895) that are present in the typical coastal forest of Arabuko-Sokoke provide an evidence that Kitobo forest species has close affinities with coastal forests (Drewes 1992, Chira 1993, Howell 1993, Schiøtz 1999, Spawls *et al*. 2002, Channing and Howell 2006, Burgess *et al*. 2007). All these species are also present in the coastal forests of Shimba Hills but this also shares a lot with the Eastern Arc Mountains, especially East Usambara Mountains of Tanzania (Howell 1993, Spawls *et al*. 2002, Malonza and Measey 2005, Channing and Howell 2006).

Despite its long distant from the coast, the herpetofaunal composition of Kitobo forest demonstrates that there are historical relationships among its fauna with the coastal forests. This therefore reflects shared environmental factors (temperature, humidity

TABLE 1. Species distribution and number of individuals detected using time-limited searches (46 at the forest interior and 37 at the forest edge). Abundance of those also caught during the 12 trapping days are indicated within parentheses

TABLA 1. *Distribución de especies y número de individuos detectados a través de búsquedas con tiempo restringido (46 en el interior de la selva, 37 en el borde de selva) La abundancia de aquellas capturadas durante los 12 días de trampeo se indica dentro de paréntesis.*

SPECIES	Forest edge	Forest interior
AMPHIBIANS		
Pipidae		
Xenopus cf. *müelleri* (Peters, 1844)	---	(2)
Bufonidae		
Amietophrynus gutturalis (Power, 1927)	9	3
Amietophrynus steindachneri (Pfeffer, 1893)	10	5
Amietophrynus xeros (Tandy, Keith et Duff-Mackay, 1976)	3	---
Hemisotidae		
Hemisus marmoratus (Peters, 1854)	9	1
Arthroleptidae		
Leptopelis flavomaculatus (Günther, 1864)	---	27
Hyeproliidae		
Hyperolius glandicolor (Peters, 1879)	55	28
Hyperolius cf. *puncticulatus* (Pfeffer, 1893)	12	25
Hyperolius tuberilinguis Smith, 1849	22	---
Ptychadinidae		
Ptychadena anchietae (Bocage, 1867)	14	2
Ptychadena mascareniensis (Duméril et Bibron, 1841)	27	29
Phrynobatrachidae		
Phrynobatrachus cf. *acridoides* (Cope, 1867)	19	45
REPTILES		
Lizards		
Gekkonidae		
Lygodactylus sp.	1	---
Lygodactylus luteopicturatus Pasteur, 1964	17	1
Hemidactylus platycephalus Peters, 1854	3	11
Hemidactylus mabouia (Moreau de Jonnés, 1818)	12	6
Hemidactylus squamulatus Tornier, 1896	1	---
Cnemaspis cf. *africana* (Werner, 1895)	---	1
Chamaeleonidae		
Chamaeleo dilepis Leach, 1819	16	---
Scincidae		
Melanoseps loveridgei Brygoo et Roux-Estève, 1981	---	14
Lygosoma sundevalli (A. Smith, 1849)	1	5
Panaspis cf. wahlbergii (A. Smith, 1849)	1	---
Trachylepis maculilabris (Gray, 1845)	27	47
Trachylepis striata (Peters, 1854)	15	4
Trachylepis planifrons (Peters, 1878)	1	---
Trachylepis brevicollis (Weigmann, 1837)	5	---
Lacertidae		
Latastia longicaudata (Reuss, 1834)	5	---
Agamidae		
Agama lionotus Boulenger, 1896	6	---
Gerrhosauridae		
Gerrhosaurus major Duméril, 1851	2	---
Gerrhosaurus flavigularis Wiegmann, 1828	4	---
Varanidae		
Varanus niloticus (Linnaeus, 1766)	1	5
Varanus albigularis (Daudin, 1802)	2	---
Snakes		
Leptotyphlopidae		
Leptotyphlops scutifrons merkeri (Werner, 1909)	1	1

Pythonidae		
**Python natalensis* A. Smith, 1840	---	---
Colubridae		
Lycophidion capense (A. Smith, 1831)	---	1
Philothamnus battersbyi Loveridge, 1951	7	2
Philothamnus punctatus Peters, 1866	---	1
Thelotornis mossambicanus (Bocage, 1895)	1	---
Dasypeltis medici medici (Bianconi, 1859)	---	2
Prosymna stuhlmanni (Pfeffer, 1893)	1	---
Atractaspididae		
***Atractaspis bibronii* A. Smith, 1849	---	1
Elapidae		
**Naja nigricollis* Reinhardt, 1843		
Dendroaspis angusticeps (A. Smith, 1849)	---	1
**Dendroaspis polylepis* (Günther, 1864)		
Viperidae		
**Bitis arietans* (Merrem, 1820)	---	---
Crocodiles		
Crocodylidae		
**Crocodylus niloticus* Laurenti, 1768	---	---

Note: * Species reported to be present by the local people but not recorded during this survey. ** Species detected through opportunistic survey.
Nota: ** Especies reportadas por gente local de estar presentes pero que no fueron registradas durante los muestreos. ** Especies detectadas a través de muestreo casual.*

and salinity) that resulted to its colonization by similar fauna, as suggested by current ecological biogeography theory (e.g. Monge-Nájera 2008).

Conservation implications

Forest associated species such the tree frog *Leptopelis flavomaculatus* and *Hyperolius puncticulatus* (Pfeffer, 1893) in our results are of conservation concern. These species reflect the habitat quality of the forest interior and their disappearance may be an indication of habitat degradation within this "island" forest refuge. Such species should be monitored more closely, since they are highly sensitive to habitat disturbance and are often the most vulnerable to habitat modification. Such species easily disappear from forest fragments after isolation and can even suffer local extinction (Urbina-Cardona *et al*. 2006). All efforts should be made to conserve the arid land paradise as a biodiversity important area with high potential for establishment of community-based ecotourism projects for sustainable community livelihood development.

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