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Research Article

Estimates of Demidoff's galago (*Galagoides demidovii*) density and abundance in a changing landscape in the Oban hills, Nigeria

James Kehinde Omifolaji[1,2,*], Emmanuel Tersea Ikyaagba[3], Abideen Abiodun Alarape[4], Victor Abiodun Ojo[5], Mala Modu[5], Lewiska Funmilayo Lateef[4], Muhammed Adewole Adeyemi[6], Shahid Ahmad[1], Xiaofeng Luan[1]

[1] *School of Ecology and Nature Conservation, Beijing Forestry University, Beijing 830001, China*
[2] *Department of Forestry and Wildlife Management, Federal University, Dutse, Nigeria*
[3] *Department of Social and Environmental Forestry, University of Agriculture, Makurdi, Nigeria*
[4] *Department of Wildlife and Ecotourism, University of Ibadan, Ibadan, Nigeria*
[5] *Department of Forestry and Wildlife, University of Maiduguri, Maiduguri, Nigeria*
[6] *Department of Forestry and Wildlife, Nnamdi Azikiwe University, Awka, Nigeria*

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Abstract

Galagos are one of the understudied family of nocturnal primates which inhabit much of Sub-Saharan Africa, some of which are potentially at risk of habitat loss due to deforestation. The rainforests of West Africa are home to six species of Lorisoidea; however, this habitat is under threat from an increasing human population and anthropogenic activities land conversion for agriculture, amongst other pressures. This study assessed the distribution of Demidoffs galago under different land use pattern in Oban sector of Cross River National Park. Line transect methods were used to estimate the density of Demidoffs galago in a human-influenced forest and an otherwise similar and relatively undisturbed forest. Galagos are mostly observed in canopy forest, secondary forest and farm fallow with a total number of 27, 21, and 14 sightings respectively after survey efforts of 72 km. The encounter rates for the three habitats were 0.56 km^{-1}, 0.35 km^{-1} and 0.23 km^{-1} for close canopy forest, secondary forest and farm fallow respectively. Close canopy forest habitat has the highest estimated density of about 0.24 km^2. The estimated density of secondary forest habitat is approximately 0.23 km^2. The proportion of total sighting of the species across the habitats varied from 43.55% in the close canopy forest habitat, 33.87% in secondary forest habitat and 22.58% in the farm-fallow habitat. The result indicates that the Demidoffs galagos density was significantly lower in farm fallow habitats (n=14, df=2, F=2.26, p=0.009) compared to close canopy forest (n=27, df=2, F=7.616 p=0.999). Higher population density and encounter rate observed in the close-canopy forest may be due to less habitat disturbance and less susceptible to population decline. It is, however, necessary to maintain the environment in its present state and to continue population monitoring over an extended period.

Introduction

Galagos (Galagidae) are a family of nocturnal primates consisting of six species which belong to the suborder Lorisoidea and are more commonly known as "bushbabies" (Jewell and Oates, 1969; Pimley, 2003, 2009). They are native to Sub-Saharan Africa and can be found in forest and thickets across the continent. Demidoff's galago is widely distributed from Senegal to the Central African Forest. Most species are almost completely arboreal, though may come to the ground briefly when foraging. Galagos sleep during the day in nests and hollows within trees (Grubb et al., 2003). There is variation in the dietary composition of different species, although common components include tree gum, insects and fruit. Some species specialize more than others in certain areas, and there is often a high level of seasonal variation depending on availability (Gottschalk et al., 2013; Pauls et al., 2013). Large and small Galagos often inhabit the same areas due to a differentiation in a niche within the same habitat (Bearder et al., 1995; Grubb et al., 2003). The differences in size often correspond to differences in nesting sites, diet, behaviour, and predation interactions (Depalma et al., 2013; Harcourt and Nash, 1986).

Habitats fragmentation and degradation due to anthropogenic activities are major threats of global diversity declines (Estrada adnCoates-Estrada, 1996; Estrada and Fleming, 2012; Estrada et al., 2017). Understanding interspecific variation in species responses to human disturbances is important to enable effective conservation decision-making such as by informing habitat protection and restoration targets to maintain critical ecological phenomena like species-area thresholds (Estrada et al., 2017; Fryxell et al., 2020; Game et al., 2013; Husseini et al., 2019; Maron et al., 2012). Protected areas are frequently viewed as safeguarding the ecological communities, including primates (Estrada et al., 2017). However, particularly regarding developing nations, where funds and national strategies for conservation and protected areas are low, protected are frequently fail to achieve desire objectives adequately. Consider the high rate of deforestation of tropical ecosystem globally, understanding the combined conservation role of protected and unprotected forests is critical for species survival and allocation of resources (Buechley et al., 2015; Cavada et al., 2019). Anthropogenic pressure most often impacts the loss and fragmentation from legal and illegal resources extraction (logging, mining and fossil fuel extraction), agriculture and infrastructure development. Assessment of abundance and vulnerability of populations should ideally account for patterns of human disturbance and habitat factors in space and how they affect pop-

*Corresponding author
Email address: h2ofolaji@gmail.com (James Kehinde Omifolaji)

ulations at multiple scales (Estrada adnCoates-Estrada, 1996; Estrada et al., 2017; Ruiz-Lopez et al., 2016).

Long-term deforestation has resulted in fragmentation of 58% subtropical and 46% of tropical forests (Farris et al., 2014; Haddad et al., 2015), forcing primates to live in isolated forest patches, including protected areas. This has led to decreasing numbers, population restructuring, and the loss of genetic diversity in many primates like pied tamarinds, northern muriquis, cross river gorillas, Bornean orangutans (Bergl et al., 2008; Chaves et al., 2011; Farias et al., 2015; Meijaard et al., 2011; Sharma et al., 2012). Edge effects predominate in many areas of disturbed forests, exacerbating habitat degradation. Human-induced forest fires devastate vast areas of forest ecosystem in primates range regions yearly, resulting in increased tree mortality and loss of canopy forest (Gouveia et al., 2014; Haddad et al., 2015; Silveira et al., 2016). Although variations in species-specific traits mediate the impacts of habitats loss, fragmentation, and degradation upon primates, usually leads to population decline. Some primates are more behaviorally and ecologically resilient than others when faced with habitats loss, fragmentation, and degradation. However, with increasing pressure being placed on primates in sub-Saharan Africa and other regions there have been studies conducted to determine how they respond to human-altered environments (Butynski and De Jong,, 2014; Estrada adnCoates-Estrada, 1996; Estrada et al., 2017; Estrada and Fleming, 2012; Laurance et al., 2012, 2014; Quach et al., 2013), including within agroecosystems, which have been proposed as a viable conservation strategy for some species. However, how these methods affect cryptic nocturnal primates such as bushbabies is currently limited, and they have frequently been overlooked in several studies.

Conservation and management of a species rely heavily on a good understanding of the variability in population density and habitat use (Lehman et al., 2006; Sawyer et al., 2017). Knowledge of little study animal or nocturnally active species is often limited; therefore, such species are particular conservation and management concerns (Forbanka, 2018a; Off et al., 2008; Pimley, 2009). Here, we aim to provide information on the distribution and density estimate across the habitat covers in a tropical ecosystem under the influence anthropogenic activities. Ecological information obtaining during this study will help to updates the urgently needed for devising management actions for the conservation of nocturnal primates (Demidoff's Galago) in Nigeria.

Materials and methods

We conducted a study in Oban Division of Cross River National Park (CRNP) in the Southeastern corner of Nigeria identify as a Biodiversity hotspot (Myers et al., 2000). Oban sector is the largest remaining rain tropical ecosystem covers an area of 3000km2 of lowland rainforest; the largest area of closed-canopy rainforest in Nigeria; contiguous with the Korup National Park, Western Cameroon. The Oban division is divided into two ranges of East and West. The vegetation is principally humid lowland tropical rainforest at 500 m above sea level and tree species include *Musanga cecropioides*, the African corkwood tree or umbrella tree, *Irvingia gabonensis* bush mango *Berlinia confusa*, *Coula edulis*, *Hannoa klaineana*, *Klainedoxa gabonensis*, African mahogany and red ironwood. Rainfall is most abundant in the monsoon season from March to August, with approximately 2500 mm–3500 mm of rainfall; and annual temperatures are between 22 °C to 32 °C (Bergl et al., 2007; Bisong and Jnr, 2006). It is an essential watershed with a mountain peak of 1000 m above sea level. The Oban hills once formed part of one the lowland rainforest refugia during the last glacial period and an internationally recognized biodiversity hotspot, and centre of species richness, and endemism particularly for primates, amphibians, butterflies, fish and small mammals. Oban division is home to sixteen (78%) primate species found in Nigeria including the vulnerable common chimpanzee, and endangered, Preuss's red colobus and Sclater's guenon and Drill have been recorded in the park (Oates et al., 2009; Reid and Miller, 1989; Schmitt, 1996), and other endangered animals such as African forest elephants, pangolin.

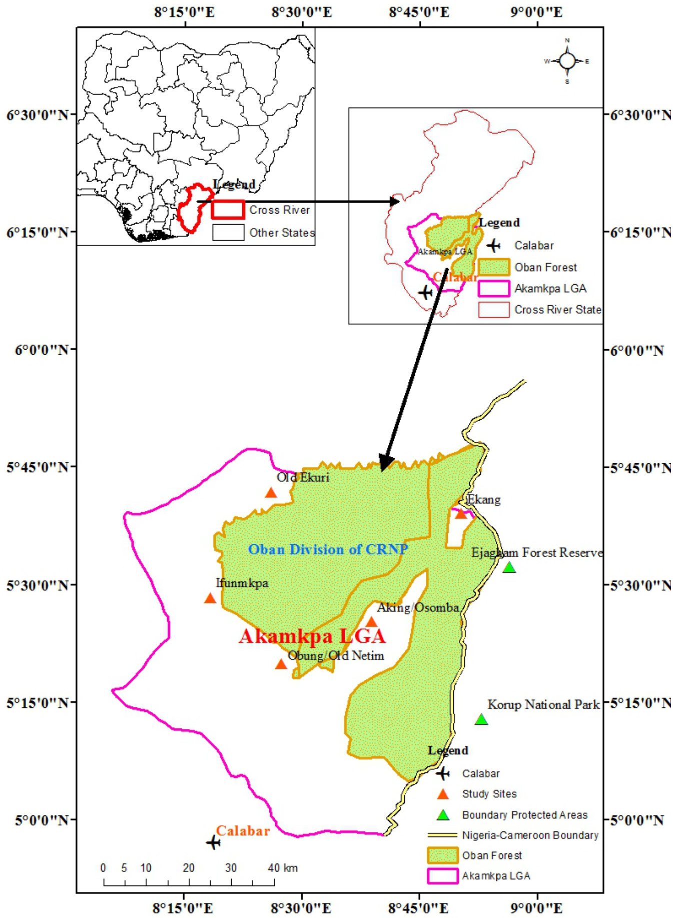

Figure 1. Map of Oban division, Cross River National Park is showing the study locations.

Data Collection

Between October 2012 and March 2013; Demidoff's galago surveys were conducted in the Oban Sector of Cross River National Park, Nigeria. The vegetation and orientation of the Oban division were stratified into three land-use types based on anthropogenic activity around the park for this study. The three broad categories were: (1) closed canopy forest (>75% canopy cover) these included matured, closed canopy forest with numerous arboreal pathways and few undergrowth; 2) secondary forest (semi-open canopy: 45% canopy cover) these sites had a mixture of regenerating forest, dense shrub vegetation; and (3) farm fallow (25% canopy cover) these sites had few mature trees, dense vines entangling regenerating trees as described by Schmitt, 1996. This was to avoid bias in forest land-use types stratification and data collection on Demidoff galago since the park is made up of different vegetation types affected by human activities. Four villages were purposely selected from two ranges within Oban Sector viz: Oban west range Obung/Netim (5°21′25″ N,8°26′24″ E), and Ifumkpa (5°31′56.7″ N,8°17′30.4″ E); and Oban east range: Aking (5°25′67″ N,8°38′10″ E), and Ekang (5°40′ N,8°49′0″ E) due to their proximity to the park (Fig. 1). Line transects technique, as described by (Buckland et al., 2001), was employed. Line transect survey method has been used by several researchers for the animal census, especially primates in Sub-Saharan Africa due to the nature of mammalian species and topography (rugged terrain) of the area. In each land use type, a 2 kilometer transect was established in selected villages in the park, taking into consideration the landscape configuration. A total of thirty-two transects were established in the selected land use types in the area using stratified sampling methods with the aid of Global positioning system (GPS). The transects established in each of the three land use types (closed canopy forest, secondary forest and farm fallow) were located at 600 m intervals using a stratified sampling technique and placed sufficiently far apart to avoid an object from being detected on two neighbouring transects (Buckland et al., 2001; Fewster et al., 2009; Thomas

A. Land clearing and bush burning for agriculture.

B. Abandoned hunting camp.

C. Wire snare.

D. Logging activities.

Figure 2. Anthropogenic activities observed in Oban forest during the study.

et al., 2010). Since the land use was made up of different strata of canopy cover, we made sure that the starting points of all transect were from the beginning of each land use types of the forests. Line transects survey has been the main method used to survey nocturnal primates (Buckland et al., 2001; Fewster et al., 2009; Thomas et al., 2010). The nocturnal surveys were conducted and walk on each transect, from 18:30–22:30 GMT with the aid of headlight/mag light and alternated every twice in a month, looking ahead and sideways to detect animals, to determine Demidoff galago group sizes. Each transect was walked by three observers, within the radius of 25 m on both sides of the transect line. In all the land use types, we focused on concentrated searches in the tree branches and forest canopy covers, once we observed the presence of galagos. We followed pre-existing human trails and maintained a straight line to have little or no influence on the perpendicular estimation. Intense searches were made in all land use types where Demidoff galagos had been observed or sighted, and all Demidoff galagos sighted, vocalization, time, location, signs, and anthropogenic activities were recorded. Also, we recorded perpendicular distance data by categorizing them into five distance intervals; 0 m–5 m, 6 m–10 m, 11 m–15 m, 16 m–20 m, 21 m–25 m and 26 m–30 m due to poor forest visibility at night. All survey and perpendicular distances estimation were carried out by experienced observers who were trained in distance estimation. They understood the principles of Distance Sampling methodology by eye before the onset of the study for accurate perpendicular to estimation (Leca et al., 2013). Demidoff galago and other wildlife species, as well as signs of anthropogenic activities from the transect, were photographed and documented using a digital camera.

Data Analysis

The perpendicular distances were measured to the nearest meter from the line transect to the position of each detected object of interest (Buckland et al., 2001). To provide estimates of Demidoff galago density and abundance in Oban, computer software program DISTANCE 7.2 were calculated as described by (Fewster et al., 2009). To estimate detection probability, half normal and hazard rate keys were fitted to pooled data from each habitat and for all study sites combined for nocturnal data. The half-normal key with cosine adjustments was chosen for the survey of the habitats, whereas hazard rate keys with cosine adjustments were selected for all remaining analysis. Model selection was based on the Akaike information criterion and chi-squared goodness of fit tests. Due to a visible drop in detection probability near the zero line in most data sets, distance data had to be grouped to eight or ten-meter distance classes, to obtain a good fit. Some right truncation (5–10% of observations) was applied in all data sets.

Table 1 – Density, encounter rate, and estimated abundance of Demidoff galago in Oban sector across land use in the Oban Division of CRNP.

Habitat	L	Sightings (%)	n	DP	N	ER	D km^2	CI	AIC
Close canopy forest	72	43.55	27	26.7	11 222	0.56	0.24	0.10670–0.53887	170.86
Secondary forest	72	33.87	21	79.9	6143	0.35	0.17	0.11278–0.24979	128.26
Farm fallow	72	22.58	14	87.5	3209	0.44	0.23	0.10889–0.48252	91.72
Pooled estimate	**216**	**100**	**62**	214.1	20 574	1.35	0.64	0.10945–0.42372	390.84

Results

We recorded a total of 62 observations of *G. demidovii* in three different land use types in the study sites. The estimates of density and abundance of Demidoff's galago varied across different habitat types (Tab.1). The result reveals that *G. demidovii* was most sighted with a total number of 27 sightings after total survey efforts of 72 km in the close-canopy forest, 21 sightings in secondary forest. Of the three habitats surveyed, farm fallow recorded the least sighted with a total of 14 sightings. The encounter rates (ERs) for the three habitats were 0.56 km^{-1}, 0.35 km^{-1} and 0.44 km^{-1} for the closed canopy forest, secondary forest and farm fallow respectively. Close canopy forest habitat recorded the highest estimated density of about 0.24 km^2. The estimated density of secondary forest habitat in the study area is approximately 0.17 km^2. The Akaike information criterion (AIC) recorded varied from 170.86, 128.26, 91.72 for close canopy forest habitat; secondary forest habitat and farm fallow habitat respectively (Tab. 1). The results reveal only slight differences in estimates of population density between habitats censuses. The density of cluster size varied from 0.2 in close canopy forest to 0.1 km^2 clusters for both secondary forest and farm fallow from the nocturnal habitat censuses with a 95% confidence interval (Tab. 2). The proportion of total sighting of the species across the habitats varied from 43.55% in the close canopy forest habitat, 33.87% in secondary forest habitat and 22.58% in the farm fallow habitat (Fig. 2). Also, various degree of anthropogenic activities was observed during the study across the habitat types. The most prevalent human activities observed around secondary forest edge are land clearing and bush-burning for agriculture, fruit collection (*Irvingia gabonensis*) and hunting respectively. While trapping, expended cartridges, hunting trails, wire snares, hunting camps and logging were the observed anthropogenic in the forest (Fig. 2a, b, c). Group size for *G. demidovii* was discarded due to insufficient sample size. In close-canopy forest, *G. demidovii* density observed was significantly higher (F=7.616, df=2, p=0.099) compared to secondary forest (F=4.128, df=2, p=0.022), and farm fallow (F=2.26, df=2, p=0.009)

Discussion

Galagoides demidovii population density was estimated using DISTANCE 6.0 software, using model detection probability modelled by stratum, and calculated by stratum based on minimum Akaike Information Criterion (AIC). The distribution and density of *Galagoides demidovii* in the three studied habitat types were unevenly distributed. The overall result remains significantly lower in fallow farm habitat compared to a close canopy forest and secondary forest; this result may be connected to the anthropogenic disturbances observed at the site including logging, land clearing for agriculture and bush burning. Encounter rate of *G. demidovii* in close canopy forest gallery and undergrowth of Oban, CRNP, Nigeria was relatively lower compared to previous studies in Bioko Island (Stokes, 2011); Angola (Bersacola et al., 2015); and Cameroon (Forbanka, 2018a,b). Habitat use and behaviour of forest-dependent animals must be unravelled to assess their conservation status. For the management of nocturnal primates species, determining the impact is also of great importance (Bersacola et al., 2015; Forbanka, 2018b,a; Off et al., 2005; Sawyer et al., 2017). According to studies on nocturnal primates in Angola, Cameroon, Madagascar and Tanzania population densities tends to decrease rapidly in reaction to anthropogenic disturbance and hunting intensity (Bersacola et al., 2015; Forbanka, 2018b,a; Off et al., 2008; Sawyer et al., 2017). Our finding corroborates the earlier studies on population densities of nocturnal primates' population due to increasing human activities in the ecosystem. However, Murphy, 2015 reported different scenario when estimating the density of galago in a human-influenced forest in a similar and relatively undisturbed forest. Changes in land use types pattern in close canopy forest, secondary forest and farm fallow for *G. demidovii* are the impacts of human activity, which has contributed to disruption and disturbance of ecosystems of the different forest types. Management and utilization of forests by the human can also play a beneficial role in *G. demidovii*, provided that the trees exploitation rate is sustainably managed as this will significantly influence Demidoff's galago population. Galago numbers showed a statistically significant though slight increase when their environment displayed signs of modification by human activities. The exact reasons why this occurs are varied to a degree of human activity in the ecosystem as reported in the previous studies in Cameroon, Bioko Island, Gabon, Tanzania and Uganda (Bersacola et al., 2015; Forbanka, 2018b; Off et al., 2005; Stokes, 2011). These would appear that human activities such as selective felling of trees and a reduction in understory thickness create a more favourable environment for the larger Galagos. Whereas, *G. demidovii* tend to remain and use the undergrowth, and the understory of the vegetation strata with higher tree density and canopy cover with other smaller galagos; and has a different social structure different from the larger Galagos (Bersacola et al., 2015; Forbanka, 2018a,b; Jewell and Oates, 1969), and reported opting to be mostly solitary with overlapping territories between males and females. Human-induced environmental changes may create conditions that favour Demidoff's galago diet composition and habitats preference when the species are more reliant on insects (Bearder et al., 1995; Bersacola et al., 2015; Masters, 1988; Masters and Lubinsky, 1988). The species may be more adaptable and able to vary its diet more than other species. They are capable of performing learned behaviours which may be advantageous in responding to human-induced habitat changes (Bearder and Martin, 1980; Farris et al., 2014; Off et al., 2005; Zimmermann, 1990). This would mean that Demidoff's galago populations within a disturbed forest are still going through a transitional period and have not yet reached new population equilibrium in a human-influenced habitat. If this is the case, then it becomes necessary to maintain the environment in its present state and to continue monitoring the population over an extended period. Also, the impact of the increased fragmentation of habitats can exacerbate these time-lagged problems through a reduction in genetics (Dixo et al., 2009; Hins et al., 2009; Masters and Lubinsky, 1988), as Demidoff's

Table 2 – Density cluster and mean cluster size of Demidoff galago in different habitats types of Oban Sector of National Park, Nigeria.

Habitat	DS (95% CI)	MCS (95% CI)	AIC	ESW	w	n	*F*	*p* density
Close canopy forest	0.216(0.16507–0.30065)	1.22(1.0377–1.4395)	170.86	14.336	30	27	7.616	0.999
Secondary forest	0.141(0.13928–0.14308)	1.20(1.0209–1.3882)	128.26	12.412	30	21	4.128	0.022
Farm fallow	0.178(0.11829–0.21443)	1.21(1.0000–1.5973)	91.72	11.588	30	14	2.256	0.009

galagos are likely to struggle to disperse across fragments. It would be reasonable to assume that this change in behaviour would lead to population changes in the species through alterations such as reduced risk-taking and less time spent foraging which has been demonstrated in other mammal species (Tewksbury et al., 2006; Shannon et al., 2014).

Conclusion

Many nocturnal species in African rainforests have been little studied, and their responses to hunting and land-use change are not well understood. This study, however, assessed Demidoff's galago density and abundance on different land use category viz: closed canopy forest, secondary forest and farm fallow. The density of *G. demidovii* at Oban Hills sector of CRNP, at an estimated 0.64 km^2 and 1.35 encountered rate showed a similar population density trends both at other sites in Bioko island, Angola; and other smaller Galagos species in Africa (Bearder, 1974; Bearder and Martin, 1980; Bersacola et al., 2015; Forbanka, 2018a,b; Harcourt and Nash, 1986; Nash et al., 1990, 2016). Also, we found that *G. demidovii* number was statistically significant in the close canopy forest compared to a lower number in farm fallow habitats. In contrast to previous studies (Bersacola et al., 2015) that the slight increase in *G. demidovii* environment tends to displayed signs of modification by human activities. This study highlights that great work on *G. demidovii* habitats to learn about and fill the scientific knowledge gap on the ecology and distribution of Lorisoid primates, especially in lowland African forest of West and Central Africa. This study contributes to the knowledge gap by providing a current update on *G. demidovii* population size and distribution in Nigeria.

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