Distribution and relative abundance of forest duikers in Dassioko Sud Forest Reserve (coastal Côte d’Ivoire)


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Distribution and relative abundance of forest duikers in Dassioko Sud Forest Reserve (coastal Côte d’Ivoire)

K. A. Yao\textsuperscript{A,B}, E. A. Bitty\textsuperscript{A,B}, K. B. Kasse\textsuperscript{A}, Y. C. Kouakou\textsuperscript{B,C}, K. H. Yaokokoré-Beibro\textsuperscript{A}, S. Gonedélé Bi\textsuperscript{B,D,F} and W. Scott McGraw\textsuperscript{E}

\textsuperscript{A}Laboratoire de Zoologie et Biologie Animale, Université Félix Houphouët Boigny d’Abidjan-Cocody, 22 BP 582 Abidjan 22, Côte d’Ivoire.
\textsuperscript{B}Centre Suisse de Recherches Scientifiques en Côte d’Ivoire, 01 BP 1303 Abidjan 01, Côte d’Ivoire.
\textsuperscript{C}Unité de Formation et de Recherche en Environnement, Université Jean Lorougou Guédé Daloa, Côte d’Ivoire.
\textsuperscript{D}Laboratoire de Génétique, Université Félix Houphouët Boigny d’Abidjan-Cocody, 22 BP 582, Abidjan 22, Côte d’Ivoire.
\textsuperscript{E}Department of Anthropology, The Ohio State University, Columbus, OH, USA.
\textsuperscript{F}Corresponding author. Email: sery.gonedele@univ-fhb.edu.ci

Abstract

\textbf{Context.} Duikers play a vital role in maintaining forest ecosystems, as both seed dispersers and prey. In West Africa, duikers are also an important source of food and income; however, it is likely that some species are now being hunted at unsustainable levels. So as to contribute to duiker conservation, we used line-transect data and additional information on dung and track counts to estimate relative abundance and establish distribution patterns of forest duikers in Côte d’Ivoire’s Dassioko Sud Forest Reserve (DSFR), a poorly known, remnant coastal rainforest. We also collected basic information on hunting pressure.

\textbf{Methods.} Forest duiker counts were made twice per month from July 2013 to March 2014 on six line transects of varying lengths (5.6–6.7 km) and in different regions of the DSFR, representing different habitat types. The number of sightings per kilometre walked, defined as ‘encounter rate’, was used to compute an index of relative abundance. We recorded all evidence of poachers and used these data to generate a poaching index (# poaching signs per kilometre) for different habitat types.

\textbf{Key results.} The DSFR has lost three of seven total forest duiker species and populations of the four remaining species are declining. Encounter rates were greatest for \textit{Philantomba maxwellii} (0.46 indices km\textsuperscript{–1}) and accounted for 68\% of total encounters. \textit{Cephalophus niger}, \textit{C. dorsalis} and \textit{C. silvicultor} were encountered at similar (0.07 indices km\textsuperscript{–1}) but much lower rates. For all species, mean encounter rates were highest in degraded forest (0.38–0.73 indices km\textsuperscript{–1}), followed by secondary (0.2–0.44 indices km\textsuperscript{–1}) and primary (0.19–0.44 indices km\textsuperscript{–1}) forest.

\textbf{Conclusions.} Of the four forest duiker species still present in the DSFR, the black, bay and yellow-backed duikers are the most affected by anthropogenic pressures. Duiker abundance in the DSFR varies with habitat type. This variation is apparently influenced by differences in forest structure, poaching pressure and proximity to villages.

\textbf{Implications.} The study provides baseline data for future managing of ungulate populations in the DSFR. We recommend that a biomonitoring study of duiker populations be initiated immediately to help determine population trends, investigate habitat preferences, and help curb illegal hunting activities in this important forest reserve.

Additional keywords: anthropogenic disturbance, conservation, dung pile, habitat preference, number of sightings, poaching signs.

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Introduction

In West Africa, the escalating demand for animal protein, combined with high prices associated with animal products, has resulted in increased harvest of local wildlife (Ntiamoah-Baidu 1997). Large-scale bushmeat extraction combined with dramatic alteration of West Africa’s original forest cover (e.g. Achard \textit{et al.} 2002; Fasona and Omojola 2009) has led to severe declines of large mammal populations within the past decades, even within protected areas (Craigie \textit{et al.} 2010). Although it is frequently difficult to forecast population trends of animals
because of the interaction of confounding factors (Fa et al. 2005; van Vliet and Nasi 2008), most authorities conclude that current offtake rates of large animals are unsustainable (e.g. Wilkie and Carpenter 1999; Robinson and Bennett 2004; Fa et al. 2006).

Duikers of Cephalophus spp. are an important source of food and income throughout the forest regions (e.g. Newing 1994; Juste et al. 1995; Muchaal and Ngandjui 1999). They are among the most heavily hunted forest animals (Muchaal and Ngandjui 1999; Wilkie and Carpenter 1999; Csuti 2010; Kümpel et al. 2010; Macdonald et al. 2012). Like other animals consumed as bushmeat, they contribute to households both nutritionally and monetarily (Fa and Brown 2009). Duikers also play a vital ecological role in maintaining the stability of forest ecosystems, as both seed dispersers and prey (Dorst 1991; Charles-Dominique 2003; Kortenhoven 2009). Unfortunately, little is known about forest duiker ecology and demography (van Vliet et al. 2007; Kortenhoven 2009; van Vliet et al. 2009), especially in Côte d’Ivoire (CI) where data on the abundance of duikers (Philantomba spp., Cephalophus spp.) and other antelopes in rain forest habitats are scarce.

Information on how forest duiker populations co-vary with habitat in Côte d’Ivoire is important because nearly 80% of the country’s protected forests have been transformed into cocoa plantations (Bitty et al. 2015). The Dassioko Sud Forest Reserve (DSFR) (~80 km²) in southern Côte d’Ivoire is an exception. This reserve (Fig. 1) is significant because its habitat type of coastal evergreen forest is increasingly scarce (Ramsar 2005) and because the reserve is home to several endangered taxa including Loxodonta africana, Pan troglodytes verus, Cercocebus atys lunulatus, Cercopithecus diana roloway, Agelastes meleagrides, and Osteolaemus tetraspis. Unfortunately, a decade of socio-political instability in CI has essentially stopped all effective conservation efforts, and the DSFR is now threatened by illegal agriculture and uncontrolled hunting, both of which have led to forest degradation and the extirpation of several mammalian taxa (Bitty et al. 2015). In addition, recent surveys of bushmeat in local restaurants have indicated that rodents and small antelopes, including duikers, represent 75% of all mammals sold in the area around the DSFR (Gonedelé Bi et al. 2016). The importance of duikers and other forest ungulates is not only limited to their value as sources of animal protein and income for humans, but these animals are also an integral component of the forest ecosystem. They serve as seed dispersers and as food for forest predators (Rabeil 2003), so their removal is likely to have deleterious effects on the long-term viability of the entire forest ecosystem.

In the present paper, we present data from line transects and other sources to provide relative abundance and distribution information on duikers in DSFR. We also discuss potential factors underlying the distribution of duikers in this reserve. Obtaining reliable estimates of forest duiker abundance and densities in different habitat types has significant value because such data can inform conservation management plans, while, at the same time, help curb hunting and other activities that threaten duiker livelihood.

Materials and methods
The study area
The DSFR is one of the last remaining protected fragments of coastal forest in CI, located from 5°00'06"–5°07'23"N to 5°49'48"–5°56'57" (Fig. 1). The climate of the region is...
equatorial, characterised by heavy rainfall and annual temperatures that range between 20°C and 33°C. The vegetation of the reserve is evergreen rainforest, typical of that within the Guinean forest block. The forest provides habitat for rare mammalian taxa endemic to the Upper Guinean forest ecosystem, including the white naped-mangabey (Cercocebus atys lunulatus; IUCN Red list status: Endangered (EN)), the Roloway monkey (Cercopithecus diana roloway; Critically Endangered (CR)), the Western chimpanzee (Pan troglodytes verus; CR), the forest elephant (Loxodonta cyclotis; Vulnerable (VU)) and Jentink’s duiker (Cephalophus jentinki; EN).

The DSFR is characterised by seven major habitat types (Fig. 2). These are (1) primary forest, a well conserved portion of the reserve, (2) gallery forest, forest patches bordering rivers, (3) mangrove, (4) secondary forest, (5) abandoned plantations (recently abandoned farms), (6) under tree regrown, the regrowths of forest after the cut down of the primary or secondary forest underwoods and (7) maintained plantations, which are active farms plots composed mainly of cocoa farms mixed with food-producing cultures such as banana, cassava and maize.

Data collection

Counts of forest duikers were made along six line transects varying in length from 5.6 to 6.7 km. These transects passed in a north–south direction and were spaced ~2 km apart from each other. Each transect passed through all habitat types within the reserve; however, all habitat types were not represented equally on each transect (Fig. 1). Line transects were walked twice per month from July 2013 to March 2014. The line-transect surveys were conducted by a team of three experienced observers. For each encounter, the time, habitat type, species, number of individuals, distance to roads, perpendicular distance of the nearest individual duiker (if multiple animals were observed) to the transect, and position of the observer along the transect were recorded. We measured the perpendicular distance from the position of each animal at first sighting to the transect with a tape graduated in metres (Buckland et al. 1993; Fewster et al. 2009). So as to reduce any disturbance effects on wildlife, we waited a minimum of 2 days before revisiting previously walked transects. We also recorded all evidence of poachers (e.g. used cartridges, gun shots, poachers encountered, poacher camps) and used these data to generate a poaching index (# poaching signs/km) for each transect. Census lines were walked, beginning at 0700 hours and usually ending at 16 hours, with an average speed of ~1 km h⁻¹. We did not use auditory detection of duikers because we were not always certain of the identity of the species heard. We recorded the numbers of dung piles within 5 m of each transect, the number of animal paths crossing each transect, and the number of forest duiker footprints. The estimated age and distance from the transect centre of each dung pile were recorded. Field workers with extensive experience as hunters were used to identify the duiker species responsible for each dung pile. Species identification from dung is possible because all ungulate species in the study have distinct dung morphologies, as described by Kortenhoven (2009). We also conducted interviews with individuals in villages surrounding the reserve, as well as with SODEFOR staff members in charge of the management of the DSFR. Interviews focussed on a person’s knowledge of wildlife, their activities related to wildlife and the management of the DSFR.

Data analysis

The number of sightings per kilometre walked, defined as ‘encounter rate’, was computed as an index of relative abundance (e.g. Seber 1982). Relative abundance constitutes an indirect measure of the size of an animal population. Its determination is based on the number of signs of animals seen per unit of time or distance (Hoppe-Dominik 1989). Differences in encounter rate among habitat types were examined with the Kruskal-Wallis test (Siegel and Castellan 1989). We could not estimate densities for all species because the number of sightings for each of the four species fell below the minimum recommended sample size of 60–80 sightings (Buckland et al. 2001).

To illustrate the spatial distribution of the duiker species, we used the encounter rates of animal signs calculated for each sampling unit. We performed mapping analysis using the deterministic interpolation method of inverse distance weighted (Li and Heap 2008). This method assumes that the influence of a known data point is inversely related to the distance from the unknown location that is being estimated.

We used Quantum GIS to produce distribution maps using coordinates of observations obtained along transects (inverse distance weighted, IDW; Li and Heap 2008). We also estimated the number of poaching indices per kilometre walked on each transect. We used multiple regression analysis to identify the variables (relative abundance, distance to road, habitat type, indices of habitat degradation) that influenced forest duiker distribution and relative abundance. These variables were log-transformed as needed to improve normality. Statistical analyses were performed using STATISTICA7.1 (StatSoft, Tulsa, OK, USA).

Results

Diversity and encounter rate

On the basis of SODEFOR records and other biogeographic references, seven forest duiker species should be present in the DSFR (SODEFOR 1996; Kingdon 1997). We found evidence of the following four forest duiker species: Maxwell’s duiker (Philantomba maxwellii), bay duiker (Cephalophus dorsalis), yellow-backed duiker (Cephalophus silvicultor) and black duiker (Cephalophus niger). We found no evidence for Ogilby’s duiker (Cephalophus ogilbyi), zebra duiker (Cephalophus zebra) and red-flanked duiker (Cephalophus rufilatus). The only duiker species observed directly was P. maxwellii; the presence of the other three species was based on dung and prints.

Using the total of dung samples encountered, we estimated the total duiker population density in the reserve. On the basis of the dung-encounter rates of 43.6 km⁻², the duiker density in the total reserve is 0.32 individuals km⁻². Philantomba maxwellii has the highest encounter rate (0.46 indices km⁻¹) and accounted for 68% of total detections. Cephalophus niger, C. dorsalis and C. silvicultor were observed at similarly lower rates (0.07 indices km⁻¹, Table 1).
Fig. 2. Different types of habitat inside the Dassioko Sud Forest Reserve.
Habitat types and relative abundance of forest duikers

For the four species combined, the mean encounter rate was highest in gallery forest (0.26 indices km⁻¹), followed by secondary forest (0.23 indices km⁻¹) and regrown undertrees (0.17 indices km⁻¹), (Table 2). With the exception for *P. maxwelli*, the four duiker species were rarely encountered in mangroves, abandoned and maintained plantations. The mean encounter rate of duikers in these habitats was two to seven times lower than the overall mean encounter rate. *Cephalophus dorsalis*, *C. niger* and *C. silvicultor* were mostly encountered in undisturbed portions of the reserve (gallery forest and primary forest; Table 2).

Anthropogenic disturbance

At the DSFR, the proportion of degraded forest (85%) greatly exceeds the amount of intact forest. Human activities inside the forest include farming, logging, hunting and fishing. Farming was the most significant activity (1.64 indices km⁻¹) and accounted for 45% of total disturbance as a result of human activity, followed by logging (1.13 indices km⁻¹), which accounted for 36% of total disturbance. Hunting activity (0.67 signs km⁻¹) accounted for 17% of anthropogenic disturbance, whereas fishing was responsible for the lowest encounter rate (0.02 signs km⁻¹).

Multivariate analysis

The results of the principal component analysis (PCA) are illustrated in Fig. 3. The first two PCA axes explained 95% of the total variation, with eigen values of \( l_1 = 0.77 \) and \( l_2 = 0.36 \) respectively. PCA Axis 1, which alone accounted for nearly 65% of the variation, was highly correlated with distance to villages. The distributions of species along the second axis indicated the habitat gradient. Along the PCA axis 1, *C. dorsalis* was the species with a positive score and was commonly found far from villages. *Cephalophus niger* and *C. silvicultor* were found far from roads and rivers respectively. *Philantomba maxwellii* was distributed close to villages. *P. Maxwellii* had a positive value along Axis 2 and was associated with all habitat types except primary forest. Of the species that had positive values along Axis 2, *C. niger* was found far from rivers and was not significantly associated with any habitat type. In contrast, *C. silvicultor* was associated with primary forest.

Spatial distribution of duikers

A representation of the spatial distribution of encounter rates for each species (Fig. 4) showed a north–south gradient in the relative abundance of duiker species within the DSFR. The total duiker abundance (total individuals of the four species

<table>
<thead>
<tr>
<th>Common name</th>
<th>Scientific name</th>
<th>Type of evidence of the presence of duiker species</th>
<th>Relative abundance (indices km⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maxwell’s duiker</td>
<td><em>Philantomba maxwelli</em></td>
<td>D: 3; Du: 8; FT: 125; S: 136</td>
<td>0.46 (Kortenhoven 2009); 1.8–11.3 (Owusu et al. 2005; Danquah et al. 2012; Wiafe and Amfo-Otu 2012)</td>
</tr>
<tr>
<td>Bay duiker</td>
<td><em>Cephalophus dorsalis</em></td>
<td>D: 0; Du: 3; FT: 17; S: 20</td>
<td>0.067 (Kortenhoven 2009); 4.1 (Danquah et al. 2012); 0.7 (Wiafe and Amfo-Otu 2012)</td>
</tr>
<tr>
<td>Black duiker</td>
<td><em>Cephalophus niger</em></td>
<td>D: 0; Du: 4; FT: 18; S: 22</td>
<td>0.074 (Kortenhoven 2009); 0.35 (Kortenhoven 2009); 0.55 (Wiafe and Amfo-Otu 2012); 4.0 (Danquah et al. 2012)</td>
</tr>
<tr>
<td>Yellow-backed duiker</td>
<td><em>Cephalophus silvicultor</em></td>
<td>D: 0; Du: 5; FT: 16; S: 21</td>
<td>0.070 (Kortenhoven 2009); 0.075 (Kortenhoven 2009); 2.2 (Danquah et al. 2012)</td>
</tr>
</tbody>
</table>

Table 2. Mean encounter-rate (indices km⁻¹) estimates of four forest duiker species by habitat type at the Dassioko Sud Forest Reserve

<table>
<thead>
<tr>
<th>Habitat type</th>
<th><em>Philantomba maxwelli</em></th>
<th><em>Cephalophus dorsalis</em></th>
<th><em>Cephalophus niger</em></th>
<th><em>Cephalophus silvicultor</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary forest</td>
<td>0.2</td>
<td>0.12</td>
<td>0.08</td>
<td>0.1</td>
</tr>
<tr>
<td>Gallery forest</td>
<td>0.62</td>
<td>0.09</td>
<td>0.12</td>
<td>0.21</td>
</tr>
<tr>
<td>Mangrove</td>
<td>0.23</td>
<td>0.04</td>
<td>0.04</td>
<td>0.04</td>
</tr>
<tr>
<td>Secondary forest</td>
<td>0.75</td>
<td>0.06</td>
<td>0.07</td>
<td>0.05</td>
</tr>
<tr>
<td>Abandoned plantation</td>
<td>0.33</td>
<td>0.05</td>
<td>0.05</td>
<td>0.02</td>
</tr>
<tr>
<td>Regrown undertree</td>
<td>0.47</td>
<td>0.06</td>
<td>0.09</td>
<td>0.06</td>
</tr>
<tr>
<td>Maintained plantation</td>
<td>0.35</td>
<td>0.03</td>
<td>0.06</td>
<td>0.03</td>
</tr>
<tr>
<td>Mean</td>
<td>0.42</td>
<td>0.06</td>
<td>0.07</td>
<td>0.07</td>
</tr>
<tr>
<td>s.d.</td>
<td>0.20</td>
<td>0.03</td>
<td>0.03</td>
<td>0.06</td>
</tr>
</tbody>
</table>
combined) in the DSFR was higher in the south-eastern portion of the reserve. The north-eastern border of the reserve was characterised by a slightly lower relative abundance. Compared with the other three species, *P. maxwellii* was widely distributed across the reserve. *Cephalophus dorsalis* was more restricted to the eastern part of the reserve, whereas *C. niger* and *C. silvicultor* were more abundant (IA >0.69 indices km$^{-1}$) in the southern part of the reserve. Forest duiker abundance was lowest near the western border of the reserve, which is dominated by active farms and plantations.

**Discussion**

**Diversity and encounter rate**

Historical distribution records indicate that, at one time, seven forest duiker species were present in the DSFR (SODEFOR 1996). On the basis of information presented here, the following four species are present now: *P. maxwellii, C. dorsalis, C. silvicultor* and *C. niger*. The following three duiker species known to exist in the area were not recorded: Ogilby’s duiker (*C. ogilbyi*), zebra duiker (*C. zebra*) and red-flanked duiker (*C. rufilatus*). Failure to detect evidence of these three species could mean that these species are now locally extinct. Recent field and bushmeat-market surveys around the DSFR failed to locate any evidence of these species (Gonedélé Bi et al. 2016).

Our study provided relative abundance estimates for the four species detected in the reserve. The smallest duiker, *P. maxwellii*, had the widest distribution and the highest encounter rate, suggesting that the larger duikers are more severely affected by human pressures. The three large species may be at a higher risk of extirpation with the continuing poaching pressure and habitat encroachment.

Encounter rates reported here are similar to the values obtained by Kortenhoven (2009) in the Loma Mountains Non-hunting Forest Reserve, Sierra Leone, but far lower than values obtained for the same four species using line transects in other rainforest regions in Africa (Table 1).

**Habitat types and relative abundance of forest duikers**

Within the DSFR, Maxwell’s duiker (*P. maxwellii*) is the most abundant forest duiker species, with the widest distribution. The species is commonly found in secondary forests and gallery forest. Yellow-backed duiker (*C. silvicultor*), bay duiker (*C. dorsalis*) and the black duiker (*C. niger*) were recorded mostly in closed canopy forest (primary forest and gallery forest), followed by regrown under trees and secondary forests. The distribution of black duikers reported here differs from that in Taï National Park, Côte d’Ivoire, where black duikers have been found to be more common in secondary forest than in undisturbed closed-canopy forest (Newing 2001).

The higher encounter rates in primary forest could be attributable to a strategy developed by the species to avoid poaching pressure. All the duikers species were also encountered in secondary forests and regrown understoreys. Regrowth vegetation offers security and more palatable foliage (Ewel 1980) with a higher nutritive value than does foliage typically found growing near the forest floor of primary forest (Davies et al. 2001).

Our findings of high abundance of *C. dorsalis* and *C. silvicultor* in primary forest are in contrast to those of Remis and Kpanou (2011) who reported that encounter rates of *C. silvicultor* in Central African Republic did not vary with habitat. However, the effect of habitat on duiker populations in our study may have been masked by anthropogenic pressure, which is higher in the secondary forest.
There is little question that the major factors responsible for the decline in duiker population in the DSFR are habitat degradation and hunting pressure. The primary cause of habitat degradation in the DSFR is conversion of forest into cocoa plantations (Bitty et al. 2015). The greater abundance of forests duikers in primary forest compared to secondary forest is likely due to the better safety against hunters, owing in part to the distance required of hunters to reach this portion of the forest. The presence of duikers in degraded forests is attributable to denser forest-floor vegetation in this habitat than in natural forests (e.g. Nummelin 1990), hence offering abundant food to duikers. Among African duikers, factors related to body size,
Forest duikers’ distribution and abundance

Activity patterns and habitat use within closed-canopy forest areas are known to delineate species-specific niches (Newing 2001). In addition, increasing hunting pressure in the reserve, with a selective bias towards medium-sized species, may explain the present discrepancy as suggested by several studies (Wilkie and Finn 1990; Muchaal and Ngandjui 1999; Hema et al. 2017).

**Anthropogenic disturbance**

Diminished abundances of forest duikers coincide with high levels of human forest use in the DSFR. Our findings of decreased abundance in relation to habitat degradation and hunting are consistent with other studies on antelopes and primates where populations of these mammals are known to be significantly and negatively affected by human activities (e.g. Dubost 1979; Wilkie and Finn 1990; Cowlishaw and Dunbar 2000).

The DSFR continues to be degraded by different forms of anthropogenic disturbance, including logging, forest encroachment and hunting. Although much of the expansion of agri-business in Côte d’Ivoire has occurred on plantations owned/leased by companies or on private land of eco-certified cocoa farmers, a growing number of illegal cocoa farms are found inside protected areas (PAs) of Côte d’Ivoire, including the DSFR (Norris et al. 2010; Bitty et al. 2015). Most protected areas within the coastal region of Côte d’Ivoire have been illegally transformed into plantations within the past two decades (Bitty et al. 2015; Gonedelé Bi et al. 2016). Although efforts to conserve the reserve have been initiated (Gonedelé Bi, pers. comm.), the dwindling wildlife populations within the DSFR are under continued threat. The western part of the reserve is particularly affected and it is this region of the reserve that shows the strongest negative effect of human pressure on forest duiker abundance.

Law enforcement is the most important factor for controlling poaching and illegal forest destruction; however, the failure of Ivorian authorities to effectively punish wildlife offenders significantly hampers any conservation efforts. Any realistic chances of preserving the remaining wildlife within this and other protected areas of Côte d’Ivoire hinge on the ability of Ivorian authorities to effectively police the habitats they oversee. Without aggressive efforts to curb activities such as, for example, illegal logging and farming, or catch, prosecurate and jail poachers, and destroy illegal plantations, there is little chance that protected areas such as the DSFR will harbor any significant wildlife in the near future.

**Conclusions**

Duikers and other forest ungulates are an integral component of forest ecosystems, serving as seed dispersers and food for forest predators (Rabel et al. 2003). Their removal is likely to have deleterious effects on the long-term viability of the entire forest ecosystem. The DSFR has lost three of the seven of its forest duiker species and populations of the remaining species are declining. Of the four species still present in the reserve, the black, bay and yellow-backed duikers are the most affected by anthropogenic pressures. Duiker abundance in the DSFR varies with habitat type. This variation is apparently influenced by differences in forest structure, poaching pressure and proximity to villages. Our study provided data for government institutions in charge of the conservation of the DSFR and could help them in deterring illegal activities inside the reserve. These data constitute an important baseline for future wildlife research activities in the areas and should allow managers to better develop their conservation strategies, including the activities of surveillance patrols.

**Conflicts of interest**

The authors declare no conflicts of interest.

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