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Using Local Ecological Knowledge to improve the effectiveness of detecting white-bellied pangolins (*Phataginus tricuspis*) using camera-traps: a case study from Deng-Deng National Park, Cameroon

Short running title: Monitoring white-bellied pangolin

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Keywords: Detection, Deng-Deng National Park, LEK, Manidae, *Phataginus tricuspis*, Presence

INTRODUCTION

Pangolins (Order: Pholidota) remain one of the most challenging groups of mammals to detect and study. Yet, locating and documenting pangolin presence is essential to provide data on their distribution and population, which help to build effective conservation strategies. Pangolins are considered to be elusive and many of their ecological traits, such as low population density, largely nocturnal and solitary lifestyle, and use of burrows and cavities make it difficult to gather relevant information from commonly-used monitoring approaches that are effective for other mammals (Ingram, Willcox, & Challender, 2019; Willcox et al., 2019; Nash, Wong, & Turvey, 2016). The white-bellied pangolin, *Phataginus tricuspis*, is a semi-arboreal species that feeds exclusively on ants and termites (Akpona et al., 2008; Kingdon et al., 2013). They typically inhabit dense forest though also occur in forest-savannah-crop mosaics at times(Pietersen et al., 2019). The ecology of this species is poorly known due in part, to the challenges of studying pangolins and a lack of standardized research methods. (Willcox et al., 2019). Here we evaluate the utility of local ecological knowledge (LEK) in tailoring camera-trap surveys, a detection method increasingly used for pangolins, to improve detection efficiency for occurrence and ecological studies for the white-bellied pangolin.

Camera-traps are an effective survey method for the detection and monitoring of rare and elusive species across large areas (McCallum, 2013). However, considerable effort (1,000-2,000 camera-trap nights) may be needed to detect the rarest species (Tobler et al., 2008). Records of pangolin from camera-traps are often from occasional events (Bruce et al.. 2018). For example, across 18 camera-trap surveys in the predicted range of white-bellied pangolins, 2,287 camera-traps produced 275 five-day trap occasions with detections of this species (Khwaja et al., 2019). Whilst the survey effort required to detect pangolins with camera-traps can be high and detections rates of pangolins generally low, adapting camera-trap survey approaches to pangolin habitat preferences and behaviours may improve their efficacy (Khwaja et al., 2019).

In Cameroon, pangolins are hunted for meat and can be regularly observed in local bushmeat markets (Fa et al., 2006; Ingram et al., 2019). Experienced hunters and other local people have knowledge of preferential resting/feeding places or travel routes of this species in the wild and might be skilled at locating and capturing them. A survey of Local Ecological Knowledge (LEK) of pangolins in communities around Deng-Deng National

Park and Mpem and Djim National Park in central Cameroon suggest the presence of pangolins in the protected areas and surrounding habitats are well known (Difouo Fopa et al., *in press*). When asked where local people had seen white-bellied pangolins, some respondents reported seeing them on dead fallen trees, and that hunters specifically placed snares on fallen trees to capture pangolins (Difouo Fopa et al., *in press*). Respondents also mentioned seeing pangolins sleeping during the day in ground and tree burrows.

Here, we conduct a preliminary test of whether these ecological features reported from local knowledge of pangolins could be targeted to detect pangolins and if some features, in general, recorded more events. If certain ecological features are regularly associated with pangolin detection then this information could be used to enhance the efficiency of presence surveys, Rapid Biodiversity Assessments, and population monitoring surveys.

METHODS

Study area

Our study was conducted in Deng-Deng National Park (DDNP; Fig. 1) located in the Eastern Region of Cameroon in the Lom et Djerem Division (5°-5° 25' N / 13°- 23° 34' E, 682 km^2, average altitude of 703 m). Deng-Deng National Park is characterised by an equatorial and humid climate with annual rainfall ranging between 1500-1600 mm (Diangha, 2015). It is located in the forest-savannah transition zone of the country. The park area is characterised by seasonal dry and wet periods (Diangha, 2015), and harbours vulnerable wildlife species including gorilla (*Gorilla gorilla*), chimpanzee (*Pan troglodytes*), and forest elephant (*Loxodonta africana*) (Maisels et al., 2011).

Local Ecological Knowledge (LEK) and pangolin signs

Based on areas within the national park where local people reported sighting white-bellied pangolins (Difouo et al., *in press*), we walked sixteen parallel 2km long transects in closed-canopy tropical forests, each separated by 1km, with four local guides to identify sites of potential activity to place camera-traps in the field. Several types of potential white-bellied pangolin signs and sites of activity were considered for camera-trap placement:

(1) fallen log – downed trees, showing signs of animal activities on the upper side, targeted as possible travel routes;

(2) feeding sites on trees – micro sites with multiple scratches either along the length of a fallen trunk (at the ground level) or at the base of an upright trunk;

(3) feeding sites on the ground – potential pangolin feeding sites on the ground as indicated by soil excavations of different ages (fresh to very old) (Newton et al., 2008). The diameter of this sign ranged from 5 cm to 10cm;

(4) burrows in the ground – potential ground burrows were holes dug in the ground at the base of trees, exhibiting multiple entrances adjacent to tree roots and ranging from 20 cm to 30cm in diameter; and

(5) Cavities in trees – Potential tree cavities indicated by holes in the central axis of very old fallen trunks with one or two entrances at one or both ends of the trunk. Whilst white-bellied pangolin are not considered to burrow, we targeted these sites because the species is suggested to use holes in trees as refuges to sleep during the day (Akpona et al., 2008).

The GPS coordinates were recorded for suspected signs of white-bellied pangolin. We only established camera-traps at sites where the four local guides all agreed could be visited by pangolins. (Fig. 1).

Camera-trap survey

Fifteen camera-traps (eight Cuddeback X Change Colour Model 1279, and Long-range IR E2 Model, seven Bushnell Trophy Camera Brown 119836 and Trophy Cam HD 119875C) were deployed at sites with good potential for pangolin activity. Cameras were strapped to trees at a height of 30-40 cm above the ground for potential ground burrows and feeding sites. Cameras targeting fallen logs were set higher according to the tree diameter and elevation above ground level, and were placed ~30-40 cm above the upper side of the tree trunk. The cameras were positioned perpendicular to the targets at a distance of 3-4m with the aim of obtaining full body lateral images of the animal. Cameras were set to take three images per trigger with the shortest delay available between consecutive triggers, depending on the camera model used. All other settings were set at default. The cameras were left in the field for a minimum of 60 trap-nights and were not checked until removal. Consecutive photographs of the same species were judged temporally independent when separated by a standard 1hr interval (Cusack et al., 2015; O'Brien et al., 2017).

RESULTS

Encounter rate of the possible pangolin signs

The most frequently encountered possible signs during the transect walks were feeding sites on the ground, followed by fallen logs and feeding sites on trees. The least frequently encountered possible signs were ground burrows and tree cavities (Fig. 2).

Camera-trapping

We accumulated a total of 982 operational camera-trap nights during this survey and recorded 54 independent events of white-bellied pangolins at nine different camera locations. This gives an overall trapping rate of five photos per 100 trap nights for the area, as a whole. The camera-traps installed adjacent to fallen logs recorded the highest trapping rate, followed by the camera-traps installed at ground feeding sites, and then those targeting feeding sites on tree trunks. The lowest trapping rates were recorded on possible ground burrows and tree cavities (Table 1). The first photographic event was recorded on a camera set perpendicular to a fallen log within three days of the camera-trap deployment.

The white-bellied pangolins appear to largely use fallen logs as pathways (Fig. 3). All five cameras installed at logs recorded photos of white-bellied pangolins walking along their length (40 events), while three foraging events were recorded. Over the five events recorded on potential ground feeding sites, no white-bellied pangolins were observed foraging. Photographic events of pangolins obtained at feeding sites on dead trunks shows the animal foraging in three events over the four recorded events at these locations. Of the two photographs recorded on potential ground burrows, the animal was photographed in front of the potential burrow with no evidence of burrow usage (e.g. visibly entering or exiting the burrow). No photographs of white-bellied pangolins were recorded at potential tree cavities.

Discussion

Pangolins are generally solitary, nocturnal, and hide when not active, thus making detection through surveys challenging (Khwaja et al., 2019; Willcox et al., 2019). Informed by LEK from hunting communities, we aimed camera-traps on several types of possible pangolin activity sites identified by local guides. This effort produced 54 independent events of white-bellied pangolin across a total of 982 operational camera-trap nights.

Targeting camera-traps at fallen trees initially appears to be a useful tactic to increase chances of detecting the presence of white-bellied pangolins in tropical forest habitats within a few days (3 days in this pilot study). By placing camera traps adjacent to logs, we achieved a trapping rate of 13 independent white-bellied pangolin events per 100 trap-days. Within the predicted range of white-bellied pangolins, trap rates per 100 days were reported as 0 event in a forest-savanna transition zone in Gabon (Hedwig et al., 2017), 0.12 in forest-woodland habitat in Uganda (Treves et al., 2010), and 0.62-0.8 events in forest in Cameroon (Bruce et al., 2018). All of these studies placed cameras within a grid and along wildlife trails. Given that white-bellied pangolins are semi-arboreal, fallen logs may facilitate travel in complex understorey or reduce noise to avoid detection by predators. Additionally to their role as a means of travel, fallen logs could also be explored by pangolins for termites searching resulting in more frequent pangolin activity on fallen logs. However, a combination of other factors could affect pangolin detectability including the semi-arboreal behaviours of white-bellied pangolin that may reduce their availability for detection by ground-based cameras, and forest cover that may affect the camera's detection zone (Hofmeester et al., 2019; Khwaja et al., 2019). Furthermore, in areas where overexploitation has resulted in low population density, detecting pangolins will likely be more challenging (Willcox et al., 2019).

Our targeted camera-traps were less successful at detecting white-bellied pangolins when targeting possible feeding signs, although perhaps still better than trail-based surveys. However, feeding signs can be unreliable due to possible misinterpretation (Ichu et al., 2017). Ichu et al. (2017) targeted camera-traps at potential feeding signs of pangolins but obtained very few photographic records. Other white-bellied pangolin sign surveys also found that feeding signs were the most common signs in forest savanna habitat (~0.5 signs/km; Ichu et al. 2017) and 2nd most common in forest habitat (0.68 signs/km; Bobo et al., 2014). However, it is possible that feeding signs could be conflated across multiple species. Many animals such as African brush-tailed porcupine (*Atherurus africanus*), Black-legged mongoose (*Bdeogale nigripes*), Cameroon cusimance (*Crossachus platycephalus*), or Red river hog (*Potamochoerus porcus*) were also recorded in the study area, and can leave similar signs to pangolins, resulting in the local guides being frequently uncertain about the species responsible for observed signs. Aardvark (*Orycteropus afer*) are also present, but we only recorded them in the savannah part of the protected area. The ground feeding sites observed may, therefore, reflect signs from other species as well as pangolins. Pangolins may also not return frequently to a feeding site on the ground that it had visited recently due to prey depletion or predator avoidance.

Relying on LEK of hunting communities to inform camera-trap placement can be a useful approach in helping to develop cost-effective monitoring protocols for elusive species like pangolins. For researchers intending to investigate presence or behaviour of white-bellied pangolins, camera-traps set on logs offer a cost-effective means of detecting and observing the animals in the field. Given the short time in which we detected pangolins, this method could be used for quickly identifying pangolin inhabited areas for Rapid Biodiversity Assessments, tagging studies, and habitat suitability assessments. The results we present here are preliminary, and we recommend a more rigorous systematic study to compare the detection rates of white-bellied pangolins using different survey designs (e.g. random, standard-grid, and arboreal placement) with a LEK-informed survey design at the same place, as well as investigating pangolin preference for particular tree species. We note that while the evidence we present here is not from a systematic methods comparison, our results are promising, considering the low number of pangolin detections acquired during 18 studies using 2,287 camera-traps across different sampling regions and sites across the species' range (Khwaja et al., 2019). Overall, the results from this study support that targeted camera trapping based on LEK can increase detection rates and, thereby, contribute towards the development of improved monitoring methods for pangolins.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

References

Akpona, H. A., Djagoun, C. A. M. S., & Sinsin, B. (2008). Ecology and ethnozoology of the three-cusped pangolin Manis tricuspis (Mammalia, Pholidota) in the Lama forest reserve, Benin. *mammalia*, *72*(3), 198–202. https://doi.org/10.1515/MAMM.2008.046

Bobo Kadiri, S., Kamgaing Towa, O. W., Ntumwel Bonito, C., Kagalang, D., Kengne Khounda, P., Nghoueda, J., Ndengue Mekongo, S.L., Ngo Badjeck, M. M., Aghomo Fodjou, F.M. (2014). Species richness, spatial distribution and densities of large- and medium-sized mammals in the northern periphery of Boumba-bek National Park, Southeastern Cameroon. *African study monographs*, 49, 91-114. https://doi.org/10.14989/189626

Bruce, T., Amin, R., Wacher, T., Fankem, O., Ndjassi, C., Ngo Bata, M., Fowler, A., Ndinga, H., & Olson, D. (2018). Using camera trap data to characterise terrestrial larger-bodied mammal communities in different management sectors of the Dja Faunal Reserve, Cameroon. *African Journal of Ecology*, *56*(4), 759-776. https://doi.org/10.1111/aje.12574

Cusack, J. J., Dickman, A. J., Rowcliffe, J. M., Carbone, C., Macdonald, D. W., & Coulson, T. (2015). Random versus Game Trail-Based Camera Trap Placement Strategy for Monitoring Terrestrial Mammal Communities. *PLOS ONE*, *10*(5), e0126373. https://doi.org/10.1371/journal.pone.0126373

Diangha, M. N. (2015). *The effects of habitat heterogeneity and human influences on the diversity, abundance, and distribution of large mammals : The case of Deng Deng National Park, Cameroon*. Consulté 8 juillet 2019, à l'adresse https://opus4.kobv.de/opus4-btu/frontdoor/index/index/docId/3571

Fa, J. E., Seymour, S., Dupain, J., Amin, R., Albrechtsen, L., & Macdonald, D. (2006). Getting to grips with the magnitude of exploitation : Bushmeat in the Cross–Sanaga rivers region, Nigeria and Cameroon. *Biological Conservation*, *129*(4), 497-510. https://doi.org/10.1016/j.biocon.2005.11.031

Hofmeester, T. R., Cromsigt, J. P. G. M., Odden, J., Andrén, H., Kindberg, J., & Linnell, J. D. C. (2019). Framing pictures : A conceptual framework to identify and correct for biases in detection probability of camera traps enabling multi-species comparison. *Ecology and Evolution*, *9*(4), 2320-2336. https://doi.org/10.1002/ece3.4878

Ichu, G., Nyumu Kambale, J., Moumbolou Mousset, C. L., Tarla Nchembi, F., & Olson, D. (2017). *Testing the Efficacity of Field Surveys and Local Knowledge for Assessing the Status and Threats to Three Species of Pangolins in Cameroon* (p. 50). Zoological Society of London, Cameroon.

Ingram, D. J., Cronin, D. T., Challender, D. W. S., Venditti, D. M., & Gonder, M. K. (2019). Characterising trafficking and trade of pangolins in the Gulf of Guinea. *Global Ecology and Conservation*, *17*, e00576. https://doi.org/10.1016/j.gecco.2019.e00576

Ingram, D. J., Willcox, D., & Challender, D. W. S. (2019). Evaluation of the application of methods used to detect and monitor selected mammalian taxa to pangolin monitoring. *Global Ecology and Conservation*, *18*, e00632. https://doi.org/10.1016/j.gecco.2019.e00632

Khwaja, H., Buchan, C., Wearn, O. R., Bahaa-el-din, L., Bantlin, D., Bernard, H., Bitariho, R., Bohm, T., Borah, J., Brodie, J., Chutipong, W., Preez, B. du, Ebang-Mbele, A., Edwards, S., Fairet, E., Frechette, J. L., Garside, A., Gibson, L., Giordano, A., … Challender, D. W. S. (2019). Pangolins in global camera trap data : Implications for ecological monitoring. *Global Ecology and Conservation*, *20*, e00769. https://doi.org/10.1016/j.gecco.2019.e00769

Kingdon, J., Happold, D., Butynski, T., Hoffmann, M., Happold, M., & Kalina, J. (2013). *Mammals of Africa Volume 5:Carnivores, Pangolins, Equids and Rhinoceroses: Vol. V* (1st éd.). Bloomsbury Natural History. https://www.bloomsbury.com/uk/mammals-of-africa-9781408122570/

Maisels, F., Ambahe, R., Ambassa, E., Fosso, B., Poumegne, J.-B., & Fotso, R. (2011). Gorilla Population in Deng Deng National Park and a Logging Concession. *Gorilla Journal*, *42*, 18-19.

McCallum, J. (2013). Changing use of camera traps in mammalian field research : Habitats, taxa and study types: Camera trap use and development in field ecology. *Mammal Review*, *43*(3), 196-206. https://doi.org/10.1111/j.1365-2907.2012.00216.x

Nash, H. C., Wong, M. H. G., & Turvey, S. T. (2016). Using local ecological knowledge to determine status and threats of the Critically Endangered Chinese pangolin (Manis pentadactyla) in Hainan, China. *Biological Conservation*, *196*, 189-195. https://doi.org/10.1016/j.biocon.2016.02.025

Newton, P., Van Thai, N., Roberton, S., & Bell, D. (2008). Pangolins in peril : Using local hunters' knowledge to conserve elusive species in Vietnam. *Endangered Species Research*, *6*, 41-53. https://doi.org/doi: 10.3354/esr00127

O'Brien, T. G., Kinnaird, M. F., & Wibisono, H. T. (2017). Crouching tigers, hidden prey : Sumatran tiger and prey populations in a tropical forest landscape. *Animal Conservation*, 131-139. https://doi.org/10.1017/S1367943003003172@10.1111/(ISSN)1469-1795.TRAPPING

Pietersen, D., Moumbolou Mousset, C., Ingram, D. J., Soewu, D., Jansen, R., Sodeinde, O. A., Keboy Mov Linkey, I., Challender, D. W. S., & Shirley, M. H. (2019). Phataginus tricuspis, White-bellied Pangolin. *The IUCN Red List of Threatened Species*. http://dx.doi.org/10.2305/IUCN.UK.2019- 3.RLTS.T12767A123586469.en

Tobler, M. W., Carrillo-Percastegui, S. E., Pitman, R. L., Mares, R., & Powell, G. (2008). An evaluation of camera traps for inventorying large- and medium-sized terrestrial rainforest mammals. *Animal Conservation*, *11*(3), 169-178. https://doi.org/10.1111/j.1469-1795.2008.00169.x

Treves, A., Mwima, P., Plumptre, A. J., & Isoke, S. (2010). Camera-trapping forest–woodland wildlife of western Uganda reveals how gregariousness biases estimates of relative abundance and distribution. *Biological Conservation*, *143*(2), 521-528. https://doi.org/10.1016/j.biocon.2009.11.025

Willcox, D., Nash, H. C., Trageser, S., Kim, H. J., Hywood, L., Connelly, E., Ichu Ichu, G., Kambale Nyumu, J., Mousset Moumbolou, C. L., Ingram, D. J., & Challender, D. W. S. (2019). Evaluating methods for detecting and monitoring pangolin (Pholidata : Manidae) populations. *Global Ecology and Conservation*, *17*, e00539. https://doi.org/10.1016/j.gecco.2019.e00539

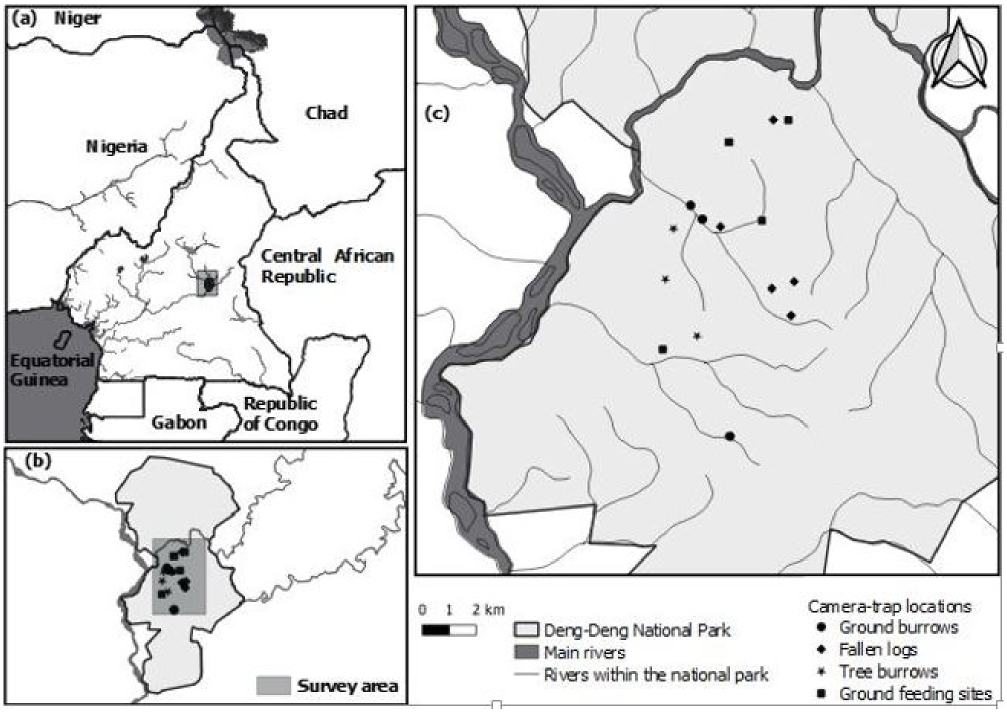

Figure 1. Location of Deng-Deng National Park, Cameroon (a) and location of camera-traps in the Central sector of the protected area (b and c).

173x121mm (96 x 96 DPI)

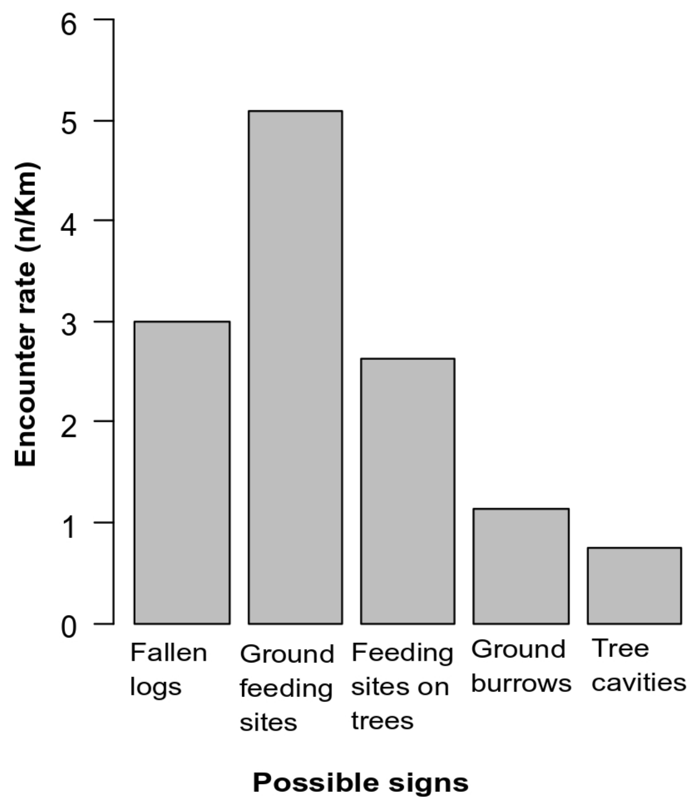

Figure 2. Encounter rate of possible pangolin signs and use areas along transects in Deng-Deng National Park, Cameroon.

424x398mm (72 x 72 DPI)

Table 1. White-bellied pangolin detections by potential pangolin activity sites.

Potential activity Sites	Number of camera locations	Sampling efforts (days)	Average number of events per camera	Percentage of events (no.)	Trapping rate per 100 days
Fallen logs	5	325	8.6	79.63% (43)	13
Ground feeding sites	3	196	1.7	9.26% (5)	3
Feeding site on trees	2	131	2	7.41% (4)	3
Ground burrows	3	199	0.7	3.7% (2)	1
Tree cavities	2	131	0	0% (0)	0
Total	15	982		100% (54)	

Figure 3. White-bellied pangolin (Phataginus tricuspis) walking along the trunk of a dead fallen tree.

194x119mm (96 x 96 DPI)