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continued on the back inside cover

Caption: Sand Cat *Felis margarita thinobius* in the Kyzylkum Desert, Bukhara Province, Uzbekistan. Credit: Robert J. Burnside.

Foreword to the small wild cats special issue

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We are delighted to present this first special issue on small wild cats on a special occasion—the Journal of Threatened Taxa's 21st anniversary!

Small wild cats are fascinating but elusive. Biologists are only beginning to fathom their vital ecological roles in maintaining and preserving biodiversity. Yet, surveys and conservation efforts targeting them are still underfunded. Most of them live in the long shadow cast by the more widely known *Panthera* cats that attract the lion's share of international funding. Much of what we know about small wild cats is a result of by-catch data from camera trap surveys targeted at larger mammals. There is still a dearth of people with passion for and expertise in research and conservation of small wild cats. With this issue, we hope to raise your awareness for their conservation needs and inspire you to join us in unravelling their mysteries.

The European Wildcat *Felis silvestris* is the only one presented in this issue that benefits from a conservation program. Running in Germany since 2004, this program aims at relinking forests and doubling the area inhabited by Europe's smallest cat until 2019. The authors scrutinize the relation between camera trap locations, human disturbance, and photographic capture success of Wildcats in an unprotected forest.

Two contributions focus on small wild cats in Uzbekistan's Kyzylkum Desert. One accounts of the cryptic Sand Cat *Felis margarita* caught red-handed in the act of feeding on a large kill. The authors were fortunate to happen upon amazing video footage. The other sheds light upon the fate of the Caracal *Caracal caracal* in the country. The author presents a sublime collection of records obtained during expeditions of over 2,000km on dusty roads to remote areas.

For decades, both the Fishing Cat *Prionailurus viverrinus* and the Clouded Leopard *Neofelis nebulosa* were known to inhabit Nepal's subtropical jungles. And still, they show up in entirely unexpected sites, prompting the authors to contribute a new locality record for both species.

The cat of many costumes is known to occur in India since the 1830s but has remained elusive in Buxa Tiger Reserve for more than 175 years. The reserve's personnel discloses new records of the Asiatic Golden Cat *Catopuma temminckii*.

For the first time in India, a team of 14 authors pooled their records on small wild cats obtained during several years of camera trapping. Their contribution provides enthralling insights into the activity patterns of the Asiatic Golden Cat, the Clouded Leopard, the Marbled Cat *Pardofelis marmorata*, and Asia's most successful small wild cat, the Leopard Cat *Prionailurus bengalensis*.

Asia's smallest wild cat broke a record in Sri Lanka. The Rusty-spotted Cat *Prionailurus rubiginosus* showed up at a location where nobody would ever have expected it. The authors also present evidence for a breeding population of the species in a montane forest in the country.

You need to know a cat's prey to understand its habits, once wrote a renowned wildlife scientist. A team

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of four authors took this insight to heart and into the field of a biosphere reserve in Thailand. For their study on the Leopard Cat *Prionailurus bengalensis*, they used a novel approach—they simultaneously set up camera traps and caught rodents—with intriguing results!

A team of eight authors set out tracing records of Fishing Cat in Thailand, teasing apart authenticated from alleged ones. Their update reveals that not only protected areas provide suitable habitat for the 'queen of the marshes'. It also indicates that the Fishing Cat found a group of champions who are committed to its protection!

Ten years of continuous camera trapping surveys reveal the diversity of small wild cats in Central Kalimantan: the Marbled Cat, the Sunda Clouded Leopard *Neofelis diardi*, the Bay Cat *Catopuma badia*, the Sunda Leopard Cat *Prionailurus javanensis*, and the Flat-headed Cat *P. planiceps*. The authors give a comprehensive insight into their ecology and persistence in Borneo's fire-prone peat-swamp forests.

We thank Luigi Boitani, Andrew Kitchener, Christine Thiel-Bender, Mariya Gritsina, Alexander Sliwa, Arash Ghoddousi, Anna Barashkova, Daniel Willcox, P.O. Nameer, Anwaruddin Choudhury, Wanlop Chutipong, Mohd Azlan Jayasilan bin Abdul Gulam Azad, Lon Grassman Jr., Tawqir Bashir, Kurtis Jai-Chyi Pei, J.W. Duckworth, Andreas Wilting, Carl Traeholt, Babu Ram Lamichhane, Honnavali Kumara, and Sagar Dahal for reviewing the submitted manuscripts for this special issue.

We have one wish—that we will all be inspired by the curiosity and enthusiasm of those who contributed to this issue, particularly when it comes to understanding and protecting our environment. As Alexander von Humboldt wrote, people only protect what they love. If people are to protect small wild cats, they must first and foremost understand and come to have a profound affection for nature to marvel and admire, but above all, to recount gripping tales.

Stay fascinated and share your experiences about small wild cats for the next issue!

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ARTICLE

Using camera traps to study the elusive European Wildcat *Felis silvestris silvestris* Schreber, 1777 (Carnivora: Felidae) in central Germany: what makes a good camera trapping site?

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Abstract: Camera traping is a widely used method to study the abundance and population density of elusive terrestrial animals. To make full use of this method, it is necessary to obtain high photographic capture rates of the target species. We examine what characteristics of camera trapping sites are associated with high photographic capture rates of European Wildcat *Felis silvestris silvestris*. We measured Wildcat capture rates across 25 camera trapping sites located in a 20km² study area within an unprotected low mountain range forest in central Germany. We measured the distance of each trapping site to the forest boundary, to the next watercourse, and to the next human settlement, and broadly defined the type of forest structure the site was located in. None of these site characteristics, however, predicted wildcat photographic capture success. We also examined the degree of human disturbance at the site, measured as the photographic capture rate of humans (including vehicles). Wildcats were detected at similar rates on dirt or gravel roads (heavily used by humans) as on soft-surfaced paths or logging trails (less frequently used by humans), and the degree of human disturbance across sites did not affect wildcat capture success. We, therefore, suggest that trail features such as course, curvature and width, or vegetation density along the trail are more important determinants of Wildcat capture success than habitat characteristics. We conclude that for European Wildcats, as for many larger felids, forest roads provide suitable camera trapping sites and that Wildcats are fairly tolerant towards human traffic on these roads.

Keywords: Capture rate, habitat selection, human disturbance, trapping success.

German Abstract: Der Einsatz von Fotofallen ist eine gängige Methode, um die Abundanz und Populationsdichte heimlicher Säugetierarten zu untersuchen. Um diese Methode voll ausschöpfen zu können, ist eine gründliche, auf die zu untersuchende Tierart abgestimmte Auswahl der Fotofallen-Standorte nötig. Die vorliegende Studie untersucht die Fotofrequenz der Europäischen Wildkatze (Felis silvestris silvestris) an 25 Fotofallen-Standorten in einem 20 km² großen Untersuchungsgebiet in einem Wirtschaftswald des deutschen Mittelgebirges. Sie geht der Frage nach, welche Charakteristiken von Fotofallen-Standorten mit einer hohen Fotofrequenz der Europäischen Wildkatze einhergehen. Gemessen wurden die Entfernung des Fotofallen-Standorts zum Waldesrand, zum nächsten Wasserlauf und zur nächsten menschlichen Siedlung. Außerdem wurde der Habitattyp des Fotofallen-Standortes grob bestimmt und der Grad des durch den Menschen verursachten Störung am Fotofallen-Standort als die Foto-frequenz von Menschen (einschließlich Fahrzeugen) gemessen. Wildkatzen wurden in ähnlichen Häufigkeiten auf Forst- und Waldwegen fotografiert wie auf Fußpfaden und Rückewegen. Jedoch hatte keine der von uns gemessenen Variablen einen Einfluss auf die Häufigkeit, mit der Wildkatzen fotografiert wurden. Auch der Grad der durch den Menschen verursachten Störung wirkte sich nicht nicht auf die Häufigkeit aus, mit der Wildkatzen fotografiert wurden. Diese Ergebnisse legen nahe, dass Forst- und Waldwege für die Wildkatze ebenso gute Fotofallen-Standorte darstellen, wie für viele größere Katzen. Zudem scheint die Wildkatze relativ tolerant zu sein gegenüber Störungen durch Menschen und Fahrzeuge auf diesen Wegen.

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GEORG-AUGUST-UNIVERSITÄT GÖTTINGEN
BUND FRIENDS OF THE EARTH GERMANY

INTRODUCTION

The past few decades saw a comeback of some previously rare or locally extinct large and medium-sized carnivores in central Europe (Chapron et al. 2014; Boitani & Linnell 2015; Thiel-Bender 2015). One of these species is the European Wildcat *Felis silvestris silvestris* Schreber 1777, even though in comparison to large mammalian carnivores such as Wolf *Canis lupus*, Lynx *Lynx lynx*, and Brown Bear *Ursus arctos*, its comeback was more secretive in nature.

The European Wildcat is a small (app. 3–6 kg), solitarily-hunting, and predominantly nocturnal felid, which in size and appearance is similar to domestic cat *Felis catus* (Piechocki 1990; Kitchener et al. 2005; Thiel-Bender 2015; Image 1). The species was once widely distributed across central Europe. Within the last two centuries, however, its population experienced a radical decline owing to human persecution, habitat loss, and hybridization with domestic cats (Piechocki 1990; Nowell & Jackson 1996; Beaumont et al. 2001; Pierpaoli et al. 2003; Oliveira et al. 2008; Klar et al. 2009; Macdonald et al. 2010; Hartmann et al. 2013). Today, Wildcats are distributed in fragmented populations ranging from Scotland to the Near East, and from Belarus to Portugal (Yamaguchi et al. 2015). Even though wildcat populations are still threatened and/ or declining in some areas of Europe, particularly on the Iberian Peninsula and in Scotland, the species is currently expanding its range in several European countries (e.g., France: Say et al. 2012; Germany: Thiel-Bender 2015, Steyer et al. 2016).

Until recently, Wildcats in Germany were considered to be distributed in two isolated populations, a central German population and a western population, the latter presumably extending into France (Birlenbach & Klar 2009). A recent large-scale genetic census carried out between 2007 and 2013 suggests that these formerly separated populations are now connected such that the species appears to be continuously distributed across large parts of western and central Germany (Steyer et al. 2016). Moreover, 44% of Wildcat samples were obtained from locations outside the previously known Wildcat distribution. These results illustrate that German Wildcats are currently regaining large parts of their historic range. Estimates of Wildcat population density, however, are often lacking, particularly from the newly colonized areas.

A frequently applied method for wildcat population monitoring is the use of valerian-treated lure sticks (Hupe & Simon 2007; Steyer et al. 2013), which enable the collection of hair samples for genetic analyses. An important advantage of this method is that samples can be sexed and their taxonomic status (i.e., Wildcat, domestic cat, or hybrid) can be determined reliably. In addition, samples can be genotyped, allowing for DNA-based individual identification of the sampled animals. This information can then be used for abundance estimations based on capture-recapture approaches (Kéry et al. 2011). For capture-recapture models to produce reliable abundance estimates, however, a sufficiently large number of genotyped samples are required, rendering the lure-stick method an expensive sampling method.

Another widely applied method for monitoring elusive animals is the use of camera traps (O'Conell et al. 2010; Rovero & Zimmermann 2016). If individual animals can be identified on camera trap images, this method, too, can be used for abundance estimations based on capture-recapture models (Zimmermann & Foresti 2016). This method is a common tool for abundance estimation of striped and spotted felids such as Tiger *Panthera tigris* (Karanth 1995), Jaguar *P. onca* (Harmsen et al. 2017), and European Lynx (Pesenti & Zimmermann 2013), and was also applied to estimate the abundance and population density of Wildcats (Can et al. 2011; Anile et al. 2014; Kilshaw et al. 2015; Velli et al. 2015). Just like any other sampling method used to carry out capture-recapture analyses, this method, too, requires a sufficient number of samples (in this case, identifiable images) for reliable abundance estimation. Yet, in comparison to the lure-stick method, camera traps have the advantage that once the initial costs of purchasing the cameras are paid, any sample 'collected' by the cameras (i.e., any image taken) comes at a low cost. To make full use of this advantage, it is necessary to make a sensible choice of trapping sites, in other words, to choose trapping sites that maximize the capture success of the target species.

The present study examines trapping site characteristics for the study of European Wildcats in a central European low mountain range, i.e., what site characteristics are associated with high photographic capture rates of European Wildcats. A first important factor that comes into mind when choosing a suitable camera trapping site is habitat. Habitat selection is comparatively well-studied in European Wildcats (Okarma et al. 2002; Lozano et al. 2003; Hötzel et al. 2007; Klar et al. 2008; Monterroso et al. 2009; Jerosch et al. 2017) and a number of habitat preferences of European Wildcats were identified. First of all, even though recent studies demonstrated that Wildcats can use significant proportions of open, agriculturally-dominated landscape

Image 1. Camera trap image of a European Wildcat *Felis silvestris silvestris,* taken in November 2016 in the Melsunger Bergland. © University of Göttingen Lynx Project.

(Jerosch et al. 2017; Götz et al. 2018), in central Europe, the Wildcat is traditionally described as a species bound to forests (Piechocki 1990; Nowell & Jackson 1996; Hötzel et al. 2007; Klar et al. 2008). Within forests, radio tracking studies revealed that Wildcats spend more time close to the forest boundary and seem to be attracted also by watercourses, meadows, and open areas within the forest (Klar et al. 2008), presumably because these habitats are characterized by higher prey population densities. A preference for such ecotone habitats was also revealed by snow tracking in the Polish Carpathian Mountains (Okarma et al. 2002). Moreover, Wildcats seem to prefer wind-throw areas and young succession stages with dense undergrowth while coniferous stands tend to be avoided (Okarma et al. 2002; Hötzel et al. 2007). Lastly, human infrastructure, such as roads or villages, are also usually avoided by Wildcats, though beyond a certain distance (ca. 200m to roads and single houses, ca. 900m to villages) human infrastructure does not seem to affect wildcat ranging pattern (Klar et al. 2008). Taking these habitat preferences into account, we should thus expect the photographic capture rate of Wildcats to increase when camera trapping sites are located (i) closer to open areas within forests or to the forest boundary, (ii) closer to watercourses, and (iii) further from human settlements. We should also expect (iv) more Wildcats to be camera trapped at sites located within preferred habitats such as wind-thrown areas, and (v) fewer Wildcats at sites located within the less-preferred habitats such as coniferous stands.

To examine whether the photographic capture rate of Wildcats is affected by the above habitat characteristics and/ or the proximity to human settlements, we analyzed data collected over a period of three months at 25 camera trapping sites within a 20km² study area in central Germany. This study area is located within an unprotected forest that is used for timber production and recreation activities such as hiking, mountain biking, and hunting. Because our trapping sites varied to the extent they were exposed to human disturbance (including vehicles), we also examined whether the photographic capture rate of Wildcats was affected by the degree of human disturbance at the sites.

STUDY AREA

The study area was located in a low mountain range known as Melsunger Bergland, approximately 20km southeast of the city of Kassel in central Germany (Fig. 1). The study area is almost completely covered by forest, consisting of approximately 40% broad-leaved forest, 30% mixed forest, and 30% coniferous forest. The forest is broken up only by the village of Kehrenbach (with a population of 320 inhabitants) and its surrounding fields, located approximately in the centre of the study

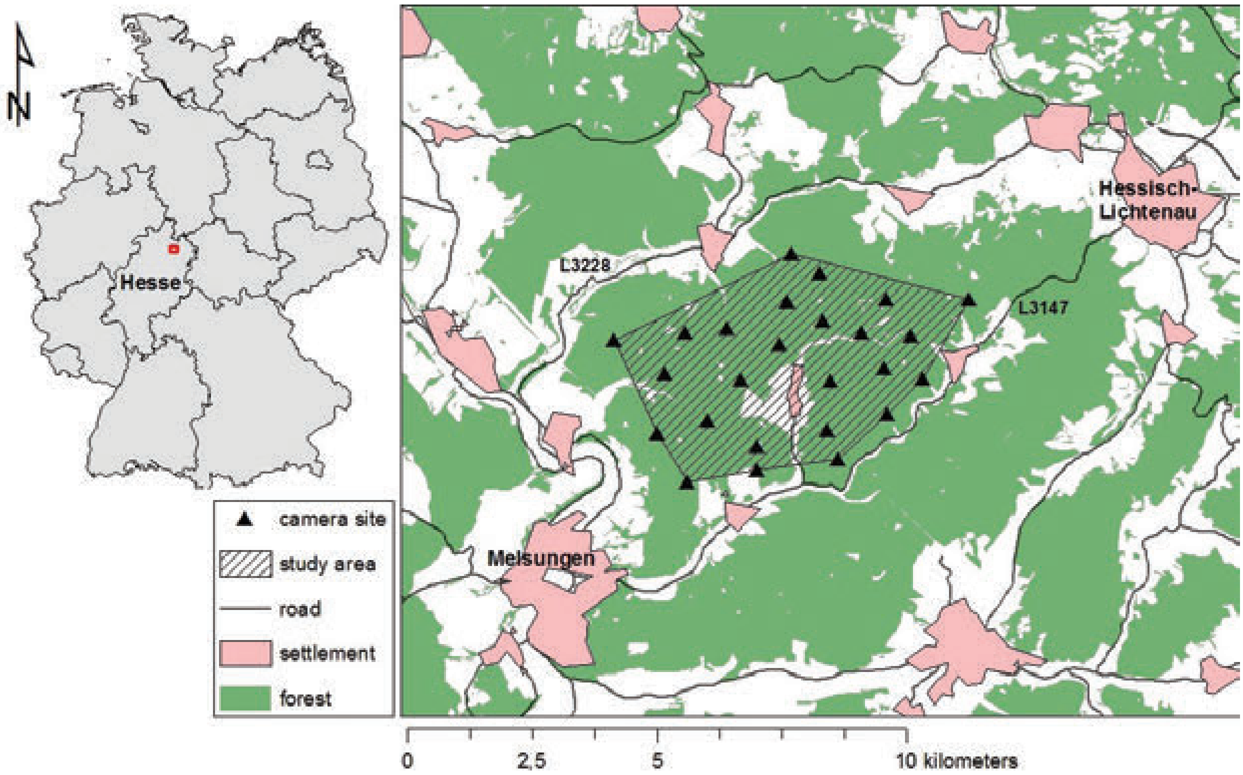

Figure 1. The left-hand image shows a schematic map of Germany with the federal state of Hesse in the center. The right-hand image shows the study area located in the north of Hesse (indicated by a red square on the left-hand image).

area, as well as by a small road (leading to the village) in the south of the study area. Even though the forest is used for timber production and recreation activities, it supports a diverse community of animal species, including large mammals such as Roe Deer *Capreolus capreolus*, Red Deer *Cervus elaphus*, Wild Pig *Sus scrofa*, European Badger *Meles meles*, and Red Fox *Vulpes vulpes*. Moreover, a small population of Eurasian Lynx started to recolonize the area since 2009 (Denk 2016).

The elevation of the study area ranges between 300m in the valley of the river Fulda in the west and 500m in the east. With an annual mean precipitation of 676cm and average temperatures from 0.2°C in January to 17.7°C in July, the Melsunger Bergland is located in the transition zone between Atlantic and continental climate with mild and humid winters.

METHODS

Camera trap placement

The study was carried out between 26 June and 8 October 2017 as part of a project aimed at estimating Wildcat population density in the area (Werner & Port in preparation). Cameras were placed at 25 trapping sites within the forest, one site located in every cell of a 1kmx1km grid (omitting only the village of Kehrenbach and its surrounding fields). The minimum convex polygon encompassing all stations amounted to 20km² with an average (±SD) distance between camera sites of 863m (±207m). Sites were located either along forest roads (n=9) or forest trails (n=16).

All cameras used were Cuddeback® camera traps (Cuddeback Digital, Green Bay, USA) of the models Ambush® and C1®. These are heat- and motion-triggered cameras that record colour images both at day and night using a white flash. We installed two camera traps per station, one on each side of the road or trail, to obtain images of both flanks of a passing animal. Cameras were set up 3.2–22.1 m apart from each other along the road to avoid overexposure of images by the flash of the opposite camera. Delay time between successive images was set to the shortest time frame possible (1–60 s, depending on camera type and time of day). Camera traps were secured inside metal boxes, locked with a padlock or cable lock, and attached to a tree or a pole approximately 30cm above ground. Camera traps were checked every four weeks to replace batteries and SD cards and to clear the areas in front of the cameras of overgrowing vegetation.

Habitat characteristics

To define habitat characteristics of our trapping sites and the proximity to human infrastructure, we used aerial images of the study area and forest management data generously provided by HessenForst, the forestry management unit of the German federal state of Hesse. Geographic data were processed using ArcMap 10.5.1 (Esri, Inc., Redlands, CA, USA).

To determine the distance between the trapping site and the closest forest boundary, we used aerial images. As forest boundary, we defined any 'outer' forest boundary (usually to villages, fields, or roads; Fig. 1), or any boundary to clearings within the forest with a minimum area of 20mx20m. Likewise, we measured the distance of our trapping sites to the closest watercourse (creek, pond, or ditch) with a permanent water body. Lastly, to determine the distance between the trapping site and human settlements, we measured the distance to the closest house with regular human activity (excluding, for example, barns or similar buildings).

We classified the habitat of our trapping sites based on the type of forest stand the cameras were located in. We distinguished broadly between three categories of forest structure that were found to predict Wildcat ranging patterns in previous studies (Okarma et al. 2002; Hötzel et al. 2007). Owing to the small number of trapping sites, a finer subdivision of forest structure types does not appear functional. These three categories were defined based on the dominating type of tree (broad-leaved, mixed, or coniferous) and the following four succession stages (Smith et al. 1997): (1) stand initiation: the earliest succession stage, consisting of young trees with a diameter at breast height (DBH) of usually <7cm, (2) stem exclusion: a succession stage consisting of trees in early development, with DBH<20cm, (3) understorey reinitiation: the stand developed a stratification with canopy, midstorey, and understorey, with older trees reaching a DBH between 21cm and 50cm, and (4) old growth: the stand reached its development climax and is multi-aged and multi-layered with a dense vegetation and a relatively high percentage of dead wood. Stands of this succession stage were rare in the study area and no trapping site was located in it.

In this way, and partially following the classifications used by Hötzel et al. (2007), we defined the following three forest structure types:

(1) Wind-throw/ stand initiation: Areas that experienced a recent disturbance, either by storm damage or clear-cutting, and are now naturally or artificially regenerating. Bushes such as blackberry and dead wood create a dense ground cover (Image 2e).

(2) Mixed/ broad-leaved forest in the succession stages of stem exclusion and older: a very broad category that characterizes large parts of the study area. Mixed and broad-leaved forest were not further distinguished since their understorey structure is similar (Image 2a).

(3) Pure coniferous stands in the succession stage stem exclusion or old: this category usually consists of even-aged, dark stands, usually of Spruce *Picea* trees with poor understorey (Image 2c).

Human disturbance

The degree of human disturbance at the trapping site was measured as the number of camera trap images showing humans and/ or vehicles (e.g., bikes, cars, trucks). In compliance with the data protection policies of the German federal state of Hesse, these images were deleted afterwards.

Wildcat detection and data analyses

The response variable in our analyses was the number of independent Wildcat detections that occurred at a trapping site. As a Wildcat detection, we defined any Wildcat recorded after at least five minutes passed since the last recorded Wildcat. Wildcats captured simultaneously by both cameras at a site were counted as only one detection. Moreover, images of a female with kittens were counted as one detection. In general, we included all recordings of wild-living cats that showed morphologic features characteristic for Wildcats (Kitchener et al. 2005; Kilshaw et al. 2015; Thiel-Bender 2015). We would have excluded images of wild-living cats that showed features characteristic for domestic cats (e.g., white paws, white spots on flanks, pointed tail tip), though no such individuals were recorded during our study.

Since it is difficult to distinguish Wildcats from hybrids based on camera trap images (but see Kilshaw et al. 2015), however, we cannot exclude the possibility that our sample of wild-living cats contained some hybrids as well, though we note that the degree of hybridization is low (3.9%) in German Wildcats (Steyer et al. 2016).

We examined the relationship between our response variable (number of Wildcat detections) and the various site characteristics (distance to forest boundary, distance to water, distance to settlement, forest structure, human disturbance) using general linear models (GLMs) with log link function and negative binomial error structure. In order to avoid overfitting of our models, we ran two separate models: a first model contained the 'habitat characteristics', distance to forest boundary, distance to water, distance to settlement, and forest structure

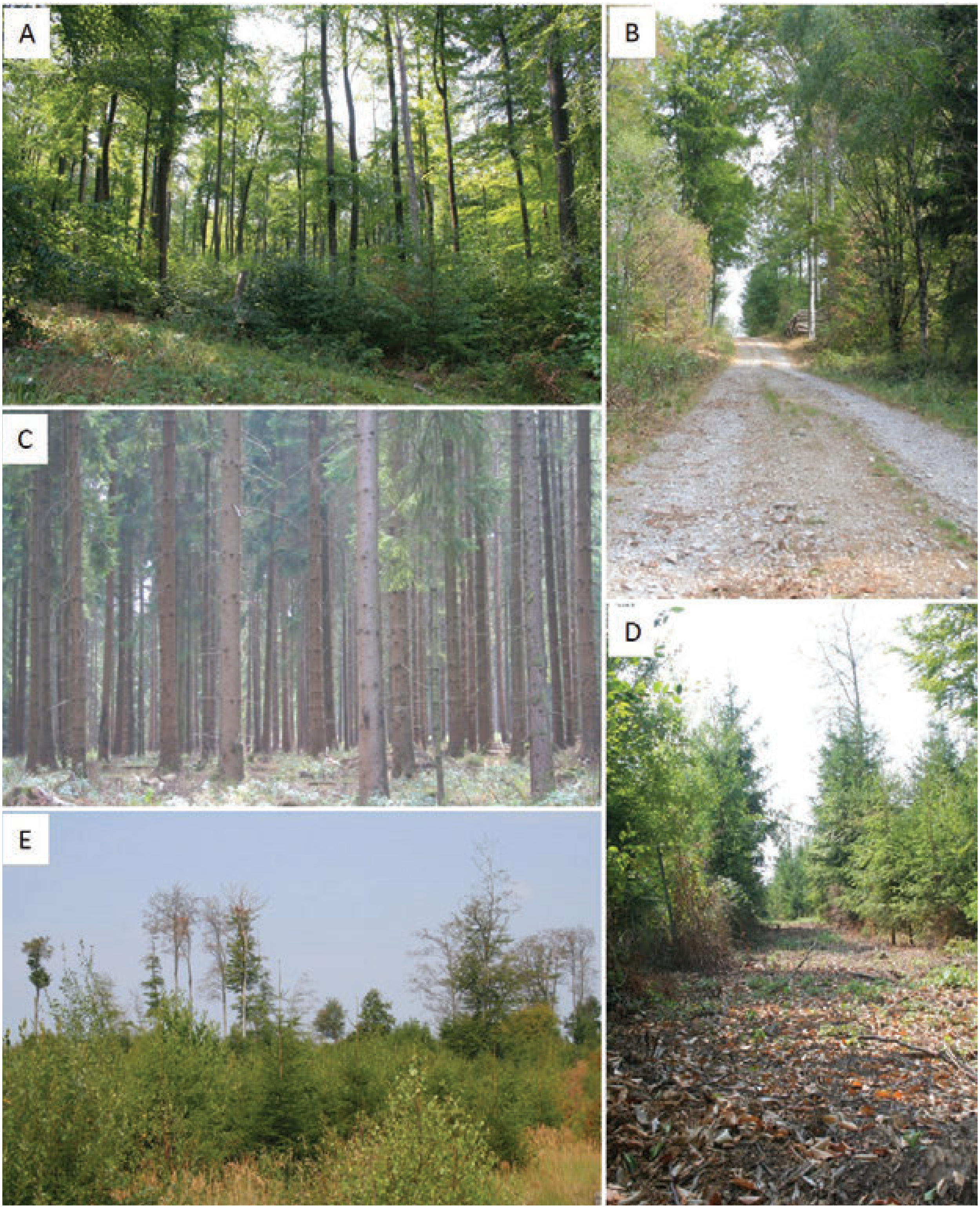

Image 2. Trapping location types and habitat types: A - broad-leaved forest typical for the study area; B - a typical forest road; C - coniferous stand; D - example of a forest trail; E - a wind-thrown area regrowing for approximately 10 years. © M. Port.

as explanatory variables. A second model contained all predictors found to significantly affect the number of Wildcat detections in the first model, as well as the degree of human disturbance measured at the trapping sites. To account for the possibility that Wildcat records differed between sites located on forest roads and sites located on forest trails, this model contained the location of the site (road, trail) as a further predictor. To account for differences in camera operation times between sites, both models contained camera operation time (in days) as an offset term. Analyses were performed in R (R Core Team, 2016, Vienna, Austria) using the package "Mass".

RESULT

Trapping success

Even though several cameras malfunctioned over the course of the study, at least one camera per site operated for 99–105 days (day=24h). Only at one site both cameras broke down during the same time period, such that this site had only 86 recording days. In total, our cameras operated for 2,552 trapping days (defined as the number of sites multiplied by the number of days during which at least one camera per site was operational).

We recorded a total number of 164 Wildcat detections (including possible hybrids), resulting in a capture rate of 6.43 records per 100 trap days. The number of Wildcat records across sites ranged between 1 and 14 detections (mean=6.56, SD=4.69). At least one Wildcat was recorded at each of our 25 sites.

Habitat characteristics

Trapping sites were located between 0m and 577m away from the next forest boundary (mean=226.88m, SD=170.03m), between 1m and 629m away from the next watercourse (mean=352.44m, SD=194.35m), and between 461m and 1,475m away from the next human settlement (mean=934.32m, SD=344.6m). Eleven sites were located within wind-throw areas/ stand initiations (forest structure type 1), 11 sites in broad-leaved or mixed forest areas of succession stages 2 or older (forest structure type 2), while only three sites were located in coniferous stands (forest structure type 3). None of the habitat characteristics had a significant effect on the number of recorded Wildcats (Table 1). On average, only 4 (SD=2) Wildcats were detected in coniferous stands, whereas on average 6.45 (SD=5.12) and 7.36 (SD=4.8) Wildcats were detected in wind-throw areas and mixed or broad-leaved forest stands, respectively, but this difference was statistically not significant.

Human disturbance

The number of human detections ranged between 0 and 1058 (mean=152.84, SD=262.2) and was on average markedly higher at the nine sites located on forest roads (mean=371.7, SD=358.99) than at the 16 sites located on trails (mean=42.93, SD=51.48). On average, 7.4 (SD=5.01) Wildcats were recorded on forest roads, while on average 6 (SD=4.55) Wildcats were recorded on trails. This difference was statistically not significant (Table 2).

Table 1. Results of the general linear model relating Wildcat capture rate to habitat characteristics. Forest structure type "Windthrow/ stand initiation" is used as the baseline level and is represented by the intercept.

	β	SE	z	p	95% CI	
Intercept	-2.99	0.75	-3.95	<0.001	-4.52	-1.43
Distance water	0.001	0.001	1.06	0.29	-0.001	0.003
Distance forest boundary	0.0004	0.001	0.34	0.74	-0.002	0.003
Distance village	-0.0002	0.0005	-0.4	0.69	-0.001	0.0009
Broad leaved/ mixed stand	0.1	0.38	0.27	0.79	-0.69	0.91
Coniferous stand	-0.71	0.56	-1.25	0.21	-1.81	0.42

Table 2. Results of the general linear model relating Wildcat capture rate to location type and human disturbance. Location type "forest trail" is used as the baseline level and is represented by the intercept.

	β	SE	z	p	95% CI	
Intercept	-2.84	0.2	-14.33	<0.001	-3.22	-2.44
Location: forest road	0.09	0.35	0.25	0.8	-0.6	0.8
Human disturbance	0.0004	0.0006	0.53	0.59	-0.0009	0.0018

The degree of human disturbance at the site had no effect on the number of Wildcat records.

DISCUSSION

This study examined whether characteristics of camera trapping sites, such as the distance of the site to the nearest forest boundary or the forest structure type the site was located in, predicted the photographic capture success of European Wildcats. Even though the number of Wildcat records ranged between 1 and 14 detections per site across 25 studied sites, none of the site characteristics examined in our study had a significant effect on the number of recorded Wildcats.

Habitat characteristics

Radio tracking studies of Wildcats revealed that they avoid the proximity of human infrastructure, such as settlements and roads, but only within a critical distance. This distance is reported as approximately 900m to settlements by Klar et al. (2008) and as approximately 500m by Hötzel et al. (2007). The minimum distance of our trapping sites to the nearest village was 461m, and 44% of sites were located more than 900m away from the next settlement. It is thus unsurprising that in our study the (generally large) distance of the trapping sites from human settlements did not affect Wildcat capture success.

Both radio tracking and snow tracking studies revealed that Wildcats strongly prefer ecotone habitats, such as forest boundaries, clearings within the forest, or riparian areas (Okarma et al. 2002; Hötzel et al. 2007; Klar et al. 2008), presumably because these habitats are characterized by high prey population densities, particularly of small rodents. For example, Hötzel et al. (2007) often found Wildcats hunting in open areas at night, whereas they occurred in sheltered forest areas during the day. Okarma et al. (2002) found a large fraction of Wildcat tracks along forest edges. Given these strong preferences of Wildcats for forest boundaries and riparian areas, it is perhaps surprising that the distance of our trapping sites to such habitats did not predict Wildcat capture success. This is not due to a lack of variation in these variables—the distance of our sites to forest boundaries and to watercourses varied greatly, ranging between 0m and 577m for forest boundaries, and between 1m and 629m for watercourses. The most likely reason why our study did not have similar results to those of radio tracking or snow tracking studies is the markedly different methodology. For example, radio collars can usually deliver several locations of an animal per day. In this way, they can draw a dense and detailed picture of animal ranging patterns. Likewise, snow tracking can also provide detailed insights into how frequently different habitat types are used by the animals (Okarma et al. 2002). In contrast, camera traps can only record animal movements at the location they are installed. Because the main aim of our survey was to estimate Wildcat population density (Werner & Port in preparation), we followed previous sampling designs and placed our cameras along human-made forest routes (roads and trails) as we presumed that Wildcats, like many other felids, would preferably use such trails (Karanth 1995; Di Bitetti et al. 2006; Harmsen et al. 2010; Weingarth et al. 2015). Forest trails yield the best capture success if they are used by individuals of the target species regularly and repeatedly, for example, because they connect preferentially used areas of an individual's home range (e.g., areas preferentially used for hunting or resting).

If this is the case, however, the capture success of the trapping site is not necessarily related to habitat characteristics of that site (other than the trail itself). For example, a site located within a coniferous stand, a habitat presumably less preferred by Wildcats, but that is located at a trail connecting two preferred hunting grounds, might still yield higher capture probabilities than a site located close to the forest boundary (a preferred habitat). For presumably the same reason, our study did also not detect any effect of the forest structure type surrounding the camera site. These results are in agreement with findings from three Neotropical felids—the photographic capture success of Jaguars, Puma *Puma concolor*, and Ocelot *Leopardus pardalis* depended only on features of the trail where camera traps were installed, but not on habitat characteristics such as altitude or distance to water (Harmsen et al. 2010).

A number of other variables that were not measured in the present study may affect Wildcat capture success. An important variable is the distribution and population density of prey. Researchers carrying out camera trap studies, however, do not usually have information on prey distributions and population densities, and can only base their choices of trapping sites on habitat characteristics likely associated with high prey abundance, in our case, for example, wind-throw areas (Niethammer & Krapp 1982). This is the approach we took in the present study but, as reported above, none of the studied site characteristics had a significant effect on Wildcat capture success. It is also possible that the abundance of potential competitors such as Red Foxes affects Wildcat ranging pattern and, as a consequence, trapping success at particular sites. Lastly, it is possible that we obtained different results at different times of the year. Our study was carried out in summer when the forest floor and some of the logging trails are covered by dense herbaceous vegetation. At this time of the year, Wildcats may use forest roads more often than in winter when ground vegetation is less dense. Likewise, females might be detected less often on forest roads in spring when they have dependent offspring and prefer areas with dense vegetation cover (Piechocki 1990; Jerosch et al. 2017). Any recommendation on the choice of camera trapping sites in European Wildcats (and other species) should thus take into account possible seasonal changes in ranging patterns. It would be interesting to compare results of the present study with results of prospective future studies carried out at different times of the year and/ or in areas with different population densities of Wildcats and their competitors.

Human disturbance

Photographic capture frequencies of Wildcats were similar on forest roads and on forest trails, despite the fact that forest roads were more extensively used by humans, including cars and trucks. Moreover, the degree of human disturbance, measured as the photographic capture rate of humans (including vehicles) at the site, did not affect Wildcat capture success. In fact, one of the highest capture frequencies of Wildcats (14 detections) occurred at a site with the highest frequency of human captures (1,058 images of humans). These results are largely in agreement with findings on other felids. For example, Ocelots preferred human-made dirt roads over animal trails, both in the Pantanal wetlands of Brazil (Trolle & Kéry 2005) and in northern Argentina (Di Bitetti et al. 2006). Moreover, Ocelots, Jaguars, and Pumas in Belize preferred wider trails over narrower trails (Harmsen et al. 2010). Finally, similar to the present study, the photographic capture rate of Bobcats *Lynx rufus* in Virginia (Kelly & Holub 2008) and of Eurasian Lynx in central Germany (Schröder 2016) was not affected by the amount of human traffic at the site. These results are easily explained by the fact that most human traffic takes place during the day and thus does not interfere with the predominantly nocturnal activity of Wildcats and other felids. They are, however, somewhat in contrast to the perception of the Wildcat as a secretive animal that avoids any human presence (Piechocki 1990). Instead, our results suggest that in areas where Wildcats are not persecuted by humans (as in our study area), they are more tolerant towards human disturbance than commonly thought.

What makes a good camera trapping site?

We started this article by asking "What makes a good camera trapping site?" for the study of European Wildcats in a central European low mountain range. Unfortunately, we cannot provide a conclusive answer to this question as none of the site characteristics examined in our study affected the photographic capture success of Wildcats. We, however, photo-captured at least one Wildcat at all of our sites (100%) and obtained a capture rate of 6.43 detections per 100 trap days. This capture rate is similar to the capture rate obtained by Anile et al. (2014) (6.48 detections/ 100 trap days) and at least twice as high as the capture rate of any other camera trapping study of European Wildcats (Can et al. 2011; Kilshaw et al. 2015; Velli et al. 2015). These results suggest that either Wildcat population density in the study area was particularly high and/ or that most, if not all, of our trapping sites were suitable for detecting Wildcats by means of camera trapping. Nevertheless, there is a large variation with respect to the trapping success across sites: at some sites as many as 13 (three sites) and 14 (two sites) Wildcats were detected, whereas at five sites only a single detection occurred. Clearly, therefore, some sites yielded higher capture rates than others. We suggest that differences in capture success are more closely related to features of the trail at which cameras were installed (Trolle & Kéry 2005; Di Bitetti et al. 2006; Harmsen et al. 2010), for example, course, curvature, and width of the trail, or the density of the vegetation along the trail, rather than to the habitat characteristics examined in the present study.

Still, there are at least two conclusions we can draw from the present study. A first conclusion is that human-made dirt or gravel roads are as suitable as camera trapping sites for the rather small-bodied European Wildcat as they are for many of her larger relatives. A second conclusion is that the extent of human traffic along these roads does not affect Wildcat capture success and that even roads heavily used by humans and vehicles can still make suitable camera trapping sites for the study of European Wildcats.

REFERENCES

Anile, S., B. Ragni, E. Randi, F. Mattucci & F. Rovero (2014). Wildcat population density on the Etna Volcano, Italy: a comparison of density estimation methods. *Journal of Zoology* 293(4): 252–261.

Beaumont, M., E.M. Barratt, D. Gottelli, A.C. Kitchener, M.J. Daniels,

J.K. Pritchard & M.W. Bruford (2001). Genetic diversity and introgression in the Scottish Wildcat. *Molecular Ecology* 10: 319–336.

Birlenbach, K. & N. Klar (2009). Aktionsplan zum Schutz der Europäischen Wildkatze in Deutschland. *Naturschutz und Landschaftsplanung* 41: 325–332.

Boitani, L. & J.D.C. Linnell (2015). Bringing large mammals back: large carnivores in Europe, pp67–84. In: Pereira, H.M. & L.M. Navarro (eds.). *Rewilding European Landscapes*. Springer International Publishing, Cham, xxi+227pp.

Can, Ö.E., İ. Kandemir & İ. Togan (2011). The Wildcat *Felis silvestris* in northern Turkey: assessment of status using camera-trapping. *Oryx* 45(1): 112–118.

Chapron, G., P. Kaczensky, J.D.C. Linnell, M. von Arx, D. Huber, H. Andrén, J.V. López-Bao, M. Adamec, F. Álvares, O. Anders & L. Balčiauskas (2014). Recovery of large carnivores in Europe's modern human-dominated landscapes. *Science* 346(6216): 1517–1519.

Denk, M. (2016). Luchshinweise in Hessen. Erfassungsjahr 2015/16. Hessisches Ministerium für Umwelt, Klimaschutz, Landwirtschaft und Verbraucherschutz, Wiesbaden, 24pp.

Di Bitetti, M.S., A. Paviolo & C. De Angelo (2006). Density, habitat use and activity patterns of Ocelots (*Leopardus pardalis*) in the Atlantic Forest of Misiones, Argentina. *Journal of Zoology* 270(1): 153–163.

Götz, M., S. Jerosch, O. Simon & S. Streif (2018). Raumnutzung und Habitatansprüche der Wildkatze in Deutschland. Neue Grundlagen zur Eingriffsbewertung einer streng geschützen FFH-Art. *Natur und Landschaft* 93: 161–169.

Harmsen, B.J., R.J. Foster, E. Sanchez, C.E. Gutierrez-González, S.C. Silver, L.E.T. Ostro, M.J. Kelly, E. Kay & H. Quigley (2017). Long term monitoring of Jaguars in the Cockscomb Basin Wildlife Sanctuary, Belize; implications for camera-trap studies of carnivores. *PLoS One* 12: e0179505.

Harmsen, B.J., R.J. Foster, S. Silver, L. Ostro & C.P. Doncaster (2010). Differential use of trails by forest mammals and the implications for camera-trap studies: a case study from Belize. *Biotropica* 42(1): 126–133.

Hartmann, S.A., K. Steyer, R.H.S. Kraus, G. Segelbacher & C. Nowak (2013). Potential barriers to gene flow in the endangered European Wildcat (*Felis silvestris*). *Conservation Genetics* 14(2): 413–426.

Hötzel, M., N. Klar, S. Schröder, C. Steffen & C. Thiel (2007). Die Wildkatze in der Eifel: Habitate, Ressourcen, Streifgebiete. Laurenti, Bielefeld, 191pp.

Hupe, K. & O. Simon (2007). Die Lockstockmethode - eine nicht invasive Methode zum Nachweis der Europäischen Wildkatze (*Felis s. silvestris*). *Informationsdienst Naturschutz Niedersachsen* 27: 66–69.

Jerosch, S., M. Götz & M. Roth (2017). Spatial organisation of European Wildcats (*Felis silvestris silvestris*) in an agriculturally dominated landscape in central Europe. *Mammalian Biology* 82: 8–16.

Karanth, K.U. (1995). Estimating Tiger *Panthera tigris* populations from camera-trap data using capture-recapture models. *Biological Conservation* 71(3): 333–338.

Kelly, M.J. & E.L. Holub (2008). Camera-trapping of carnivores: trap success among camera types and across species, and habitat selection by species, on Salt Pond Mountain, Giles County, Virginia. *Northeastern Naturalist* 15(2): 249–262.

Kéry, M., B. Gardner, T. Stoeckle, D. Weber & J.A. Royle (2011). Use of spatial capture-recapture modeling and DNA data to estimate densities of elusive animals. *Conservation Biology* 25(2): 356–364.

Kilshaw, K., P.J. Johnson, A.C. Kitchener & D.W. Macdonald (2015). Detecting the elusive Scottish Wildcat *Felis silvestris silvestris* using camera-trapping. *Oryx* 49(2): 207–215.

Kitchener, A.C., N. Yamaguchi, J.M. Ward & D.W. Macdonald (2005). A diagnosis for the Scottish Wildcat (*Felis silvestris*): a tool for conservation action for a critically endangered felid. *Animal Conservation* 8(3): 223–237.

Klar, N., N. Fernández, S. Kramer-Schadt, M. Herrmann, M. Trinzen, I. Büttner & C. Niemitz (2008). Habitat selection models for European Wildcat conservation. *Biological Conservation* 141: 308–319.

Klar, N., M. Herrmann & S. Kramer-Schadt (2009). Effects and mitigation of road impacts on individual movement behavior of wildcats. *Journal of Wildlife Management* 73(5): 631–638.

Lozano, J., E. Virgós, A.F. Malo, D.L. Huertas & J.G. Casanovas (2003). Importance of scrub-pastureland mosaics for wild-living cats occurrence in a Mediterranean area: implications for the conservation of the Wildcat (*Felis silvestris*). *Biodiversity & Conservation* 12(5): 921–935.

Macdonald, D.W., N. Yamaguchi, A.C. Kitchener, M. Daniels, K. Kilshaw & C. Driscoll (2010). Reversing cryptic extinction: the history, present and future of the Scottish Wildcat. pp471–492. In: Macdonald, D.W. & A. Loveridge (eds.). *The Biology and Conservation of Wild Felids*. Oxford University Press, Oxford, 784pp.

Monterroso, P., J.C. Brito, P. Ferreras & P.C. Alves (2009). Spatial ecology of the European Wildcat in a Mediterranean ecosystem: dealing with small radio-tracking datasets in species conservation. *Journal of Zoology* 279(1): 27–35.

Niethammer, J. & F. Krapp (1982). Handbuch der Säugetiere Europas. Bd. 2/1 Rodentia II (Cricetidae, Arvicolidae, Zapodidae, Spalacidae, Hystricidae, Capromyidae). Akademische Verlagsgesellschaft, Wiesbaden, 649pp.

Nowell, K. & P. Jackson (1996). *Wild Cats: Status Survey and Conservation Action Plan*. IUCN SSC Cat Specialist Group, Gland, Switzerland, xxiv+384pp.

O'Conell, A.F., J.D. Nichols & K.U. Karanth (eds.) (2010). *Camera-traps in Animal Ecology: Methods and Analyses*. Springer, Tokyo.

Okarma, H., S. Śnieżko & A. Olszańska (2002). The occurrence of Wildcat in the Polish Carpathian Mountains. *Acta Theriologica* 47(4): 499–504.

Oliveira, R., R. Godinho, E. Randi, N. Ferrand & P.C. Alves (2008). Molecular analysis of hybridisation between wild and domestic cats (*Felis silvestris*) in Portugal: implications for conservation. *Conservation Genetics* 9: 1–11.

Pesenti, E. & F. Zimmermann (2013). Density estimations of the Eurasian Lynx (*Lynx lynx*) in the Swiss Alps. *Journal of Mammalogy* 94(1): 73–81.

Piechocki, R. (1990). *Die Wildkatze Felis silvestris*. Ziemsen, Wittenberg, 232pp.

Pierpaoli, M., Z.S. Birò, M. Herrmann, K. Hupe, M. Fernandes, B. Ragni, L. Szemethy & E. Randi (2003). Genetic distinction of Wildcat (*Felis silvestris*) populations in Europe, and hybridization with domestic cats in Hungary. *Molecular Ecology* 12(10): 2585–2598.

Rovero, F. & F. Zimmermann (2016). *Camera-trapping for Wildlife Research*. Pelagic Publishing, Exeter, UK, 320pp.

Say, L., S. Devillard, F. Léger, D. Pontier & S. Ruette (2012). Distribution and spatial genetic structure of European Wildcat in France. *Animal Conservation* 15(1): 18–27.

Schröder, F. (2016). Estimation of abundance and density of Eurasian Lynx (*Lynx lynx*) in central Germany using camera-traps. Master's Thesis. University of Göttingen, Göttingen, 41pp.

Smith, D.M., B.C. Larson, M.J. Kelty & P.M.S. Ashton (1997). *The Practice of Silviculture: Applied Forest Ecology*. John Wiley & Sons, New York, 537pp.

Steyer, K., O. Simon, R.H.S. Kraus, P. Haase & C. Nowak (2013). Hair trapping with valerian-treated lure sticks as a tool for genetic Wildcat monitoring in low-density habitats. *European Journal of Wildlife Research* 59(1): 39–46.

Steyer, K., R.H.S. Kraus, T. Mölich, O. Anders, B. Cocchiararo, C. Frosch, A. Geib, M. Götz, M. Herrmann, K. Hupe & A. Kohnen (2016). Large-scale genetic census of an elusive carnivore, the European Wildcat (*Felis s. silvestris*). *Conservation Genetics* 17(5): 1183–1199.

Thiel-Bender, C. (2015). Die Wiederausbreitung der Europäischen Wildkatze in Deutschland. *Zeitschrift des Kölner Zoos* 58: 139–148.

Trolle, M. & M. Kéry (2005). Camera-trap study of Ocelot and other secretive mammals in the northern Pantanal. *Mammalia* 69(3–4): 409–416.

Velli, E., M.A. Bologna, C. Silvia, B. Ragni & E. Randi (2015). Non-invasive monitoring of the European Wildcat (*Felis silvestris silvestris* Schreber, 1777): comparative analysis of three different monitoring techniques and evaluation of their integration. *European Journal of Wildlife Research* 61(5): 657–668; https://doi.org/10.1007/s10344-015-0936-2

Weingarth, K., T. Zeppenfeld, C. Heibl, M. Heurich, L. Bufka, K. Daniszová & J. Müller (2015). Hide and seek: extended camera-trap session lengths and autumn provide best parameters for estimating Lynx densities in mountainous areas. *Biodiversity and Conservation* 24: 2935–2952.

Yamaguchi, N., A. Kitchener, C. Driscoll & B. Nussberger (2015). *Felis silvestris*. In: The IUCN Red List of Threatened Species: e.T60354712A50652361. Accessed on 15 August 2018; https://doi.org/10.2305/IUCN.UK.2015-2.RLTS.T60354712A50652361.en

Zimmermann, F. & D. Foresti (2016). Capture-recapture methods for density estimation, pp95–141. In: Rovero, F. & F. Zimmermann (eds.). *Camera-trapping for Wildlife Research*. Pelagic Publishing, Exeter, UK, 320pp.

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Activity patterns of the small and medium felid (Mammalia: Carnivora: Felidae) guild in northeastern India

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Abstract: Fifteen extant species of cats inhabit India, and the northeastern region of the country is among the richest with nine species. Among these are the "standard four", an assemblage of Clouded Leopard *Neofelis nebulosa*, Asiatic Golden Cat *Catopuma temminckii*, Marbled Cat *Pardofelis marmorata*, and Leopard Cat *Prionailurus bengalensis*, which also occur across southeastern Asia. Within India, despite several surveys in this region, very little information exists on the ecology of this assemblage to explain their co-occurrence. In this paper, we put together data from several independent camera trapping studies over 10 sites across northeastern India to examine and interpret diel activity patterns of this group. While we present results for all the four species, we focus on two species, the Marbled Cat and Leopard Cat, which are of very similar body size and are potential competitors. We used kernel density estimates to measure diel activity patterns of all four species and overlap in activity between Marbled Cat and Leopard Cat at the regional scale as well as the point scale. We obtained 783 captures of the standard four from >27,500 trap nights. The Asiatic Golden Cat and Marbled Cat were strongly diurnal, Clouded Leopard largely crepuscular and nocturnal, and Leopard Cat largely nocturnal. The degree of overlap between Marbled Cat and Leopard Cat activity was low and in consensus with other studies across southeastern Asia. We interpret this as the differing niche spaces of the two cats due to their specific pre-existing adaptations, not restricted to the effects of competition. The point scale analysis when both cats are captured at the same location and separately show no shift in activity pattern, supporting our hypothesis of pre-existing differences in resources, such as food, playing a major role in facilitating co-existence. Our study, however, is preliminary and additional information with robust analysis is required to test this finding.

Keywords: Asiatic Golden Cat, camera trap, *Catopuma temminckii*, Clouded Leopard, competitive exclusion, Leopard Cat, Marbled Cat, *Neofelis nebulosa*, *Pardofelis marmorata*, *Prionailurus bengalensis,* standard four.

Abbreviations: CF - community forest, CL - Clouded Leopard, GC - Golden Cat, IUCN - International Union for Conservation of Nature, LC - Leopard Cat, MC - Marbled Cat, NP - national park, TR - tiger reserve, VCR - village community reserve, WS - wildlife sanctuary.

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INTRODUCTION

India's geographic location at the confluence of major biogeographic realms has contributed towards its extraordinary biodiversity (Mani 1974). The family Felidae is particularly well-represented in India with 15 extant species, constituting around 37% of the global felid diversity (Kitchener et al. 2017). While speciation seems to have played a major role in structuring the felid assemblage of South America, the Indian felid assemblage resulted from a series of colonization events (Johnson et al. 2006). Consequently, of the 14 felid genera recognized by Kitchener et al. (2017), nine occur in India.

Due to different environment conditions and species adaptations, felids are not homogenously distributed throughout the country. The highest species richness (nine species) is observed in the semi-arid and arid region to the west due to colonization from Middle-Eastern species, and in the northeastern forests due to the colonization of species from southeastern Asia (Johnson et al. 2006). Obligate carnivory in cats along with very similar physiologies and overall morphologies shared across the family raise interesting questions related to sympatry. Several studies throughout the globe addressed co-occurrence patterns in the Felidae and in most studies inferences are drawn around possible competitive interactions and avoidance thereof. Segregation over body size, diet, space, and time are recognized as the major facilitators of co-existence in carnivores, including wild cats (Caro & Stoner 2003; Morales & Giannini 2010; Sunarto et al. 2015; Cruz et al. 2018; Hearn et al. 2018).

In northeastern India, felid body mass spans almost two orders of magnitude. The smallest are Marbled Cat and Leopard Cat with body mass ranging from 2.4–3.7 kg and 2.7–3.6 kg, respectively (Pocock 1939; Sunquist & Sunquist 2002), while the largest, the Tiger *Panthera tigris,* weighs up to 260kg in the Indian subcontinent (all of these were Chitwan tigers immobilised by Smith et al. 1983). The other species include the Leopard *P. pardus* (31–63 kg), Snow Leopard *P. uncia* (30–50 kg), Clouded Leopard (18–20 kg), Asiatic Golden Cat (9–16 kg), Fishing Cat *Prionailurus viverrinus* (5–16 kg), and Jungle Cat *Felis chaus* (2.3–8.6 kg) (Pocock 1939; Sunquist & Sunquist 2002; Athreya & Belsare 2006; Hunter 2015). The larger species such as the Tiger tend to prey on large or medium-sized ungulates (Andheria et al. 2007; Lyngdoh et al. 2014), while the Clouded Leopard and Asiatic Golden Cat are likely to focus on small ungulates, primates, larger rodent species, and pheasants (Ross et al. 2013; Xiong et al. 2017). On the other hand, small wild cats like Leopard Cat and Jungle Cat are largely dependent on murid rodents, and to a smaller extent on birds, amphibians, and reptiles to meet their energy requirements (Mukherjee et al. 2004; Shehzad et al. 2012; Xiong et al. 2017).

Though similar body sizes and diet could impose potential inter-species competition, some species are mainly found in specific habitats. For instance, the Fishing Cat inhabits mainly the lowland swamps and wetlands, the Jungle Cat occurs in open habitat and shrubland areas, and the Snow Leopard is restricted to higher elevations (Nowell & Jackson 1996). The remaining six wild cat species tend to co-occur in the northeastern forests. In similar habitats across southeastern Asia, the assemblage of Leopard Cat, Marbled Cat, Asiatic Golden Cat, and Clouded Leopard is common and was named as the standard four by Duckworth et al. (2014).

The similar body size of Leopard Cat and Marbled Cat raises interesting questions related to co-occurrence. Asynchronous activity patterns can potentially explain co-occurrence, and Marbled Cat and Leopard Cat were found to have low activity overlap (Lynam et al. 2013; Singh & Macdonald 2017; Hearn et al. 2018), thereby supporting this argument. Apart from competition, predation from a larger cat could also determine temporal patterns of activity and it would be expected for specific pairs of cats, Clouded Leopard-Golden Cat, Golden Cat-Marbled Cat, and Golden Cat-Leopard Cat, to have low temporal activity overlaps. Clouded Leopard-Golden Cat and Golden Cat-Marbled Cat, however, were found to have similar activity periods (Azlan & Sharma 2006; Lynam et al. 2013; Singh & Macdonald 2017). Activity patterns can also vary regionally, but current information on the activity of the standard four comes mainly from southeastern Asia with very few studies from India (e.g., Singh & Macdonald 2017).

In this collaborative study that collates activity information from ten independent camera trapping studies in northeastern India, we address a knowledge gap pertaining to the activity of the standard four in India. Northeastern India comprises of the northwestern edge of Clouded Leopard, Asiatic Golden Cat, and Marbled Cat distribution, and hence is of geographic significance to these species (Grassman et al. 2016; McCarthy et al. 2016; Ross et al. 2016). We estimated activity patterns of small to medium felids (<20kg average body mass) and compared them to patterns found throughout southeastern Asia. In addition, we explored potential activity pattern variation at different elevations, where larger cats tend to be absent or less abundant, and under different management regimes associated with different levels of human disturbance.

STUDY AREAS

The northeastern region of India encompasses a vast gradient of elevations (<50–>8,000 m), climate conditions, and vegetation associations. As a result, the region provides a wide range of habitats and species adapted to each of these habitats.

This study incorporates camera trap data obtained from 10 study sites spread over five states of northeastern India, which include Assam, Arunachal Pradesh, Nagaland, Meghalaya, and Mizoram (Table 1; Fig. 1). The predominant vegetation across most of these sites is tropical evergreen, subtropical evergreen, tropical semi-evergreen, or moist deciduous forest (Champion & Seth 1968). Temperate broad-leaved and temperate conifers occur in the higher elevations (2,000–4,000 m) in Arunachal Pradesh, within the study sites included in this paper (Kaul & Haridasan 1987). Management regimes range from legally delineated NPs and WSs to locally-managed CFs and VCRs. While Arunachal Pradesh and part of Assam constitute a part of the eastern Himalayan biodiversity hotspot, the study locations in Nagaland, Meghalaya, part of Assam, and Mizoram fall within the Indo-Burma biodiversity hotspot (Mittermeier et al. 2004).

Arunachal Pradesh: This study incorporates data collected between May 2013 and March 2017 from Pakke-Eaglenest landscape and Talle Valley WS. The Pakke-Eaglenest landscape comprises of Pakke TR, which covers an area of 862km^2, Eaglenest WS spread over 217km^2, and the recently proposed Singchung-Bugun VCR. While Pakke TR has an elevation gradient of ≥100m to 1,500m, Eaglenest WS is located at a higher elevation, between 500m and 3,250m. Talle Valley covers an area of 337km^2 in the Lower Subansiri Valley, northeast of the Pakke-Eaglenest landscape. The elevation gradient of the reserve is between 1,500m and 2,825m. Though all study sites within this landscape support most mammalian species typical of this landscape, the larger cats, Tiger and Leopard, are found largely in Pakke TR.

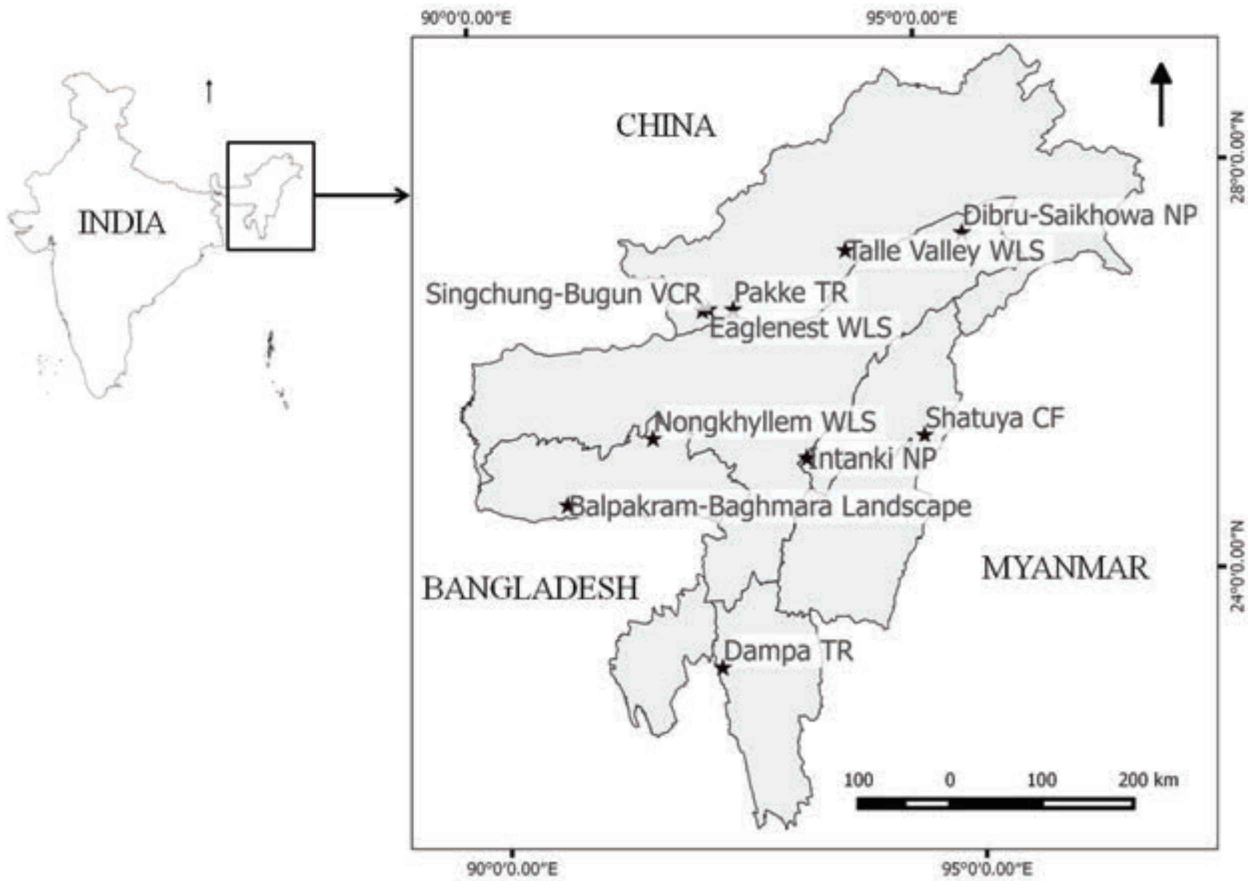

Figure 1. Sampling sites in northeastern India.

Table 1. Sampling areas and results of camera trapping used in this study.

State	Sampling areas	Approximate number of camera trap locations	Trap nights	Trapping period	Min-Max elevation (m) of records	Small felid species (<25kg average body mass) detected
Arunachal Pradesh	Pakke TR	213	~10,260	Nov 2015 to Mar 2017	123–732	Clouded Leopard (n=40), Asiatic Golden Cat (n=3), Marbled Cat (n=40), Leopard Cat (n=394), Jungle Cat (n=4), Tiger, Leopard
Arunachal Pradesh	Eaglenest WS	250	8,044	May 2013 to Apr 2016	1,640–3,220	Clouded Leopard (n=4), Asiatic Golden Cat (n=28), Marbled Cat (n=27), Leopard Cat (n=59)
Arunachal Pradesh	Singchung-Bugun VCR	100	1,155+	May 2013 to Mar 2018	1,459–3,217	Clouded Leopard (n=3), Asiatic Golden Cat (n=22), Marbled Cat (n=1), Leopard Cat (n=43)
Arunachal Pradesh	Talle-Valley WS	22	1,063	Mar 2016 to May 2016	2,352–2,446	Asiatic Golden Cat (n=8), Leopard Cat (n=14), Tiger
Nagaland	Intanki NP	23	826	May 2015 to Jul 2015	304–532	Leopard Cat (n=14)
Nagaland	Shatuya CF	5	≤50	Jun 2011	~1,300	Leopard Cat (n=1)
Meghalaya	Nongkhyllem NP	31	1,094	Mar 2015 to May 2015	378–863	Clouded Leopard (n=4), Asiatic Golden Cat (n=2), Leopard Cat (n=12)
Meghalaya	Balpakram-Baghmara landscape	425	3,857	Jan 2013 to Jun 2015	104–856	Clouded Leopard (n=4), Marbled Cat (n=2), Leopard Cat (n=40), Jungle Cat (n=1), Leopard
Mizoram	Dampa TR	9	~150	Nov 2017 to Dec 2017	567–826	Clouded Leopard (n=6), Marbled Cat (n=1), Leopard Cat (n=2)
Assam	Dibru-Saikhowa NP	27	1,065	May 2016 to Jul 2016	119–123	Leopard Cat (n=9), Leopard
Total	**10 sites**	**~1105**	**~27,567**			**(n=788)**

Tiger presence was recorded in Talle Valley (André P. Silva unpublished data), while there are no recent reports of the big cats from Eaglenest WS or Singchung-Bugun VCR.

Assam: Located in Upper Assam, Dibru-Saikhowa NP along with the adjoining reserved forest cover an area of 340km^2 in Tinsukia District. To its north, Brahmaputra and Lohit rivers form the park boundary, while to the south Dibru River demarcates the reserve. Elevation of the area is generally below 150m. Data were collected in this study site between May and July 2016. The park faces threats from illegal logging and poaching, erosion by the Brahmaputra River, and military activities (Sekhsaria 2012). Among big cats, only Leopard was detected at this site.

Nagaland: Data used in this study were derived mainly from a single study conducted in Intanki NP between May and July 2015. A single data point was also incorporated from a survey conducted in 2011 in Shatuya CF in Phek District of eastern Nagaland (Grewal et al. 2012), along the international border with Myanmar. Intanki NP covers an area of ~200km^2, located in Peren District along the Dhansiri River, and is contiguous with the Dhansiri Reserve Forest in Assam. It is a low-lying protected area with elevation ranging between 200m and 682m. The reserve faces high hunting pressure and is impacted by insurgency and encroachment (Longchar 2013). Leopard was the only big cat detected in the area.

Meghalaya: We used data collected between 2013 and 2015 in the Balpakram-Baghmara landscape. This site is in the South Garo Hills District of Meghalaya, in proximity to the border with Bangladesh to the south, covering ~600km^2. While Balpakram NP covers an area of 220km^2, Baghmara Reserve Forest covers ~45km^2. The two protected areas are disjunct, with community-owned land called 'Aking' separating them. Data collected in Nongkhyllem WS between March and May 2015 was also used in this study. Nongkhyllem is located in Ri Bhoi District, close to the border with Assam. It covers an area of 29km^2 with an elevation ranging from 200m to 965m. Among big cats, Leopard was detected in the Baghmara-Balpakram landscape.

Mizoram: Data collected in November–December 2017 from a limited area, covering ~20km^2 in Dampa TR was used in this study. Located in western Mizoram, Dampa TR is contiguous to the west with the Chittagong Hill tract region of Bangladesh. The protected area is highly undulating with elevation ranging between 150m and 1,100m. A recent study by Singh & Macdonald (2017) reports the presence of the standard four felid species in the region, although no Leopard or Tiger was recorded during the same period.

MATERIALS AND METHODS

Camera trapping

We used data on small and medium-sized sympatric felids found in northeastern India, obtained via camera traps. This data was assembled from multiple studies (Table 1) that used camera traps as a tool to assess the distribution and population status of the mammalian fauna of the region. The general study design followed by all contributors to this study involved placement of camera traps 20–50 cm above ground level, along animal trails, river beds, or ridge-lines, which are expected to support the highest animal movement in forested landscapes. We chose this height above ground to increase the detectability of small mammals by the camera traps. Camera traps used in all studies were equipped with in-built wide lenses and placed with the aim of capturing all felid species found in the landscape. Camera traps were regularly checked to ensure uninterrupted functioning and continuous data-collection in 24-hour cycles. All images obtained the contained date and timestamps.

Activity patterns

To ensure the independence of camera trap images, we considered consecutive records of the same species at the same camera trap location within an interval of ≤30min as a single capture event (Linkie & Ridout 2011; Sunarto et al. 2015; Singh & Macdonald 2017). If two consecutive images, however, were triggered by the same species within the 30min-period, but by differently marked individuals, we recognized each photographed individual as a separate event. Similarly, if a single image captured multiple individuals of a single or different cat species, we treated each individual as a separate event.

To visualize activity patterns for each species and to estimate activity overlaps, we used a method designed by Ridout & Linkie (2009), which accounts for the circular nature of time by using a non-parametric kernel density estimation approach. We used package Overlap (Meredith & Ridout 2018) available in R (R Core Team 2014), to analyse species-specific activity patterns and overlaps after pooling data from all sites. We used a smoothing parameter of 1.2 for sample sizes >75, and a smoothing parameter of 0.8 for sample sizes <50, to smoothen spikes in the graphs as recommended by Meredith & Ridout (2018) to generate the coefficient of overlap ($\hat{\Delta}_1$). $\hat{\Delta}_1$ was defined following Ridout & Linkie (2009) as $\hat{\Delta}_1 = \int_0^1 \min\{\hat{f}(t), \hat{g}(t)\}dt$. To calculate 95% CI, we generated 10,000 bootstraps of our samples and present bootstrap bias-corrected percentiles.

To explore the variation of activity patterns, we compared the extent of overlap in the same species reported in other studies across southeastern Asia that also used the kernel density analysis. In addition, we analysed activity patterns across an elevation gradient and management regimes for all species, depending on data availability. For elevation comparisons, we divided our samples into two categories, ≤1,500m and ≥1,500m, given variations in habitat and vegetation types across these categories and availability of data. We had ≥20 samples for Leopard Cat from several different sites (n=4); hence, we compared activity cycles for the same species across different study sites.

Since Marbled Cat and Leopard Cat are very similar in body size, we attempted to examine if competition influences their activity patterns. To determine this, we analysed activity patterns for the two cats at the point location at every camera trap location, a) where both species were recorded, b) where only one of the species was recorded, and c) overlap of the activity results for each of the two species, i.e., Marbled Cat captured with Leopard Cat at the same location and Marbled Cat captured individually, and the same for Leopard Cat.

RESULTS

We obtained 788 records of five felid species, namely, Clouded Leopard (n=61), Asiatic Golden Cat (n=63), Marbled Cat (n=71), Leopard Cat (n=588), and Jungle Cat (n=5) from >27,500 trap nights in 10 sampling areas across northeastern India (Images 1–4). Details about results from the different study areas are provided in Table 1.

Of these, the highest records (61%) were from Pakke TR, since annual camera trapping is conducted in the reserve, primarily to assess the Tiger population as part of the All India Tiger Monitoring exercise followed by Eaglenest WS and the contiguous Singchung-Bugun VCR (24%). Clouded Leopard showed weak activity during the day and was most active during dawn and dusk (Fig. 2a). Marbled Cat (Fig. 2b) and Asiatic Golden Cat (Fig. 2c) were almost entirely diurnal, while Leopard Cat (Fig. 2d) was predominantly nocturnal. The highest overlap in diel activity patterns was seen between Marbled Cat and Asiatic Golden Cat with $\hat{\Delta}_1$ of 0.82 (0.71–0.92), and Clouded Leopard and Leopard Cat with of 0.79 (0.71–0.87; Fig. 3). The lowest $\hat{\Delta}_1$ was observed between

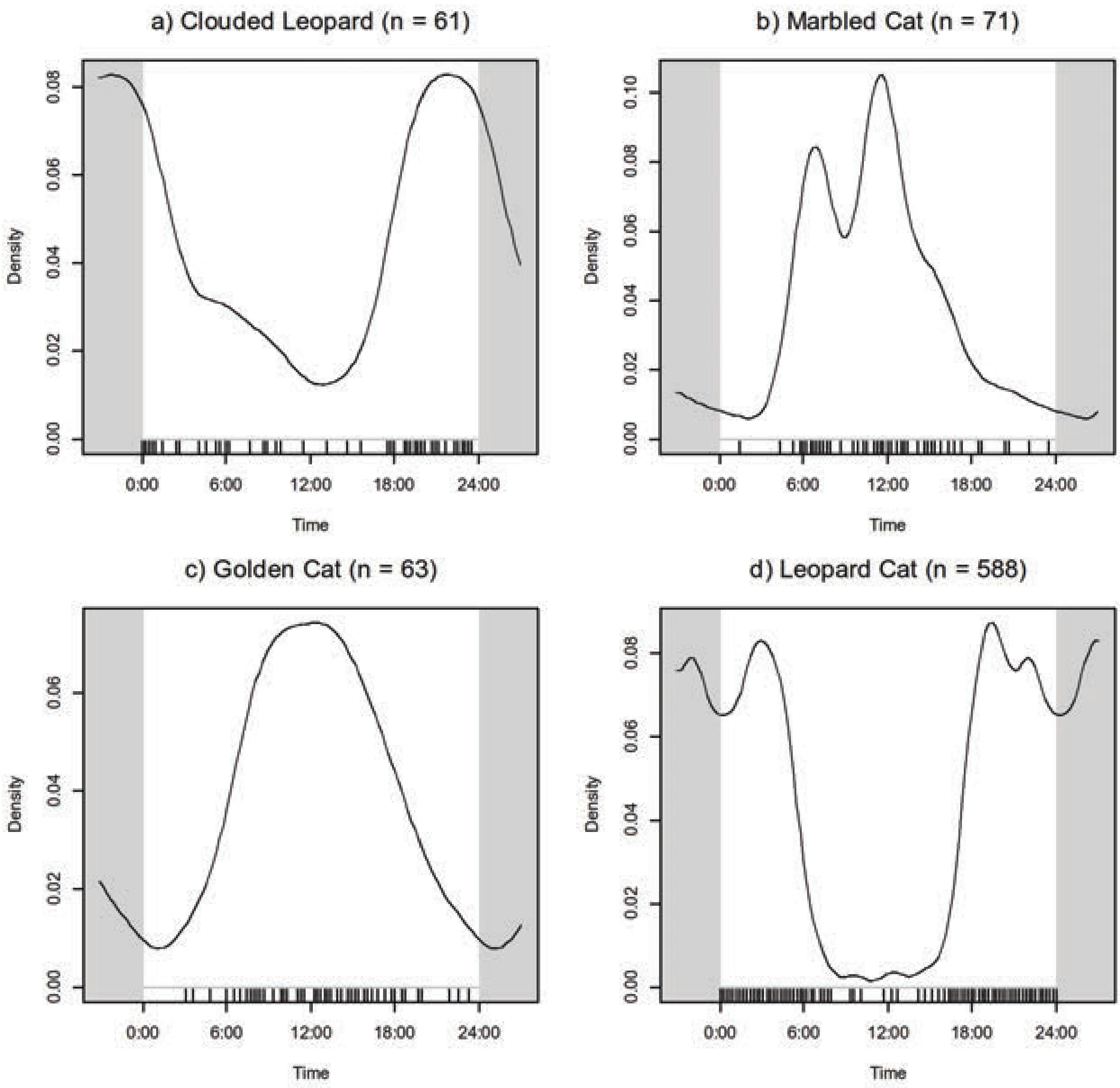

Figure 2. Kernel density plots of activity patterns of four felids in northeastern India.

Leopard Cat and Marbled Cat (0.32; 0.19–0.35), and Leopard Cat and Asiatic Golden Cat (0.38; 0.24–0.43; Fig. 3).

Comparison of activity overlap between pairs of cats from several studies (Lynam et al. 2013; Sunarto et al. 2015; Singh & Macdonald 2017; Fig. 3) reveals similar overall patterns, with the highest $\hat{\Delta}_1$ between Clouded Leopard and Leopard Cat (0.73–0.90) and lowest between Leopard Cat and Marbled Cat (0.26–0.54). In the current study, however, Clouded Leopard and Asiatic Golden Cat were spatially separated and hence could not be compared for overlap. The detected $\hat{\Delta}_1$ in the current study between Leopard Cat and Marbled Cat (0.32; 0.19–0.35) is within that observed in other studies.

At the point scale, Marbled Cat showed a slight variation in activity when captured on locations with (n=34) and without (n=37) Leopard Cat captures, with $\hat{\Delta}_1$ of 0.81 (0.79–0.91), while Leopard Cat activity did not change in the presence (n=85) or absence (n=503) of Marbled Cat (Fig. 4). With respect to management regimes, 90% of our image-captures were obtained from protected areas and the remaining 10% from community forests. We could not compare differences in activity patterns for Clouded Leopard (n=3, OPA)

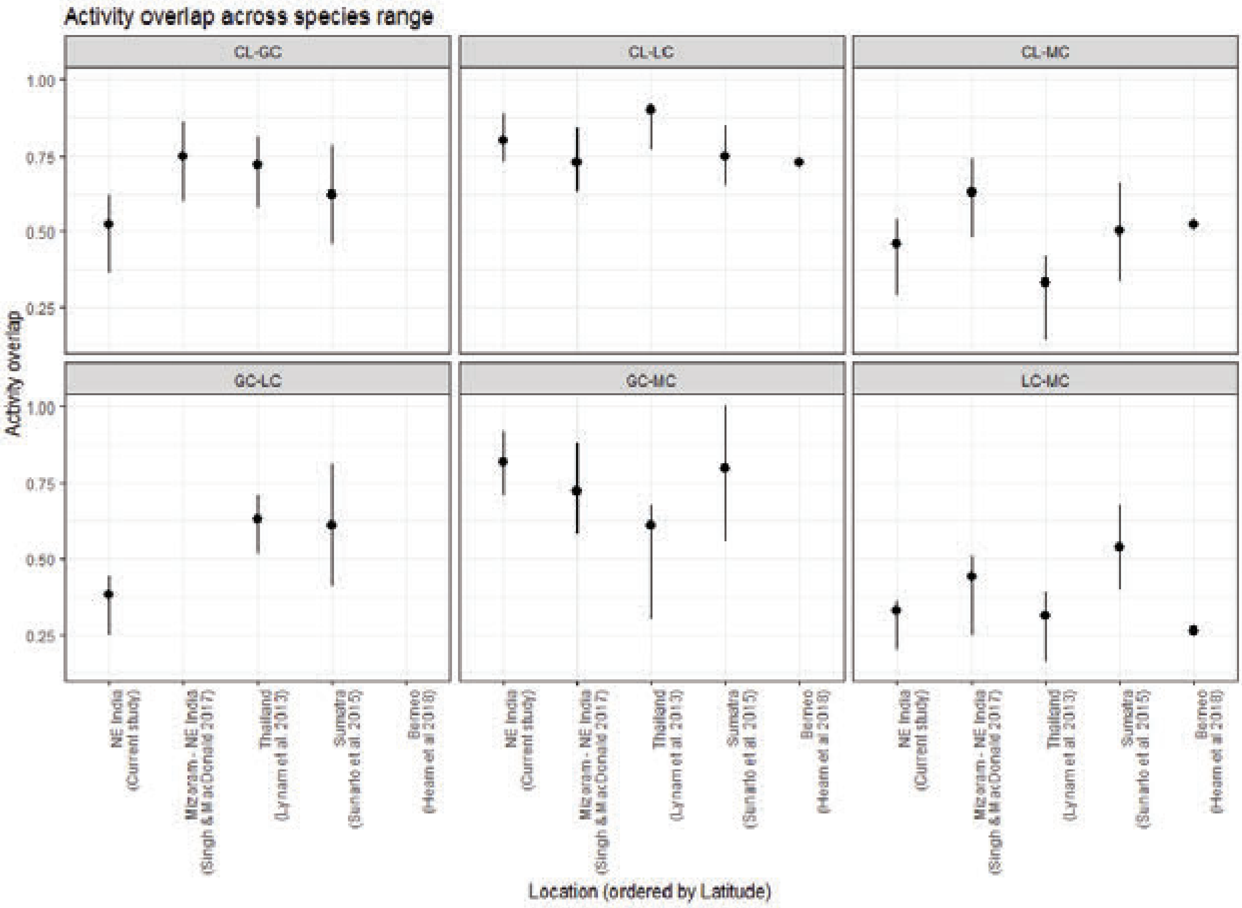

Figure 3. Comparison of activity overlaps for the standard four felids across their geographic range, based on information obtained from other comparable studies (Lynam et al. 2013; Sunarto et al. 2015; Singh & Macdonald 2017; Hearn et al. 2018). Asiatic Golden Cat does not occur in Borneo and, therefore, activity estimates for the species are not present in Hearn et al. (2018). Estimates for overlaps of Asiatic Golden Cat and Leopard Cat are not provided in Singh & Macdonald (2017).

and Marbled Cat (n=1, OPA) across protected and non-protected landscapes due to limited data, while Asiatic Golden Cat showed the same activity pattern across differing management regimes (Fig. SD1.3). In the case of altitude, we had two categories, ≥1,500m (25% samples) and ≤1,500m (75% samples). Leopard Cat was the only felid captured across all sites and accounted for 75% of total captures. Leopard Cat activity remained mostly unchanged irrespective of altitude category (Fig. SD1.1), study site (Fig. SD1.2), or management regime (Fig. SD1.3). The $\hat{\Delta}_1$ of 0.76 for Marbled Cat across the two elevation categories, however, indicates a slight variation in its activity pattern (Fig. SD1.1). Above 1,500m, Marbled Cat showed a decline in activity post a pre-noon peak.

DISCUSSION

For the first time, we estimated activity patterns of small wild cats across northeastern India complementing the existing studies in southeastern Asia, allowing future analyses on the variation of activity patterns across the species range. Interestingly, we simultaneously unveiled new information on the species distribution across the northeastern Indian landscape. Based on information used in this study, an assemblage of the four felids Clouded Leopard, Asiatic Golden Cat, Leopard Cat, and Marbled Cat occurred in three of the 10 study sites, namely, Pakke TR, Eaglenest WS, and Singchung-Vugun VCR. Marbled Cat had very low captures (≤2; Singchung-Bugun VCR, Baghmara-Balpakram landscape, Dampa) or was not captured at several sites (n=5), except for Pakke TR and Eaglenest WS, while the Clouded Leopard had very low captures in all but Pakke TR. This could be an indication of the sensitivity of these species to habitat

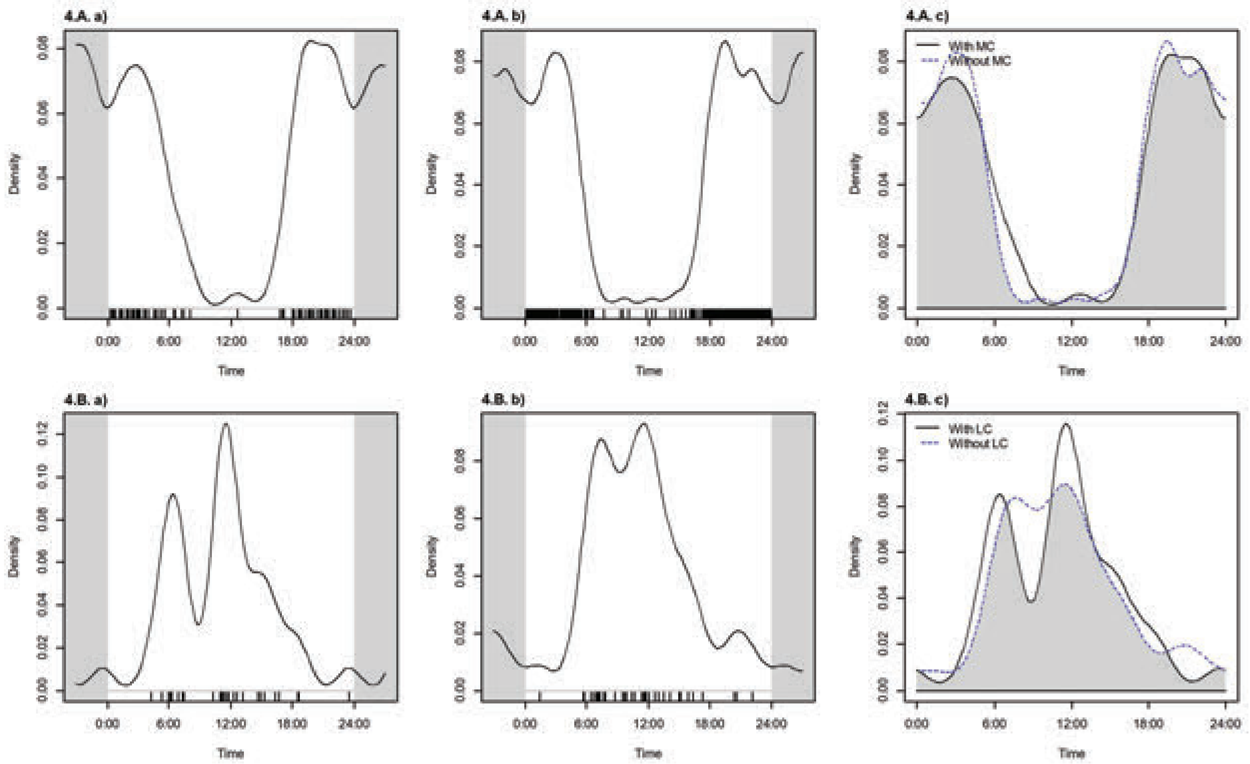

Figure 4. Point scale analyses of activity patterns of Leopard Cat (A) and Marbled Cat (B): a - when both were photographed at the same location (Marbled Cat, n=34; Leopard Cat, n=85); b - when only one species was photographed at a location (Leopard Cat, n=503; Marbled Cat, n=37); c - overlap of activity of each species with and without the presence of the other.

Image 1. Asiatic Golden Cat *Catopuma temminckii* (Eaglenest Wildlife Sanctuary 25 March 2015). © SACON Eaglenest Small Cat Team.

change and forest loss, both being species largely associated with primary closed-canopy forests or, more likely, of unequal capture efforts. The effort in Dampa TR and Shatuya CF may not have been adequate in terms of camera placements as well as the number of trap nights at each location to record Marbled Cat and Clouded Leopard, which are intrinsically rare and arboreal.

Our data capture one aspect of the ecology of an assemblage of felids, and despite the relatively large dataset for a group of little known, rare, and elusive species, our analysis remains preliminary. Although the results of our work are not very different from other studies on the same assemblage of cats, we suggested an alternative explanation for the temporal segregation between Marbled Cat and Leopard Cat. This needs to be tested through further information on diet and spatial use of habitats of these two cats. Several camera trapping studies by various groups were conducted in India, mostly focusing on the large cat, and by-catch data on the smaller cats often remains unanalyzed (e.g., Borah et al. 2014). Moreover, studies at individual sites are often limited in time and areas covered and hence are data-poor. Joint analysis of data through collaborative ventures such as ours could provide important information on basic ecological aspects such as activity patterns and habitat use of this poorly studied group.

Given the range and overlap of body sizes between pairs of cats, we expected temporal segregation in activity patterns between Asiatic Golden Cat and Clouded Leopard, and Leopard Cat and Marbled Cat. Consistent with our expectations, Leopard Cat and Marbled Cat were mainly nocturnal and diurnal, respectively. In our study, the Clouded Leopard and Asiatic Golden Cat captures were spatially separated. Most Clouded Leopard captures were in Pakke TR and Asiatic Golden Cat captures in the Eaglenest landscape, and hence were not compared for their activity overlaps. Individual species activity patterns of the standard four over several studies, however, are in consensus with some exceptions. For example, Gumal et al. (2014) report crepuscular activity of Asiatic Golden Cat and nocturnal activity of Clouded Leopard in peninsular Malaysia. In contrast, Zaw et al. (2014) report diurnal and nocturnal activity of Clouded Leopard and cathemeral activity of Asiatic Golden Cat in Myanmar. In northeastern India, we found Clouded Leopard to be largely crepuscular and Asiatic Golden Cat diurnal, in accordance with results from Dampa TR reported by Singh & Macdonald (2017).

The pattern of species segregation over space, time, or diet can be a result of various processes including competition for resources and species sorting over a gradient of resources (Leibold et al. 2004). Competition occurs when species that require similar resources and function in an ecologically similar manner meet at range boundaries and overlap zones, the outcomes of which are either competitive exclusion or co-occurrence through adjustments in specific character traits. Co-occurrence in the face of stiff competition for limited resources is often attained through character displacement where species shift some characteristics of their niches to fit into sympatry (Brown & Wilson 1956; Schoener 1974; Dayan et al. 1990; Losos 2000). On the other hand, species sorting occurs over a gradient of resources where each species is adapted to procuring a specific set of resources (Leibold et al. 2004). In this scenario, species from an assemblage would not require shifting of their niche characters and would fit in due to pre-existing differences in their requirements and adaptations.

In the case of the similar-sized Marbled Cat and Leopard Cat, competition is expected, especially in prime habitats, and their diel activity patterns would lead to that conclusion since they are largely segregated over time. This contrasting pattern of the nocturnal Leopard Cat and diurnal Marbled Cat is consistent almost throughout their range and is often attributed to competition due to the significant overlap in body size (Gumal et al. 2014; Pusparini et al. 2014; McCarthy et al. 2015; Singh & Macdonald 2017; Hearn et al. 2018). The Marbled Cat, though sometimes detected by on-ground camera traps, is morphologically suited for an arboreal life, as indicated by its very long tail (longer than its body) and perhaps also largely restricted to prime, closed canopy forests (Pocock 1939; Sunquist & Sunquist 2002; Gumal et al. 2014; Hunter 2015, Mukherjee et al. 2016). Northeastern India has an impressive diversity of Sciuridae as well (Pocock 1939), and they are largely diurnal and arboreal. Therefore, the Marbled Cat's diurnal and arboreal activities could be a result of targeting arboreal prey (Hearn et al. 2018) and not necessarily related to the presence of the Leopard Cat. Unfortunately, there is limited and incidental data on Marbled Cat diet. Borries et al. (2014) account of one observation of a Marbled Cat attempting predation on a juvenile Phayre's Leaf Monkey *Trachypithecus phayrei.* It was not clear, however, whether the attempt was made on the ground or in the canopy. Davis (1962 as cited in Hearn et al. 2018) reported a species of *Rattus* in the stomach of a Marbled Cat. On the other hand, studies on Leopard Cat diet across its global range show a very strong dependence on murid rodents that are

Image 2. Clouded Leopard *Neofelis nebulosa* (Pakke Tiger Reserve, 19 December 2015). © A.P. Silva, S. Nadig & R. Navya.

Image 3. *Prionailurus bengalensis* (Pakke Tiger Reserve, 9 December 2015). © A.P. Silva, S. Nadig & R. Navya.

Image 4. Marbled Cat *Pardofelis marmorata* (Pakke Tiger Reserve, 18 December 2015). © A.P. Silva, S. Nadig & R. Navya.

largely nocturnal (Shehzad et al. 2012; Lorica & Heaney 2013; Mukherjee et al. 2016; Xiong et al. 2017). Future studies on Marbled Cat diet are therefore a priority to test our inference.

The spatial scale of focus also matters since sympatry could occur at regional or local scales (Palomares et al. 2016). One way to test for species-sorting over competition for explaining co-existence in these pairs would be to look at diel activity patterns and habitat use in areas where each of the species occurs in allopatry and to compare it to areas of co-occurrence to look for character displacement and release. This can be done at various spatial scales, e.g., the point scale of camera trap locations, the grid scale in studies that use grids within their sampling design, at the scale of estimated home ranges of focal species, within a protected area and at larger regional scales.

Our analyses at the point scale for Marbled Cat and Leopard Cat showed that the pattern of activity did not change significantly for either cat when both were recorded at the same location or separately. This lends support to our hypothesis that their activity patterns could be largely determined by factors other than competition. Additional data on diet, activity and the influence of climate factors on both species, however, is required to robustly address this hypothesis.

Predation from larger cats could also play a role in determining activity patterns and habitat use. The Leopard appears to be absent in Eaglenest WS and Singchung-Bugun VCR while the Clouded Leopard was recorded on rare occasions by Velho et al. (2015) and in the current study. This could be an explanation for the highest number of Golden Cat captures in this study being from Eaglenest WS and the adjacent Singchung-Bugun VCR.

This, however, is speculative and needs to be tested. The combined impact of several processes acting at different spatial scales is likely to be responsible for structuring assemblages (Leibold et al. 2004).

REFERENCES

Andheria, A.P., K.U. Karanth & N.S. Kumar (2007). Diet and prey profiles of three sympatric large carnivores in Bandipur Tiger Reserve, India. *Journal of Zoology* 273(2): 169–175; https://doi.org/10.1111/j.1469-7998.2007.00310.x

Athreya, V.R. & A.V. Belsare (2006). Report providing the Maharashtra Forest Department Technical and Veterinary Support to better deal with Wild Animals that require Human Intervention. Wildlife Trust of India, New Delhi & Office of the Chief Wildlife Warden, Maharashtra, 29pp.

Azlan, J.M. & D.S. Sharma (2006). The diversity and activity patterns of wild felids in a secondary forest in peninsular Malaysia. *Oryx* 40(1): 36–41; https://doi.org/10.1017/S0030605306000147

Borries, C., Z.M. Primeau, K. Ossi-Lupo, S. Dtubpraserit & A. Koenig (2014). Possible predation attempt by a marbled cat on a juvenile Phayre's Leaf Monkey. *Raffles Bulletin of Zoology* 62: 561–565.

Brown, J. & E.O. Wilson (1956). Character displacement. *Systematic Zoology* 5: 49–64.

Caro, T.M. & C.J. Stoner (2003). The potential for interspecific competition among African carnivores. *Biological Conservation* 110(1): 67–75; https://doi.org/10.1016/S0006-3207(02)00177-5

Champion, H.G. & S.K. Seth (1968). *A Revised Survey of the Forest Types of India*. Natraj Publishers, Dehradun, 404pp.

Cruz, P., M.E. Lezzi, C.D. Angelo, D. Varela, M.S.D. Bitetti & A. Paviolo (2018). Effects of human impacts on habitat use, activity patterns and ecological relationships among medium and small felids of the Atlantic forest. *PloS ONE* 13(8): e0200806; https://doi.org/10.1371/journal.pone.0200806

Dayan, T., D. Simberloff, E. Tchernov & Y. Yom-Tov (1990). Feline canines: community-wide character displacement in the small cats of Israel. *American Naturalist* 136(1): 39–60; https://doi.org/10.1086/285081

Duckworth, J.W., A.J. Lynam & C. Breitenmoser-Würsten (2014). Non-*Panthera* cats in southeast Asia: present knowledge and recommendation. *Cat News Special Issue* 8: 62–67.

Grewal, B., R. Sreenivasan & B. Haralu (2012). Report on the Nagaland Wildlife & Biodiversity Conservation Project: An Action Document. Nagaland Wildlife Conservation Project, Dimapur, 156pp.

Grassman, L., A. Lynam, S. Mohamad, J.W. Duckworth, J. Borah, D. Wilcox, Y. Ghimirey, A. Reza & H. Rahman (2016). *Neofelis nebulosa*. In: The IUCN Red List of Threatened Species: e.T14519A97215090. Downloaded on 28 December 2018; https://doi.org/10.2305/IUCN.UK.2016-1.RLTS.T14519A97215090.en

Gumal, M., A.B.B.M. Salleh, M.N. Yasak, L.S. Horng, B.P.Y.H. Lee, L.C. Pheng, H. Hamzah, D. Kong, D. Magintan, D.T.C. Yung, A.Z.B. Zalaluddin, A.B. Azmi, N.B. Khalid, T.P. Yen, V. Mufeng, F.C.F. Meng & S. Ng (2014). Small-medium wild cats of Endau Rompin Landscape in Johor Peninsular Malaysia. *Cat News Special Issue* 8: 10–18.

Hearn, A.J., S.A. Cushman, J. Ross, B. Goossens, L.T.B. Hunter & D.W. Macdonald (2018). Spatio-temporal ecology of sympatric felids on Borneo. Evidence for resource partitioning? *PLoS ONE* 13(7): e0200828; https://doi.org/10.1371/journal.pone.0200828

Hunter, L. (2015). *Wild Cats of the World, 1st Ed*. Bloomsbury, London, 240pp.

Johnson, W.E., E. Eizirik, J. Pecon-Slattery, W.J. Murphy, A. Antunes, E. Teeling & S.J. O'Brien (2006). The late Miocene radiation of modern Felidae: a genetic assessment. *Science* 311(5757): 73–77; https://doi.org/10.1126/science.112227

Kaul, R. & K. Haridasan (1987). Forest types of Arunachal Pradesh—a preliminary study. *Journal of Economic and Taxonomic Botany* 9(2): 379–389.

Kitchener, A.C., C. Breitenmoser-Würsten, E. Eizirik, A. Gentry, L. Werdelin, A. Wilting, N. Yamaguchi, A.V. Abramov, P. Christiansen, C. Driscoll, J.W. Duckworth, W. Johnson, S.-J. Luo, E. Meijaard, P. O'Donoghue, J. Sanderson, K. Seymour, M. Bruford, C. Groves, M. Hoffmann, K. Nowell, Z. Timmons & S. Tobe (2017). A revised taxonomy of the Felidae. The final report of the Cat Classification Task Force of the IUCN/ SSC Cat Specialist Group. *Cat News Special Issue* 11: 1–80.

Leibold, M.A., M. Holyoak, N. Mouquet, P. Amarasekare, J.M. Chase & M.F. Hoopes (2004). The metacommunity concept: a framework for multi-scale community ecology. *Ecology Letters* 7(7): 601–613; https://doi.org/10.1111/j.1461-0248.2004.00608.x

Longchar, S. (2013). Study on the Trends of Bushmeat Consumption and Traditional Hunting on Wild Fauna by Indigenous Community living near Protected Area in Nagaland. Master's Dissertation. Saurashtra University, Rajkot.

Lorica, M.R.P & L.R. Heaney (2013). Survival of a native mammalian carnivore, the Leopard Cat *Prionailurus bengalensis* Kerr, 1792 (Carnivora: Felidae), in an agricultural landscape on an oceanic Philippine island. *Journal of Threatened Taxa* 5(10): 4451–4460; https://doi.org/10.11609/JoTT.o3352.4451-60

Losos, J.B. (2000). Ecological character displacement and the study of adaptation. *Proceedings of the National Academy of Sciences USA* 97(11): 5693–5695; https://doi.org/10.1073/pnas.97.11.5693

Lynam, A.J., K.E. Jenks, N. Tantipisanuh, W. Chutipong, D. Ngoprasert, G.A. Gale, R. Steinmetz, R. Sukmasuang, N. Bhumpakphan, L.I. Grassman Jr., P. Cutter, S. Kitamura, D.H. Reed, M.C. Baker, W. McShea, N. Songsasen & P. Leimgruber (2013). Terrestrial activity patterns of wild cats from camera-trapping. *The Raffles Bulletin of Zoology* 61(1): 407–415.

Lyngdoh, S., S. Shrotriya, S.P. Goyal, H. Clements, M.W. Hayward & B. Habib (2014). Prey preferences of the snow leopard (*Panthera uncia*): regional diet specificity holds global significance for conservation. *PloS ONE* 9(2): e88349; https://doi.org/10.1371/journal.pone.0088349

Mani, M.S. (ed.) (1974). *Ecology and Biogeography in India*. Dr. W. Junk B.V. Publishers, The Hague, 772pp.

McCarthy, J.L., H.T. Wibisono, K.P. McCarthy, T.K. Fuller & N. Andayani (2015). Assessing the distribution and habitat use of four felid species in Bukit Barisan Selatan National Park, Sumatra, Indonesia. *Global Ecology and Conservation* 3: 210–221; https://doi.org/10.1016/j.gecco.2014.11.009

McCarthy, J., S. Dahal, T. Dhendup, T.N.E. Gray, S. Mukherjee, H. Rahman, P. Riordan, N. Boontua & D. Willcox (2015). *Catopuma temminckii*. In: The IUCN Red List of Threatened Species: e.T4038A97165437. Downloaded on 28 December 2018; https://doi.org/10.2305/IUCN.UK.2015-4.RLTS.T4038A50651004.en

Meredith, M. & M. Ridout (2018). Package 'overlap': estimates of coefficient of overlapping for animal activity patterns. R Package Version 0.3.2. Available online at https://cran.r-project.org/web/packages/overlap/overlap.pdf.

Mittermeier, R.A., R. Robles-Gil, M. Hoffman, J. Pilgrim, T. Brooks, C.G. Mittermeier, J. Lamoreux & G.A.B. Da Fonseca (2004). *Hotspots Revisited: Earth's Biologically Richest and Most Endangered Terrestrial Ecoregions*. CEMEX, Mexico City, 392pp.

Morales, M.M. & N.P. Giannini (2010). Morphofunctional patterns in Neotropical felids: species co-existence and historical assembly. *Biological Journal of the Linnean Society* 100(3): 711–724; https://doi.org/10.1111/j.1095-8312.2010.01461.x

Mukherjee, S., S.P. Goyal, A.J.T. Johnsingh & M.L. Pitman (2004). The importance of rodents in the diet of Jungle Cat (*Felis chaus*), Caracal (*Caracal caracal*) and Golden Jackal (*Canis aureus*) in Sariska Tiger Reserve, Rajasthan, India. *Journal of Zoology* 262(4): 405–411; https://doi.org/10.1017/S0952836903004783

Mukherjee, S., R. Athreya, P.V. Karunakaran & P. Choudhary (2016). Report on Ecological Species Sorting in relation to Habitat Structure in the Small Cat Guild of Eaglenest Wildlife Sanctuary, Arunachal Pradesh. Salim Ali Centre for Ornithology and Natural History, Coimbatore, 52pp.

Nowell, K. & P. Jackson (eds.) (1996). Wild Cats: Status Survey and Conservation Action Plan, Vol. 382. IUCN SSC Cat specialist Group, Gland, 383pp.

Palomares, F., N. Fernández, S. Roques, C. Chávez, L. Silveira, C. Keller & B. Adrados (2016). Fine-scale habitat segregation between two ecologically similar top predators. *PLoS ONE* 11(5): e0155626; https://doi.org/10.1371/journal.pone.0155626

Pocock, R.I. (1939). Family Felidae, pp191–330. In: *The Fauna of British India, including Ceylon and Burma: Mammalia, Vol. 1, Primates and Carnivora*. Taylor & Francis, Ltd., London, 572pp.

Pusparini, W., H.T. Wibisono, G.V. Reddy, T. Tarmizi & P. Bharata (2014). Small and medium-sized cats in Gunung Leuser National Park, Sumatra, Indonesia. *Cat News Special Issue* 8: 4–9.

R Core Team (2014). R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Available online at https://www.R-project.org/.

Ridout, M.S. & M. Linkie (2009). Estimating overlap of daily activity patterns from camera-trap data. *Journal of Agricultural, Biological, and Environmental Statistics* 14(3): 322–337; https://doi.org/10.1198/jabes.2009.08038

Ross, J., A.J. Hearn, P.J. Johnson & D.W. Macdonald (2013). Activity patterns and temporal avoidance by prey in response to Sunda Clouded Leopard predation risk. *Journal of Zoology* 290(2): 96–106; https://doi.org/10.1111/jzo.12018

Ross, J., J. Brodie, S. Cheyne, A. Datta, A. Hearn, B. Loken, A. Lynam, J. McCarthy, C. Phan, A. Rasphone, P. Singh & A. Wilting (2016). *Pardofelis marmorata*. In: The IUCN Red List of Threatened Species: e.T16218A97164299. Downloaded on 28 December 2018; https://doi.org/10.2305/IUCN.UK.2016-1.RLTS.T16218A97164299.en

Schoener, T.W. (1974). Resource partitioning in ecological communities. *Science* 185(4145): 27–39; https://doi.org/10.1126/science.185.4145.27

Sekhsaria, P. (2012). Report on the State of Wildlife in northeast India 1996–2011: A Compilation of News from the Protected Area Update. Foundation for Ecological Security, 293pp.

Shehzad, W., T. Riaz, M.A. Nawaz, C. Miquel & C. Poillot (2012). Carnivore diet analysis based next generation sequencing: application to the Leopard Cat (*Prionailurus bengalensis*) in Pakistan. *Molecular Ecology* 21(8): 1951–65; https://doi.org/10.1111/j.1365-294X.2011.05424.x

Singh, P. & D.W. Macdonald (2017). Population and activity patterns of Clouded Leopards and Marbled Cats in Dampa Tiger Reserve, India. *Journal of Mammalogy* 98(5): 1453–1462; https://doi.org/10.1093/jmammal/gyx104

Smith, J.L.D., M.E. Sunquist, K.M. Tamang & P.B. Rai (1983). A technique for capturing and immobilizing tigers. *The Journal of Wildlife Management* 47(1): 255–259.

Sunarto, S., M.J. Kelly, K. Parakkasi & M.B. Hutajulu (2015). Cat coexistence in central Sumatra: ecological characteristics, spatial and temporal overlap, and implications for management. *Journal of Zoology* 296(2): 104–115; https://doi.org/10.1111/jzo.12218

Sunquist, M. & F. Sunquist (2002). *Wild Cats of the World*. University of Chicago Press, Chicago, Illinois, 462pp.

Velho, N., U. Srinivasan, P. Singh & W.F. Laurance (2015). Large mammal use of protected and community-managed lands in a biodiversity hotspot. *Animal Conservation* 19(2): 199–208; https://doi.org/10.1111/acv.12234

Xiong, M., D. Wang, H. Bu, X. Shao, D. Zhang, S. Li, R. Wang & M. Yao (2017). Molecular dietary analysis of two sympatric felids in the Mountains of southwest China biodiversity hotspot and conservation implications. *Scientific Reports* 7: 41909; https://doi.org/10.1038/srep41909

Zaw, T., T. Myint, S. Htun, S.H.T. Po, K.T. Latt, M. Maung & A.J. Lynam (2014). Status and distribution of smaller cats in Myanmar. *Cat News Special Issue* 8: 24–30.

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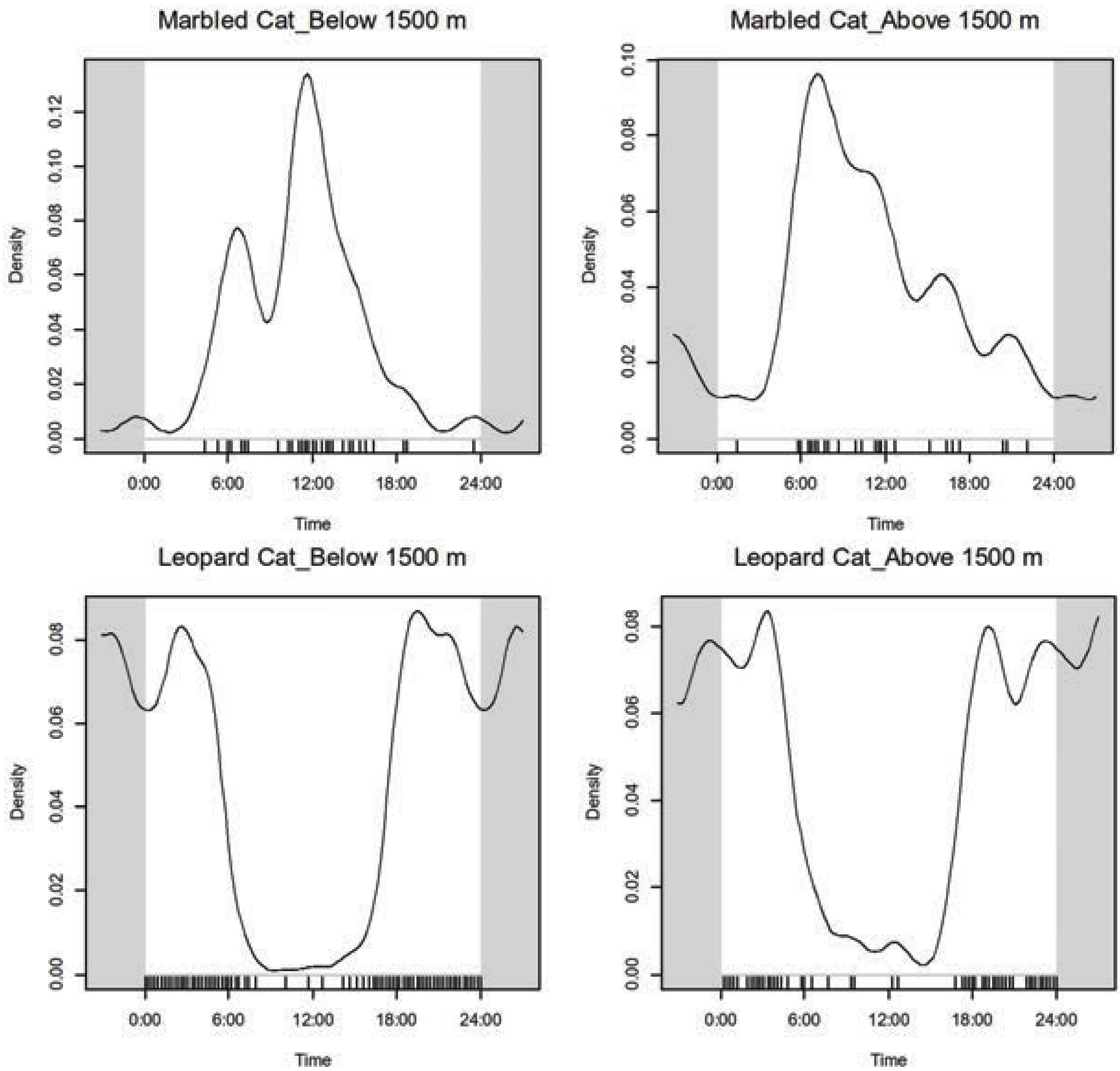
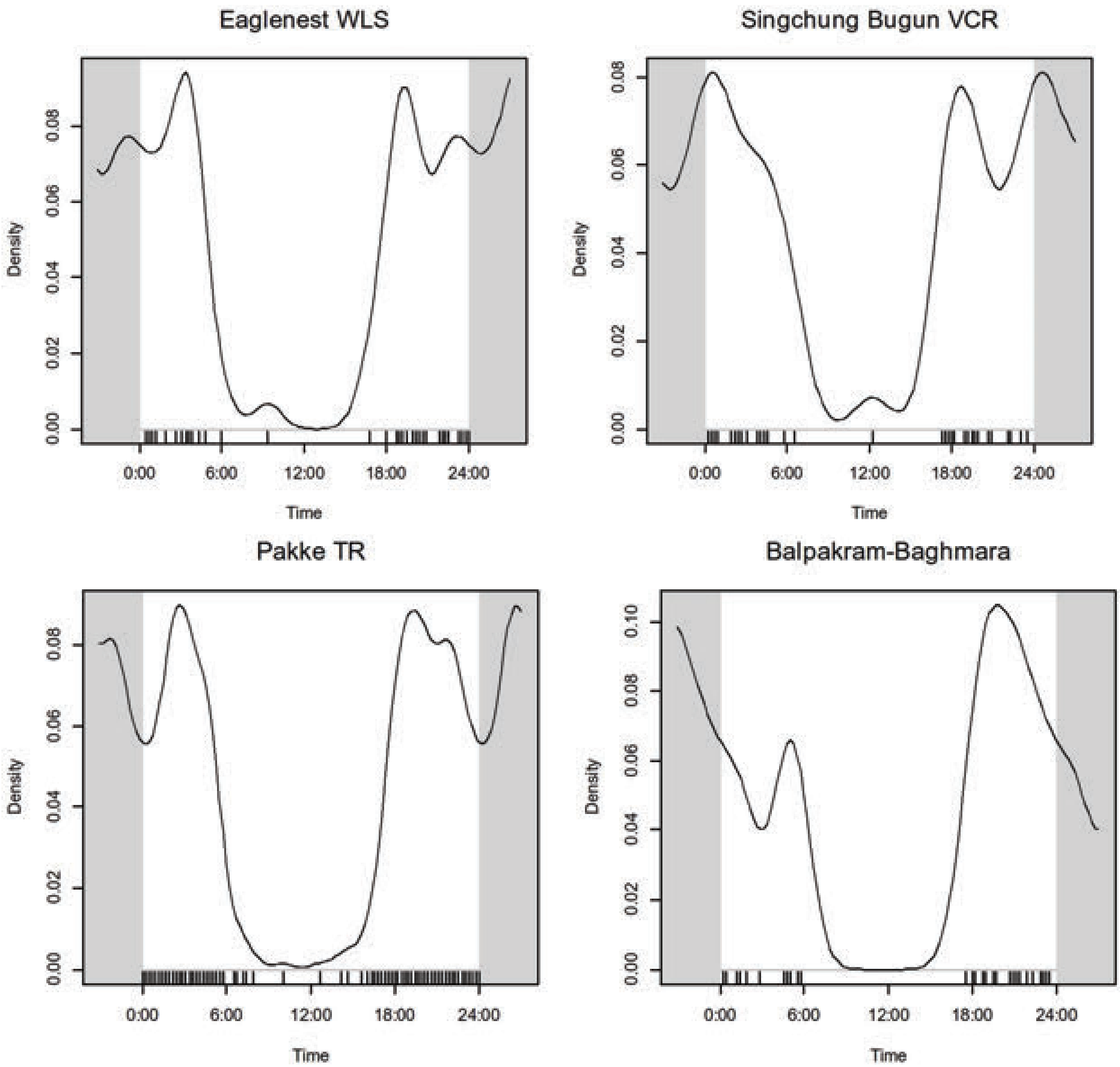
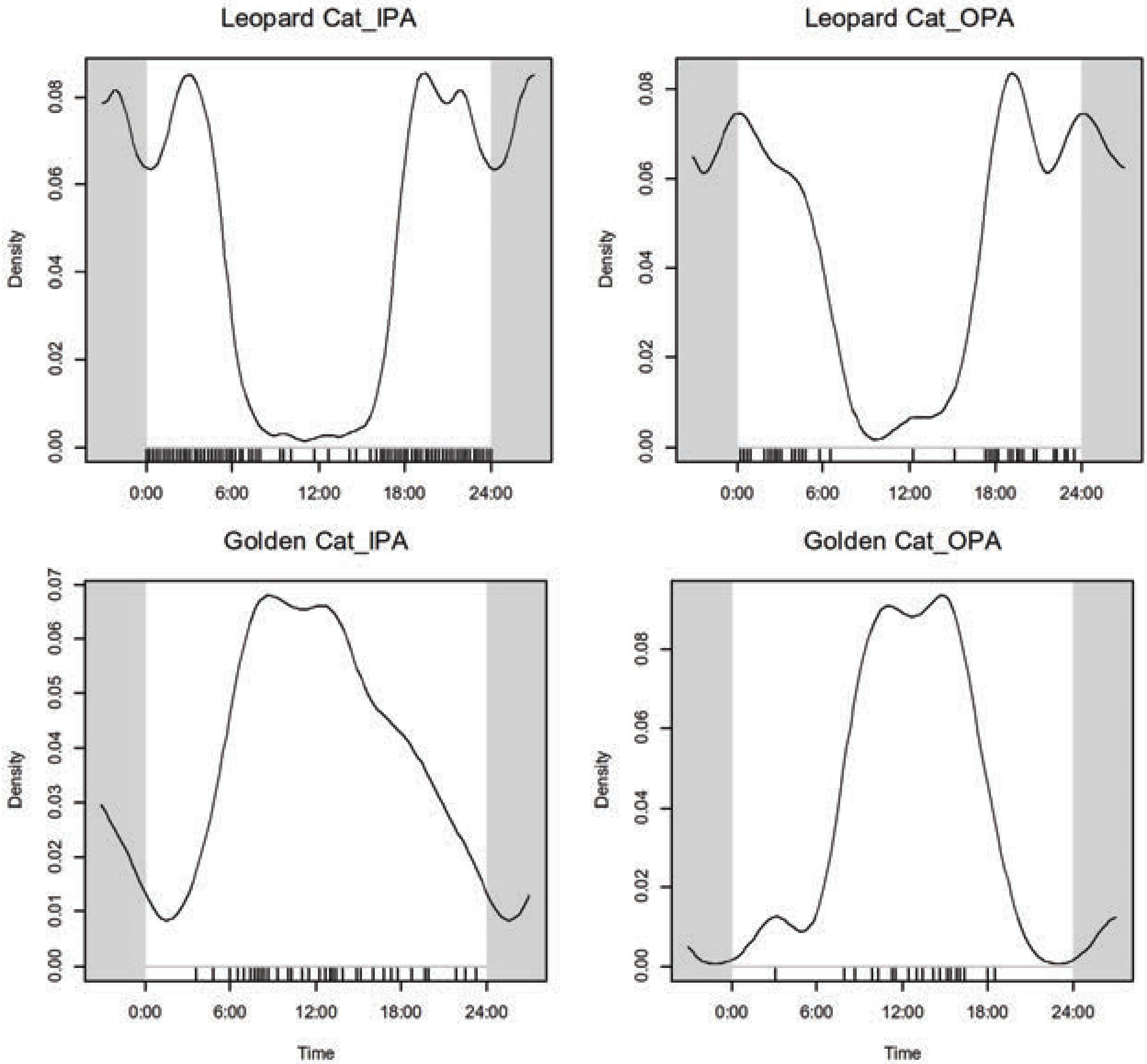


Supplementary Figure 1.1. Marbled Cat and Leopard Cat activity across different elevation categories (Marbled Cat below 1,500m, n=43; Marbled Cat above 1,500m, n=28; Leopard Cat below 1,500m, n=482; Leopard Cat above 1,500m, n=106).



Supplementary Figure 1.2. Leopard Cat activity across different study sites (Eaglenest WS, n=59; Singchung-Bugun VCR, n=43; Pakke TR, n=394; Balpakram-Baghmara, n=40).



Supplementary Figure 1.3. Leopard Cat and Asiatic Golden Cat activity across different protection regimes (Leopard Cat IPA, n=536; Leopard Cat OPA, n=52; Asiatic Golden Cat IPA, n=41; Asiatic Golden Cat OPA, n=22). IPA - inside protected area; OPA - outside protected area.

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Estimating Leopard Cat *Prionailurus bengalensis* Kerr, 1792 (Carnivora: Felidae) density in a degraded tropical forest fragment in northeastern Thailand

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Abstract: The Leopard Cat *Prionailurus bengalensis* is thought to be Asia's most abundant wild cat. Yet, the species' status is poorly known due to a lack of rigorous population estimates. Based on the few studies available, Leopard Cats appear to be more abundant in degraded forests, potentially due to increased prey availability. We conducted camera trap surveys, rodent live-trapping, and spatially-explicit capture-recapture analyses to estimate the density of Leopard Cats within a degraded tropical forest fragment (148km^2) in northeastern Thailand. A total effort of 12,615 camera trap nights across 65km^2 of trapping area resulted in at least 25 uniquely identified individuals. Average rodent biomass (the main prey of Leopard Cats) was highest in the dry evergreen forest (469.0g/ha), followed by dry dipterocarp forest (287.5g/ha) and reforested areas (174.2g/ha). Accordingly, Leopard Cat densities were highest in the dry evergreen forest with 21.42 individuals/100km^2, followed by the reforested areas with 7.9 individuals/100km^2. Only two detections came from the dry dipterocarp forest despite both an extensive survey effort (4,069 trap nights) and available prey. Although the dipterocarp supported the second highest average rodent biomass, it lacked a key prey species, *Maxomys surifer*, possibly explaining low encounter rates in that habitat. Our results provide important baseline information concerning the population status of Leopard Cat in southeastern Asia. Further, our findings corroborate with other studies that found a tolerance among Leopard Cats for degraded forests, highlighting the potential for forest fragments to serve as long-term conservation areas for the species.

Keywords: Camera trapping, Least Concern, predator-prey, prey availability, rodent biomass, Sakaerat Biosphere Reserve, southeastern Asia, spatially-explicit capture-recapture.

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Author contribution: WJP, DN, RS, TS conceived the ideas and designed field methodology; WJP collected the data; WJP, DN analyzed the data; WJP, DN, RS, TS contributed critically to the drafts and all authors gave final approval for publication.

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INTRODUCTION

When confronted with a lack of rigorous population estimates, status assessments such as the IUCN Red List of Threatened Species must rely on expert opinion of trends in population abundance or geographic range (Mace et al. 2008). This, however, can be problematic given both the subjective nature of expert opinion (Regan et al. 2005) as well as the wide variation in population dynamics and threats faced across a species range. The Leopard Cat *Prionailurus bengalensis*, for example, is thought to be the most abundant small cat species in Asia due to its wide distribution and supposed tolerance towards human-modified landscapes (Nowell & Jackson 1996; Macdonald et al. 2010; Ross et al. 2010). Yet, little is known regarding Leopard Cat population status in most parts of its range. Furthermore, recent studies suggest that Leopard Cat populations, in at least some areas, are being adversely affected by habitat loss, fragmentation, and poaching (e.g., Seto et al. 2012; Coudrat et al. 2014a,b; Willcox et al. 2014). As a result, the Leopard Cat may be threatened in many areas at a local scale, despite its global status on the IUCN Red List as Least Concern (Ross et al. 2010).

Camera trapping is an effective approach for estimating the density of uniquely marked animals such as Leopard Cats (Balme et al. 2009; Royle et al. 2013). However, despite widespread use of camera traps throughout the Leopard Cat's extensive geographic range, estimates of density are available from just a few sites in India and Malaysian Borneo (Bashir et al. 2013; Mohamed et al. 2013; Selvan et al. 2014; Srivathsa et al. 2015). This paucity of data may be due to multiple reasons such as 1) a lack of interest or incentive among researchers towards studying a species listed as Least Concern by the IUCN or 2) an inherent bias in survey effort towards other species and habitats not utilized by Leopard Cats. Moreover, Marshall et al. (2016) clearly demonstrated tropical research to be heavily biased towards large, charismatic, and threatened species as well as towards large, intact, primary forests. This bias is relevant given that several studies from primary forests found Leopard Cats to be among the least recorded Asian felids (e.g., Ross et al. 2010; McCarthy et al. 2015). Furthermore, studies by Mohamed et al. (2013) and Srivathsa et al. (2015) found Leopard Cat densities to be higher in more degraded habitats, which tend to be ignored by researchers. Despite their high tolerance for degraded habitats, telemetry studies suggest that Leopard Cats are still forest-dependent to some extent (Rajaratnam et al. 2007) and may even avoid large artificial open areas such as agriculture lands and human settlements (Chen et al. 2016).

An association between Leopard Cats and degraded habitats may reflect the species diet, which consists predominantly of murid rodents (e.g., Yasuma 1981; Rabinowitz 1990; Grassman 1998; Grassman 2000; Grassman et al. 2005; Rajaratnam et al. 2007). Indeed, rodent biomass is often elevated in degraded habitats owing to either increased resource availability (e.g., invertebrates), reduced predation pressure, or both (Lambert et al. 2006; Wells et al. 2007; Pimsai et al. 2014). Yet, in most studies on Leopard Cat habitat use and diet, prey distribution and abundance were not measured, despite these apparent associations between predator, prey, and habitat. Of the studies that did measure prey distribution and abundance, several indicated that Leopard Cats may preferentially select habitats based on the availability of a specific key prey species, rather than overall prey abundance (Yasuma 1981; Rabinowitz 1990; Rajaratnam et al. 2007).

In this study, we estimated Leopard Cat density using spatially-explicit capture-recapture models applied to a camera trapping dataset from a degraded tropical forest fragment in northeastern Thailand. Our study spanned periods of rodent abundance and scarcity in three forest types, allowing us to observe the response of Leopard Cats to both spatial and temporal changes in resource availability. We made two predictions. First, Leopard Cat density should be highest in the forest type with the highest average rodent biomass (g/ha), as forest types with more food should support higher Leopard Cat densities compared to forest types with less food. Second, Leopard Cat movements (sigma parameter) should be larger when and where resources are scarce, compared to when and where they are abundant. This pattern would reflect possible increases in ranging behaviour in response to low resource availability (Fuller & Sievert 2001). We then compared overall density at our site to density estimates from other sites throughout the species range.

STUDY AREA

Established in 1977, the Sakaerat Biosphere Reserve (hereafter Sakaerat) in northeastern Thailand (14.510^{0}N & 101.930^{0}E) covers 148km^2 of fragmented forest with an elevation range of 280–762 m (Fig. 1). Historically, the areas comprising Sakaerat's present-day reserved forest underwent periods of extensive deforestation and conversion to agriculture (the 1950s–1970s), followed

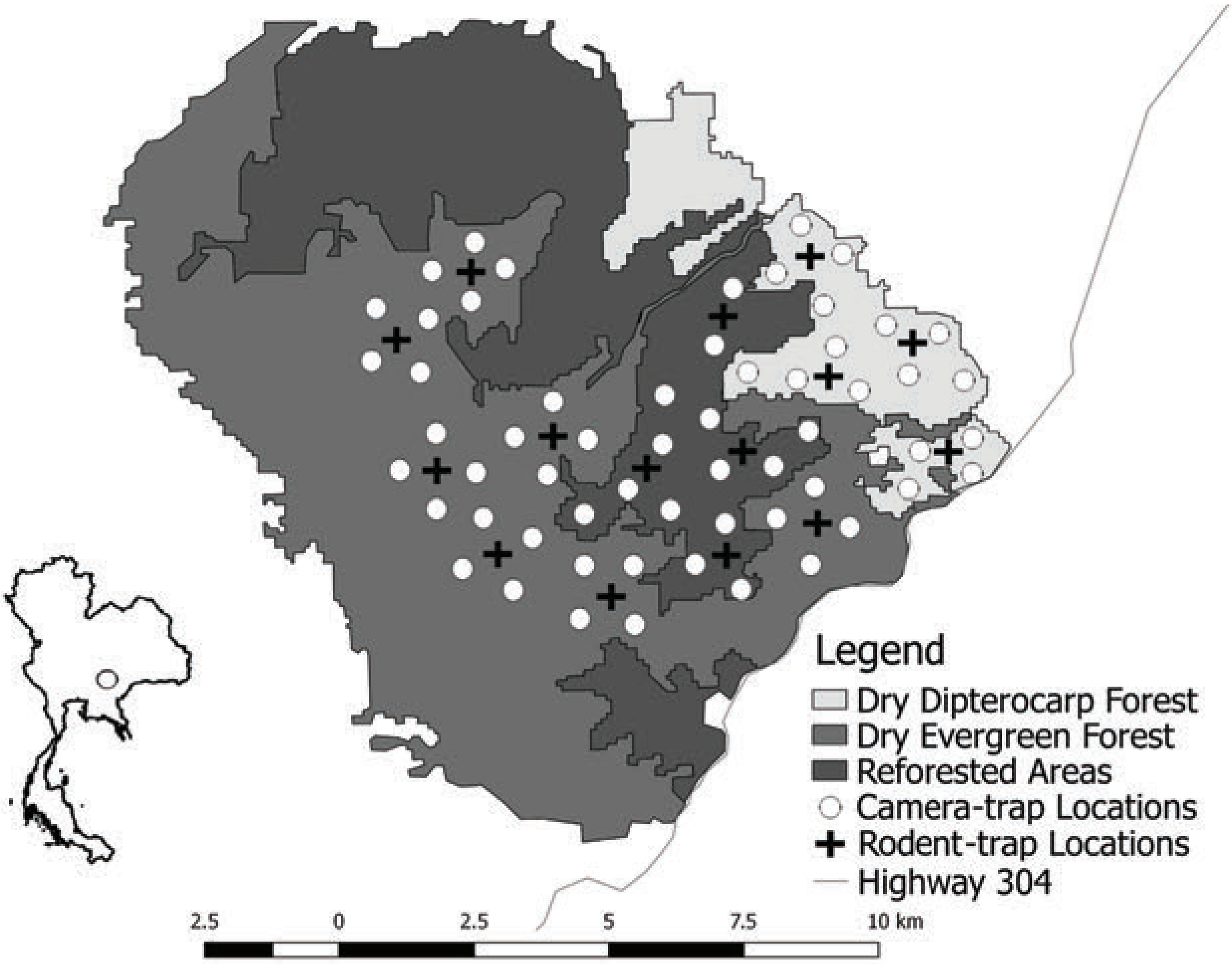

Figure 1. Sakaerat Biosphere Reserve in Thailand, including three dominant habitat types, camera trap locations, rodent live-trapping locations, and Highway 304.

by state-run reforestation efforts using non-native tree species (1977 onwards). This process of deforestation and reforestation resulted in the fragmentation and isolation of Sakaerat from nearby forests (including Dong Phayayen-Khao Yai forest complex) and greatly altered the reserve's current forest structure, with no primary forest remaining (Kamo et al. 2002; TISTR 2018).

Dominant forest types today include secondary dry evergreen forest (hereafter evergreen; 54%), secondary dry dipterocarp forest (hereafter dipterocarp; 11%), and reforested areas (33%) which include secondary evergreen regrowth and mixed acacia (*Acacia* spp.) and eucalyptus (*Eucalyptus* spp.) forest plantations (Fig. 1; Ashton et al. 2014). Sakaerat has a seasonal climate with a dry season starting from November to April and a wet season from May to October. The average annual precipitation is 1,071mm, while the average annual temperature is 26.1^{0}C (TISTR 2018).

MATERIALS AND METHODS

Camera trap surveys

We deployed 60 camera traps (Scout Guard SG565) spaced 1km apart in three forest types (evergreen: 28 camera traps; dipterocarp: 16 camera traps; reforested areas: 16 camera traps) from mid-January 2017 through October 2017 (Fig. 1). One camera trap was deployed per station. Camera traps were attached to trees approximately 45cm above the ground and 3m from a target zone, which was lured with fish oil scent. We visited camera traps once per month to replace batteries, memory cards, and the scent lure. We calculated trapping effort by summing the number of trap nights (24h-periods starting from 00.00h and ending at 23.59h), in which camera traps were both active and functioning.

Rodent biomass estimation

We sampled terrestrial rodents during four periods (February–March; April–May; July–August; September–October) in 2017 at 15 sites (seven sites in evergreen, four in dipterocarp, and four in reforested areas) using Sherman live traps (7.62cmx8.89cmx22.86cm). At each site, we arranged 25 traps on the ground in a 5x5 grid with 20m spacing between traps and used peanut butter as bait. Each session consisted of seven consecutive trap nights at one site, with sites being visited once per two-month period (60 sessions total). Captured animals were identified to species, weighed, uniquely marked with an ear tag (mouse ear-tag – style 1005-1), and then released at their capture sites. Rodent live-trapping protocol was approved by King Mongkut's University of Technology Thonburi's Animal Care and Use Committee and permitted by Thailand's Department of National Parks, Wildlife and Plant Conservation.

To estimate the biomass of rodents, we first estimated density (D) using the 'secr' package (Efford 2018) in program R (version 3.42; R Development Core Team, 2016). Due to the limited number of captures and recaptures at some sites, we pooled all species and sites from the same forest type and sampling period for analysis, with each site designated as a separate session. Data from different two-month sampling periods were analyzed separately. Multi-session analyses were then conducted whereby the capture parameters g0 (capture probability when the distance between an animal's activity center and the trap is zero) and sigma (σ; a scaling parameter reflecting animal movement) were shared among sessions. To account for potential bias in our small mammal capture-probabilities introduced by "trap-happy" or "trap-shy" individuals, we incorporated various behavioral responses into our models (Otis et al. 1978; Efford 2018). Models tested included a constant model [D(*session*) g0(.) σ(.)], learned response model [D(*session*) g0(b) σ(.); "trap-happy"], site-specific learned response model [D(*session*) g0(bk) σ(.); trap-specific "trap-happy"], transient response model [D(*session*) g0(B) σ(.); "trap-shy"], and site-specific transient response model [D(*session*) g0(Bk) σ(.); trap-specific "trap-shy"]. Session-specific density estimates were then derived using the best-supported model as determined by AIC_c scores and AIC_c weights (Burnham & Anderson 2002).

Session-specific density estimates were then multiplied by the session's corresponding mean individual body mass to obtain session-specific estimates of rodent biomass (Chutipong et al. 2017). Session-specific rodent biomass estimates were then assigned as a covariate to the nearest four camera trap stations within the same habitat type for use in estimating Leopard Cat density.

Leopard Cat density estimation

Spatially-explicit capture-recapture analyses were used to estimate Leopard Cat densities (Efford 2018) based on each animal's unique spot patterns observed

Image 1. A diurnal Leopard Cat *Prionailurus bengalensis* investigating the fish oil scent lure placed at the centre of a camera trap's target zone within the dry evergreen forest of Sakaerat Biosphere Reserve, northeastern Thailand.

in camera trap images (Image 1). Because Leopard Cats are patterned asymmetrically, there is a possibility of photographing what is known as "partial identities" or individuals known from only a single flank. To include these "partial" individuals into the analyses, researchers typically analyze left and right flanks separately or discard the flank with the least detections (e.g., Wang & Macdonald 2009; Kalle et al. 2011; Srivathsa et al. 2015). These approaches, however, result in a loss of precision and the potential introduction of bias (Meredith 2017). To avoid this, we used a new method that combines data from both flanks into the same analysis, modelling each flank as a separate 'session' and estimating shared values for D, g0, and σ across sessions under the assumption that the latent ("true") density and capture probabilities of both flanks are equal (Meredith 2017).

After identifying individuals, we generated capture histories using daily occasions starting from 00.00h and ending at 23.59h. Capture histories were then split into different sessions based on the period of resource availability (i.e., high or low rodent biomass), habitat type (i.e., evergreen or reforested area), and flank (i.e., left or right). A mask (buffer=1500m; designated using the 'suggest.buffer' function) was also applied around each station, limited by the study area's boundary. We then conducted multi-session analyses, comparing a constant model [D(.) g0(.) σ(.)] to models where D, g0, and σ parameters varied by the season of resource availability (high rodent biomass and low rodent biomass; termed "season") and habitat type (evergreen and reforested area; termed "habitat"). In addition to these session-covariates, we also modelled the g0 parameter using the trap-covariates "rodent biomass" which corresponds to the actual rodent biomass (g/ha) from the nearest rodent live-trapping site (see Rodent biomass estimation) and behavioral responses (e.g., trap-happy or trap-shy), using covariates "b", "bk", "B", and "Bk". Sigma (σ) was additionally modelled by the trap covariate "rodent biomass".

We performed our model selection in three steps using AIC_c scores and AIC_c weights to determine the best-supported model (Burnham & Anderson 2002). First, we modelled all g0 covariates individually, while leaving D and σ constant. Second, any individual g0 covariates performing better than the constant model [g0(.)] were then modelled together using all possible combinations. The top-ranked covariate combinations ($\Delta AIC_c<6.0$) from this second step were then considered "candidate covariate combinations". These two steps were then repeated for the D and σ parameters. Finally, we modelled D, g0, and σ parameters using all combinations of D, g0, and σ "candidate covariate combinations". Due to our limited sample size, we restricted each model to a maximum of two covariates. All models were fit using the full likelihood approach.

RESULTS

In 12,615 camera trap nights, we obtained 115 images from 59 detections of Leopard Cats, of which 50 detections contained images that could be used to identify individuals (Table 1). Due to the species small body size, we could not identify the sex of the individuals. During the period of low rodent biomass, 14 left-flank individuals (12 in evergreen, two in reforested) and 13 right-flank individuals (12 in evergreen, one in reforested) were detected. Ten left-flank individuals (five in evergreen and five in reforested) and 11 right-flank individuals (six in evergreen and five in reforested) were detected during the period of high rodent biomass. Two left-flank individuals were detected in the dipterocarp

Table 1. Summary of Leopard Cat images by period of rodent biomass from Sakaerat Biosphere Reserve, northeastern Thailand. "Identifiable detections" refers to the number of Leopard Cat detections that contain images that are usable for individual identification. "Partial individuals" corresponds to the number of individuals that only had a single flank photographed (either right or left). "Complete individuals" corresponds to the number of individuals that had both flanks photographed. Dry evergreen forest: DEF; reforested areas: RFA; dry dipterocarp forest: DDF.

Survey Information	Low rodent biomass				High rodent biomass			
	Total	DEF	RFA	DDF	Total	DEF	RFA	DDF
Period	January–May 2017				June–October 2017			
Camera stations	58	28	14	16	58	28	14	16
Survey area	$65km^2$	$34km^2$	$15km^2$	$16km^2$	$65km^2$	$34km^2$	$15km^2$	$16km^2$
Trap nights	7,193	3,726	1,341	2,126	5,422	2,136	1,349	1,937
Identifiable detections	25	22	3	0	25	13	10	2
Partial individuals (right-flank)	7	6	1	0	10	6	4	0
Partial individuals (left-flank)	7	5	2	0	11	5	4	2
Complete individuals (both flanks)	7	7	0	0	1	0	1	0

during the period of high rodent biomass. Because of our low sample size in the dipterocarp, we did not estimate Leopard Cat density in that habitat type.

Rodent biomass

In total, we conducted 10,500 small mammal trap nights, during which we captured 297 unique individuals of at least six rodent species (Table 2). Average density in the evergreen was highest in September–October (mean=7.3 individuals/ha; range of site-specific densities: 5.3–10.5 individuals/ha) and lowest in April–May (mean=1.3 individuals/ha; range: 0.4–1.7 individuals/ha). In the dipterocarp, average density was highest in July–August (mean=13.1 individuals/ha; range of site-specific densities: 0 individuals captured–38.6 individuals/ha) and lowest in April–May (mean=2.2 individuals/ha; range: 0 individuals captured–3.4 individuals/ha). In the reforested areas, the average density was highest in September–October (mean=5.2 individuals/ha; range of site-specific densities: 3.3–6.6 individuals/ha) and lowest in April–May (0 individuals captured).

Average rodent biomass was consistently highest in the evergreen (mean=469.0 g/ha) throughout our study, followed by the dipterocarp (mean=287.5g/ha) and reforestation areas (mean=174.2 g/ha; Fig. 2). Seasonally, overall average rodent biomass was 3.6 times higher during the rainy season (July–October; mean=527.5g/ha) compared to the dry season (February–May; mean=145.6g/ha). Overall rodent biomass peaked in the months of September–October (mean=763.8g/ha), especially in the evergreen (mean=995.0g/ha). April–May had the lowest overall rodent biomass (mean 91.8g/ha), especially in the reforested areas (0 captures). As such, February–May was considered the period of low rodent biomass for all habitats and July–October was considered the period of high rodent biomass (Fig. 2).

Leopard Cat density

Our two top-ranked models based on AIC_c and AIC_c weights included D(.) g0(*b*) σ(*habitat*) (43% AIC_cw_i; Table 3) and D(*habitat*) g0(*b*) σ(.) (20% AIC_cw_i; Table 3). According to D(.) g0(*b*) σ(*habitat*), the Leopard Cat density within Sakaerat (excluding dipterocarp) was 17.7 individuals/100km^2 (SE 3.9; 95% CI 11.5–27.2; Table 4). The movement parameter, sigma (σ), was 480.2m

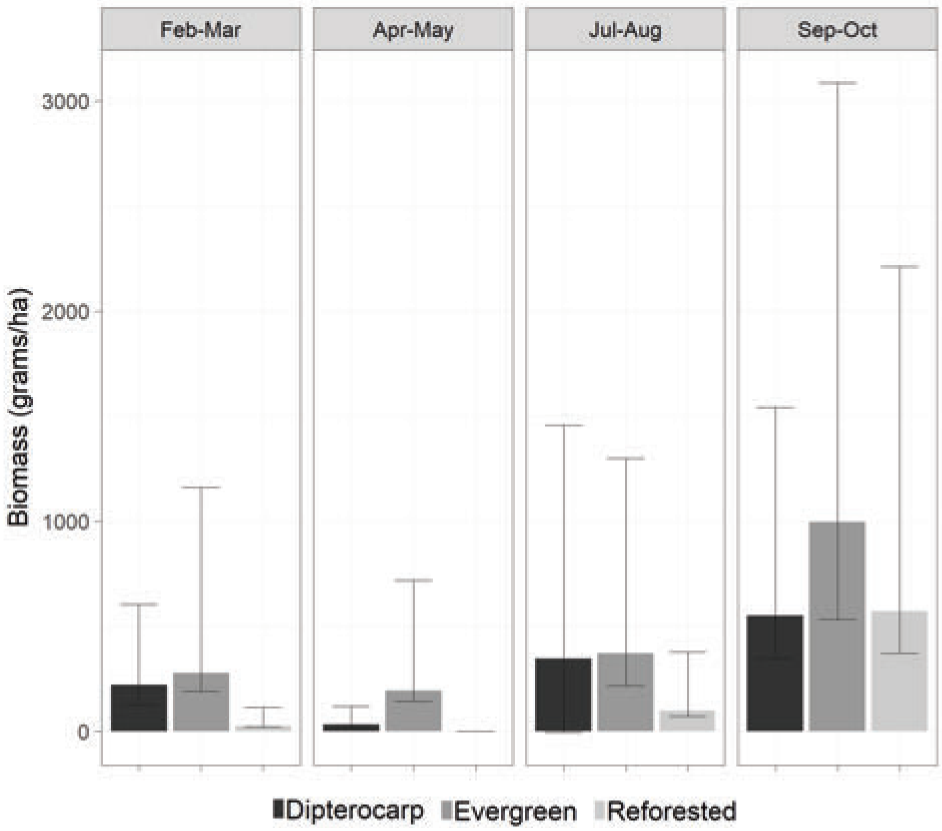

Figure 2. Rodent biomass by habitat and bimonthly period. The period of high rodent biomass corresponds with July–August and September–October, while the period of low rodent biomass corresponds with February–March and April–May.

Table 2. Summary of small mammal live-trapping results including trap nights by habitat, the number of unique individuals captured by both habitat and species, and the average individual body mass by species. Live-trapping data from Sakaerat Biosphere Reserve, northeastern Thailand, 2017.

Survey information	Overall	Dry dipterocarp	Dry evergreen	Reforested areas	Average mass
Trap nights	10,500	2,800	4,900	2,800	-
Total capture events	297	137	133	27	-
Maxomys surifer	162	6	133	23	132.3g/indiv SE 2.0
Mus spp.	118	116	0	2	17.4g/indiv SE 0.5
Tupaia belangeri	10	10	0	0	177.6g/indiv SE 14.6
Menetes bermorei	4	4	0	0	198.3g/indiv SE 24.0
Crocidura attenuata	2	0	0	2	9.5g/indiv SE 0.5
Rattus rattus	1	1	0	0	79g/indiv

Table 3. Model selection for Leopard Cat density using spatially-explicit capture-recapture. 'K' represents the number of estimated parameters. AIC_c, ΔAIC_c, and AIC_c weights 'w_i' provide a measure of relative support for each model. Only models with a cumulative $w_i \leq 0.95$ are included. For all models, see Appendix B.

Models	K	AIC_c	ΔAIC_c	w_i
D(.) g0(*b*) sigma(*habitat*)	5	961.17	0.00	0.43
D(*habitat*) g0(*b*) sigma(.)	5	962.69	1.52	0.20
D(.) g0(.) sigma(*habitat*)	4	963.66	2.49	0.12
D(.) g0(*habitat*) sigma(*habitat*)	5	964.69	3.52	0.07
D(*habitat*) g0(.) sigma(*habitat*)	5	965.94	4.77	0.04
D(*habitat*) g0(.) sigma(.)	4	966.12	4.94	0.04
D(.) g0(*habitat + bk*) sigma(.)	5	966.30	5.13	0.03

(SE 98.6; 95% CI 322.1–715.9) in the evergreen and 236.2m (SE 53.1; 95% CI 152.8–365.1) in the reforested areas. The capture parameter g0 was 0.009 (SE 0.004) when b=0 and 0.002 (SE 0.0007) when b=1. Based on our second top-ranked model, D(*habitat*) g0(b) σ(.) Leopard Cat density was 21.2 individuals/100km^2 (SE 5.3; 95% CI 13.1–34.3; Table 3) in the evergreen and 7.9 individuals/100km^2 (SE 2.7; 95% CI 4.1–15.0; Table 3) in the reforested areas. Sigma (σ) was 476.0m (SE 93.4; 95% CI 325.2–696.7). g0 was 0.007 (SE 0.003) when b=0 and 0.001 (SE 0.0006) when b=1.

DISCUSSION

Our study is among the first to simultaneously conduct camera trapping and rodent live-trapping to assess the relationship between small wild cat density and prey biomass. Specifically, we estimated Leopard Cat density and examined the influence of rodent biomass and forest type on the species density and movements in a degraded tropical forest fragment. Contrary to our predictions, top-ranked models did not indicate a direct effect of rodent biomass or season on Leopard Cat density or movements (Table 3; Appendix B). This result could have several explanations. First, although we found major differences in rodent biomass between seasons and within habitat types, rodents were nonetheless always available throughout the year and the differences may not have been biologically significant enough to warrant detectable changes in Leopard Cat behavior. Second, although dietary studies indicate Leopard Cats predominantly eat murid rodents, the species also consumes other prey items including birds, reptiles, amphibians, and invertebrates (Grassman 1998; Grassman 2000; Grassman et al. 2005; Rajaratnam et al. 2007). The availability of such alternative prey, which we did not sample, may have mitigated the influence of rodent biomass on Leopard Cat density and behavior.

Our raw data, though, do suggest that seasonal differences in rodent biomass may influence Leopard Cat capture probability. For example, during the low rodent period, we obtained seven recaptures, five of which were relocations (i.e., recaptures at different

Table 4. Comparison of density estimates (D; individual/100km²), standard errors (SE), and coefficient of variation (CV) from our study and other studies of Leopard Cats using both maximum likelihood (MLE) and Bayesian spatially-explicit capture-recapture. For this study, density estimates come from two models: [a]D(.) g0(*b*) σ(*habitat*) and [b]D(*habitat*) g0(*b*) σ(.). [c]Standard deviation (SD) and [d]coefficient of variation (CV) are included for Bayesian estimates.

Study	D	SE	CV	Location
This study	17.7[a]	3.9	0.22	Overall, Sakaerat Biosphere Reserve, Thailand
	21.2[b]	5.3	0.25	Semi-evergreen forest, Sakaerat Biosphere Reserve, Thailand
	7.9[b]	2.7	0.34	Artificially reforested areas, Sakaerat Biosphere Reserve, Thailand
Srivathsa et al. 2015	10.5	3.0[c]	0.29[d]	Semi-evergreen and moist deciduous forest, Bhadra Tiger Reserve, India
	4.5	1.3[c]	0.29[d]	Various habitats, Biligiri Rangaswamy Temple Tiger Reserve, India
Selvan et al. 2014	2.9	0.2	0.07	Wet evergreen forest, Pakke Tiger Reserve, India
Mohamed et al. 2013	12.4	1.6	0.13	Mixed dipterocarp forest, Tangkulap-Pinangah Forest Reserve, Malaysian Borneo
	16.5	2.0	0.12	Mixed dipterocarp forest, Segaliud Lokan Forest Reserve, Malaysian Borneo
	9.6	1.7	0.18	Mixed dipterocarp forest, Deramakot Forest Reserve, Malaysian Borneo
Bashir et al. 2013	17.0	5.3	0.31	Temperate broadleaf forest, Khangchendzonga Biosphere Reserve, India

camera locations). By contrast, during the high rodent period, there were only four recaptures, one of which was a relocation. We hypothesize that this reflects Leopard Cats being easier to capture during the period of low prey biomass, due to being more receptive to our scent lure and having larger home ranges, both of which would result in higher capture probabilities.

Our top-ranked model, D(.) g0(*b*) σ(*habitat*), suggests that Leopard Cat movement was lower in reforested areas compared to the evergreen forest. Because reforested areas supported lower rodent biomass compared to the evergreen, this finding is contrary to our prediction that Leopard Cat movement would be negatively influenced by rodent biomass. This finding, however, may be an artefact of our data collection. Although we did not target dirt roads, there was an abundance of dirt roads within the reforested area due to its artificial nature, and one camera in the reforested area was placed (at random) near a dirt road (<10m). This camera alone recorded 50% of our reforested area individuals and 100% of the reforested area's recaptures. Thus, the finding that the Leopard Cat movement was lower in the reforested area likely stems from the absence of recaptures at different camera sites. Based on this experience, we recommend that future studies targeting Leopard Cats implement stratified study designs whereby camera traps are placed both on and off roads to explicitly explore differences in Leopard Cat density, capture probability, and movement.

Consistent with our predictions, our second top-ranked model [D(*habitat*) g0(b) σ(.)] does indicate that Leopard Cat density varied by habitat type in a manner that reflects prey availability, with both average rodent biomass and Leopard Cat density being 2.7 times higher in the evergreen compared with the reforested areas. Only two detections (out of 4,063 trap nights), however, came from Sakaerat's dry dipterocarp forest, the habitat with the second highest estimate of rodent biomass. Rabinowitz (1990) similarly observed Leopard Cats using dry dipterocarp forest less than other habitat types, noting that the dipterocarp contained lower densities of the Red Spiny Rat *Maxomys surifer*, the main prey item of Leopard Cats during that study. Results from rodent trapping in the current study had similar findings, with *M. surifer* being the most frequently captured rodent in both evergreen (100% of captures) and reforested areas (89.1% of captures), but only a few captures in the dipterocarp (3% of captures).

In addition to having the lowest capture rate of a key Leopard Cat prey species, the dipterocarp also had relatively high encounter rates for three sympatric small carnivore species: Golden Jackal *Canis aureus*, Javan Mongoose *Herpestes javanicus*, and Small Indian Civet *Viverricula indica* (Appendix A). Although direct evidence of competition between these three species and Leopard Cats was not reported, interspecific competition among other sympatric carnivores is well-documented within the literature (Palomares & Caro 1998; Donadio & Buskirk 2006). Future studies should be careful to account for both the prey community and the potential for interspecific competition among sympatric small carnivores when considering the suitability of a specific patch of forest for Leopard Cats.

Leopard Cats and degraded forests

With an estimate of 17.7 individuals/100km^2 overall and 21.2 individuals/100km^2 in the evergreen, Sakaerat supports the highest recorded SECR-derived Leopard Cat density to date (range from other studies: 2.9–17.0 individuals/100km^2; Table 3). These findings corroborate other studies which also found Leopard Cat densities to be higher in more degraded environments (Mohamed et al. 2013; Srivathsa et al. 2015). Srivathsa et al. (2015), for example, compared Leopard Cat densities in four protected areas in India, finding higher densities clustered around secondary, disturbed, or partially modified forests. Bhadra Tiger Reserve, which supported the study's highest Leopard Cat density (10.5 individuals/100km^2), consists predominantly of semi-evergreen forest still recovering from the voluntary resettlement of 26 forest villages in 2002 and currently adjoins large tracts of coffee plantations and several unprotected forest reserves (Srivathsa et al. 2015). Similarly, Mohamed et al. (2013) recorded a higher Leopard Cat density in more intensively logged commercial forest reserves (12.4 individuals/100km^2 and 16.5 individuals/100km^2) compared to a more sustainably logged reserve (9.6 individuals/100km^2) in Sabah, Malaysian Borneo.

It is hypothesized that the Leopard Cat's association with degraded environments is related to elevated rodent populations within such areas (Lambert et al. 2006; Rajaratnam et al. 2007; Wells et al. 2007; Pimsai et al. 2014), given the tendency for murid rodents to be key prey items of Leopard Cats (Rabinowitz 1990; Grassman et al. 2005; Rajaratnam et al. 2007; Shehzad et al. 2012). Researchers and conservationists, however, should be careful when interpreting these general findings as not all degraded areas are alike. Oil palm plantations, for example, support abnormally high murid rodent densities, which in some cases can exceed 100 individuals/ha, whereas during our study the highest recorded density within the evergreen was only 10.5 individuals/ha (Wood & Fee 2003; Scott et al. 2004). Variation in prey communities among degraded habitats may also play a deciding role in habitat selection among Leopard Cats. As mentioned previously, Leopard Cat encounter rates in our study strongly reflected capture rates of *M. surifer*, which were highest in the evergreen and lowest in the dipterocarp. This emphasis on a specific murid species as primary prey was documented previously for Leopard Cats in Thailand (Rabinowitz 1990), Japan (Yasuma 1981), and Malaysian Borneo (Rajaratnam et al. 2007). Similar findings were also documented in other tropical small felids, including Serval *Leptailurus serval* (Geertsema 1985), Jaguarundi *Herpailurus yagouaroundi* (Konecny 1989), and Guigna *Leopardus guigna* (Dunstone et al. 2002).

Other proposed factors influencing whether the habitat is suitable for Leopard Cats include habitat structure and its effect on prey 'catchability' (Rajaratnam et al. 2007). In addition to supporting high murid densities, oil palm plantations are notable for being relatively free of understory vegetation, potentially facilitating successful predation events (Rajaratnam et al. 2007). This may be relevant to our study's findings due to the ubiquity of tall dense bamboo *Arundinaria pusilla* within Sakaerat's dipterocarp forest. If the presence of this grass reduced the catchability of prey in the dipterocarp, it may potentially explain why so few Leopard Cats were recorded in this habitat. Although we lack evidence to directly support this hypothesis, studies of other felids demonstrated a preference for habitats with high prey catchability over areas with high prey availability (e.g., Cheetah *Acinonyx jubatus*, Broomhall et al. 2003; Lion *Panthera leo*, Hopcraft et al. 2005).

Leopard Cats tolerate habitat degradation and even associate with specific human land uses such as oil palm (Ross et al. 2010) and sugar cane plantations (Lorica & Heaney 2013) and logged forests (Ross et al. 2010; Mohamed et al. 2013). Yet, despite a growing body of literature, their habitat requirements, population sizes, and long-term viability within both degraded forests and agriculture habitats remain unclear. Our study not only contributes to the current need for information on population density and habitat selection within forest fragments but also supports the idea that forest fragments may be crucial for the conservation of Leopard Cats in human-dominated landscapes. More research, however, is needed concerning the long-term viability of these populations. To fill this crucial knowledge gap, we recommend future studies leave the confines of protected areas in order to investigate the role their surroundings play both as habitat and as facilitators of connectivity.

REFERENCES

Ashton, P.S., R. Reinmar & A.R. Kassim (2014). *On the Forests of Tropical Asia: Lest the Memory Fade*. Kew Publishing, Richmond, 670pp.

Balme, G.A., L.T.B. Hunter & R. Slotow (2009). Evaluating methods for counting cryptic carnivores. *Journal of Wildlife Management* 73(3): 433–441; https://doi.org/10.2193/2007-368

Bashir, T., T. Bhattacharya, K. Poudyal, S. Sathyakumar & Q. Qureshi (2013). Estimating Leopard Cat *Prionailurus bengalensis* densities using photographic captures and recaptures. *Wildlife Biology* 19(4): 462–472; https://doi.org/10.2981/12-098

Broomhall, L.S., M.G.L. Mills & J.T. du Toit (2003). Home range and habitat use by cheetahs (*Acinonyx jubatus*) in Kruger National Park. *Journal of Zoology* 261: 119–128; https://doi.org/10.1017/S0952836903004059

Burnham, K.P. & D.R. Anderson (2002). *Model Selection and Multimodel Inference: A Practical Information-theoretic Approach*. Springer, New York, 488pp; https://doi.org/10.1007/b97636

Chen, M., Y. Liang, C. Kuo & K.J. Pei (2016). Home ranges, movements and activity patterns of Leopard Cats (*Prionailurus bengalensis*) and threats to them in Taiwan. *Mammal Study* 41(2): 77–86; https://doi.org/10.3106/041.041.0205

Chutipong, W., R. Steinmetz, T. Savini & G.A. Gale (2017). Assessing resource and predator effects on habitat use of tropical small carnivores. *Mammal Research* 62(1): 21–36; https://doi.org/10.1007/s13364-016-0283-z

Coudrat, C.N.Z., C. Nanthavong, S. Sayavong, A. Johnson, J. Johnston & W.G. Robichaud (2014a). Conservation importance of Nakai-Nam Theun National Protected Area, Laos, for small carnivores based on camera trap data. *Raffles Bulletin of Zoology* 62: 31–49.

Coudrat, C.N.Z., C. Nanthavong, S. Sayavong, A. Johnson, J. Johnston & W.G. Robichaud (2014b). Low abundance of small medium-sized wild cat species in large primary forests: a case study of Nakai-Nam Theun National Protected Area, Lao PDR. *Cat News Special Issue* 8: 45–52.

Donadio, E. & S.W. Buskirk (2006). Diet, morphology, and interspecific killing in carnivora. *The American Naturalist* 167(4): 524–536; https://doi.org/10.1086/501033

Dunstone, N., L. Durbin, I. Wylie, R. Freer, G.A. Jamett, M. Mazzolli & S. Rose (2002). Spatial organization, ranging behaviour and habitat use of the kodkod (*Oncifelis guigna*) in southern Chile. *Journal of Zoology* 257: 1–11; https://doi.org/10.1017/S0952836902000602

Efford, M.G. (2018). secr: Spatially explicit capture-recapture models. R package version 3.1.6. Available online at https://CRAN.R-project.org/package=secr.

Fuller, T.K. & P.R. Sievert (2001). Carnivore demography and the consequences of changes in prey availability, pp163–177. In: Gittleman, J.L., S.M. Funk, D.W. Macdonald & R.K. Wayne (eds.). *Carnivore Conservation*. Cambridge University Press, New York, 675pp.

Geertsema, A.A. (1985). Comparative feeding ecology of felids in a neotropical rainforest. *Behavioral Ecology and Sociobiology* 20: 271–283; https://doi.org/10.1007/BF00292180

Grassman, L.I. Jr. (1998). Movements and prey selection of the Leopard Cat (*Prionailurus bengalensis*) in a subtropical evergreen forest in southern Thailand. *Societa Zoologica ''La Torbiera''* 4: 9–21; https://doi.org/10.1644/11-MAMM-A-394.1

Grassman, L.I. Jr. (2000). Movement and diet of the Leopard Cat *Prionailurus bengalensis* in a seasonal evergreen forest in southcentral Thailand. *Acta Theriologica Scientific Report* 45(3): 421–426; https://doi.org/10.4098/AT.arch.00-41

Grassman, L.I. Jr., M.E. Tewes, N.J. Silvy & K. Kreetiutanont (2005). Ecology of three sympatric felids in a mixed evergreen forest in north-central Thailand. *Journal of Mammalogy* 86(1): 29–38; https://doi.org/10.1644/1545-1542(2005)086<0029:EOTSFI>2.0.CO;2

Hopcraft, J.G.C., A.R.E. Sinclair & C. Packer (2005). Planning for success: Serengeti lions seek prey accessibility rather than abundance. *Journal of Animal Ecology* 74(3): 559–566; https://doi.org/10.1111/j.1365-2656.2005.00955.x

Kalle, R., T. Ramesh, Q. Qureshi & K. Sankar (2011). Density of tiger and leopard in a tropical deciduous forest of Mudumalai Tiger Reserve, southern India, as estimated using photographic capture-recapture sampling. *Acta Theriologica* 56(4): 335–342; https://doi.org/10.1007/s13364-011-0038-9

Kamo, K., T. Vacharangkura, S. Tiyanon, C. Viriyabuncha, S. Nimpila & B. Doangsrisen (2002). Plant species diversity in tropical planted forests and implication for restoration of forest ecosystems in Sakaerat, northeastern Thailand. *Japan Agricultural Research Quarterly* 36(2): 111–118; https://doi.org/10.6090/jarq.36.111

Konecny, M.J. (1989). Movement patterns and food habits of four sympatric carnivore species in Belize, central America, pp243–264. In: Redford, K.H. & J.F. Eisenberg (eds.). *Advances in Neotropical Mammalogy.* Sandhill Crane Press, Gainesville, 614pp.

Lambert, T.D., J.R. Malcolm & B.L. Zimmerman (2006). Amazonian small mammal abundances in relation to habitat structure and resource abundance. *Journal of Mammalogy* 87(4): 766–776; https://doi.org/10.1644/05-MAMM-A-261R1.1

Lorica, M. & L. Heaney (2013). Survival of a native mammalian carnivore, the Leopard Cat *Prionailurus bengalensis* Kerr, 1972 (Carnivora: Felidae), in an agricultural landscape on an oceanic Philippine island. *Journal of Threatened Taxa* 5(4): 4451–4460; https://doi.org/10.11609/JoTT.o3352.4451-60

Macdonald, D.W., A.J. Loveridge & K. Nowell (2010). Dramatis personae: an introduction to the wild felids, pp3–58. In: Macdonald, D.W. & A.J. Loveridge (eds.). *The Biology and Conservation of Wild Felids.* Oxford University Press, Oxford, United Kingdom, 762pp.

Mace, G.M., N.J. Collar, K.J. Gaston, C. Hilton-Taylor, H.R. Akçakaya, N. Leader-Williams, E.J. Milner-Gulland & S.N. Stuart (2008). Quantification of extinction risk: IUCN's system for classifying threatened species. *Conservation Biology* 22(6): 1424–1442; https://doi.org/10.1111/j.1523-1739.2008.01044.x

Marshall, A.J., E. Meijaard, E.V. Cleave & D. Sheil (2016). Charisma counts: the presence of great apes affects the allocation of research effort in the paleotropics. *Frontiers in Ecology and the Environment* 14: 13–19; https://doi.org/10.1002/14-0195.1

McCarthy, J.L., H.T. Wibisonobo, K.P. McCarthy, T.K. Fuller & N. Andayani (2015). Assessing the distribution and habitat use of four felid species in Bukit Barisan Selatan National Park, Sumatra, Indonesia. *Global Ecology and Conservation* 3: 210–221; https://doi.org/10.1016/j.gecco.2014.11.009

Meredith, M. (2017). SECR with unpaired cameras. Available online at https://www.mikemeredith.net/blog/2017/SECR_unpaired_cameras.htm. Accessed 19 April 2018.

Mohamed, A., R. Sollmann, H. Bernard, L.N. Ambu, P. Lagan, S. Mannan, H. Hofer & A. Wilting (2013). Density and habitat use of the Leopard Cat (*Prionailurus bengalensis*) in three commercial forest reserves in Sabah, Malaysian Borneo. *Journal of Mammalogy* 94(1): 82–89; https://doi.org/10.1644/11-MAMM-A-394.1

Nowell, K. & P. Jackson (1996). Wild Cats: Status Survey and Conservation Action Plan. IUCN/SSC Cat Specialist Group, Gland, Switzerland and Cambridge, UK, 382pp.

O'Brien, T.G., M.F. Kinnaird & H.T. Wibisono (2003). Crouching tigers, hidden prey: Sumatran Tiger and prey populations in a tropical forest landscape. *Animal Conservation* 6(2): 131–139; https://doi.org/10.1017/S1367943003003172

Otis, D.L., K.P. Burnham, G.C. White & D.R. Anderson (1978). Statistical inference from capture data on closed animal populations. *Wildlife Monographs* 62: 1–135.

Palomares, F. & T.M. Caro (1999). Interspecific killing among mammalian carnivores. *The American Naturalist* 153: 492–508; https://doi.org/10.1086/303189

Pimsai, U., M.J. Pearch, C. Satasook, S. Bumrungsri & P.J.J. Bates (2014). Murine rodents (Rodentia: Murinae) of the Myanmar-Thai-Malaysian peninsula and Singapore: taxonomy, distribution, ecology, conservation status, and illustrated identification keys. *Bonn Zoological Bulletin* 63(1): 15–114.

R Development Core Team (2016). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Available online at https://www.R-project.org/.

Rabinowitz, A.R. (1990). Notes on the behavior and movements of the Leopard Cat, *Felis bengalensis*, in a dry tropical forest mosaic in Thailand. *Biotropica* 22: 397–403; https://doi.org/10.2307/2388557

Rajaratnam, R., M. Sunquist, L. Rajaratnam & L. Ambu (2007). Diet and habitat selection of the Leopard Cat (*Prionailurus bengalensis borneoensis*) in an agricultural landscape in Sabah, Malaysian Borneo. *Journal of Tropical Ecology* 23(2): 209–217; https://doi.org/10.1017/S0266467406003841

Regan, H.M., Y. Ben-Haim, B. Langford, W.G. Wilson, P. Lundberg,

S.J. Andelman & M.A. Burgman (2005). Robust decision-making under severe uncertainty for conservation management. *Ecological Applications* 15(4): 1471–1477; https://doi.org/10.1890/03-5419

Ross, J., A.J. Hearn, H. Bernard, K. Secoy & D. Macdonald (2010). *A Framework for a Wild Cat Action Plan for Sabah*. Global Canopy Programme, Oxford, 45pp.

Royle, J.A., R.B Chandler, R. Sollmann & B. Gardner (2013). *Spatial Capture-Recapture*. Academic Press, Cambridge, 612pp.

Scott, D.M., E. Gemita & T.M. Maddox (2004). Small cats in human modified landscapes in Sumatra. *Cat News* 40: 23–25.

Selvan, M., S. Lyngdoh, G.V. Gopi & B. Habib (2014). Density estimation of Leopard Cat *Prionailurus bengalensis* using capture recaptures sampling in lowland forest of Pakke Tiger Reserve, Arunachal Pradesh, India. *Mammalia* 78(4): 555–559; https://doi.org/10.1515/mammalia-2013-0084

Seto, K.C., B. Güneralp & L.R. Hutyra (2012). Global forecasts of urban expansion to 2030 and direct impacts on biodiversity and carbon pools. *Proceedings of the National Academy of Sciences* 109(40): 16083–16088; https://doi.org/10.1073/pnas.1211658109

Shehzad, W., T. Riaz, M.A. Nawaz, C. Miquel, C. Poillot, S.A. Shah & P. Taberlet (2012). Carnivore diet analysis based on next-generation sequencing: application to the Leopard Cat (*Prionailurus bengalensis*) in Pakistan. *Molecular Ecology* 21(8): 1951–1965; https://doi.org/10.1111/j.1365-294X.2011.05424.x

Srivathsa, A., R. Parameshwaran, S. Sharma & K.U. Karanth (2015). Estimating population sizes of Leopard Cats in the Western Ghats using camera surveys. *Journal of Mammalogy* 96(4): 742–750; https://doi.org/10.1093/jmammal/gyv079

TISTR (2018). Sakaerat Environmental Research Station. Available online at https://www.tistr.or.th/sakaerat/SakaeratE/index.php. Accessed 14 May 2018.

Wang, S.W. & D.W. Macdonald (2009). The use of camera traps for estimating tiger and leopard populations in the high altitude mountains of Bhutan. *Biological Conservation* 142(3): 606–613; https://doi.org/10.1016/j.biocon.2008.11.023

Wells, K., E.K.V. Kalko, M.B. Lakim & M. Pfeiffer (2007). Effects of rain forest logging on species richness and assemblage composition of small mammals in southeast Asia. *Journal of Biogeography* 34: 1087–1099; https://doi.org/10.1111/j.1365-2699.2006.01677.x

Willcox, D.H.A., Q.P. Tran, M.D. Hoang & T.T.A. Nguyen (2014). The decline of non-*Panthera* cat species in Vietnam. *Cat News Special Issue* 8: 53–61.

Wood, B.J. & C.G. Fee (2003). A critical review of the development of rat control in of rat control in Malaysian agriculture since 1960s. *Crop Protection* 22: 445–461; https://doi.org/10.1016/S0261-2194(02)00207-7

Yasuma, S. (1981). Feeding behaviour of the Iriomote Cat (*Prionailurus iriomotensis* Imaizumi, 1967). *Bulletin of the Tokyo University Forests* 70: 81–140.

Appendix A. Encounter rates (independent detections/100 trap nights) of four species of small carnivores, by forest type and period of resource availability, in Sakaerat Biosphere Reserve, Thailand, 2017. Images were classified as "independent detections" only if the time between images was greater than or equal to 30min (O'Brien et al. 2003).

	Dipterocarp	Evergreen	Reforested
Leopard Cat	0.1	0.7	0.6
Golden Jackal	2.5	0.8	15.9
Javan Mongoose	19.6	0.0	0.2
Small Indian Civet	3.2	0.2	0.4

Appendix B. Full model selection for Leopard Cat density using spatially-explicit capture-recapture. 'K' represents the number of estimated parameters. AIC_c, ΔAIC_c, and AIC_c weights 'w_i' provide a measure of relative support for each model.

Models	K	AIC_c	ΔAIC_c	w_i
D(.) g0(*b*) sigma(*habitat*)	5	961.17	0.00	0.43
D(*habitat*) g0(*b*) sigma(.)	5	962.69	1.52	0.20
D(.) g0(.) sigma(*habitat*)	4	963.66	2.49	0.12
D(.) g0(*habitat*) sigma(*habitat*)	5	964.69	3.52	0.07
D(*habitat*) g0(.) sigma(*habitat*)	5	965.94	4.77	0.04
D(*habitat*) g0(.) sigma(.)	4	966.12	4.94	0.04
D(.) g0(*habitat + bk*) sigma(.)	5	966.30	5.13	0.03
D(.) g0(*habitat + b*) sigma(.)	5	966.76	5.59	0.03
D(.) g0(*habitat*) sigma(.)	4	967.88	6.70	0.02
D(*habitat*) g0(*habitat*) sigma(.)	5	968.61	7.44	0.01
D(.) g0(*b*) sigma(.)	4	970.67	9.50	0.00
D(.) g0(*b*) sigma(*season*)	5	971.29	10.12	0.00
D(.) g0(bk) sigma(.)	4	972.55	11.38	0.00
D(.) g0(*b*) sigma(*rodent biomass*)	5	973.98	12.80	0.00
D(.) g0(.) sigma(.)	3	974.20	13.03	0.00
D(.) g0(.) sigma(*season*)	4	975.05	13.88	0.00
D(*season*) g0(.) sigma(.)	4	975.83	14.66	0.00
D(.) g0(*season*) sigma(*season*)	4	976.18	15.01	0.00
D(.) g0(*B*) sigma(.)	4	976.26	15.09	0.00
D(.) g0(.) sigma(*rodent biomass*)	4	976.31	15.14	0.00
D(.) g0(rodent biomass) sigma(.)	4	976.42	15.25	0.00
D(.) g0(*Bk*) sigma(.)	4	976.49	15.32	0.00

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An update on the status of Fishing Cat *Prionailurus viverrinus* Bennett, 1833 (Carnivora: Felidae) in Thailand

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Abstract: Fishing Cat *Prionailurus viverrinus* is threatened throughout its range by habitat loss, persecution, and non-targeted hunting; it is listed as Vulnerable on the IUCN Red List of Threatened Species. Even basic distribution data are still lacking in many parts of its range, particularly in southeastern Asia where most wildlife surveys focus on large charismatic carnivores in protected habitats, typically inland blocks of evergreen or semi-evergreen and deciduous forests. This report aims to update on distribution and status of Fishing Cat in Thailand. Historic (the 1980s) and current (2007–2017) records from Thailand were compiled based on personal communications, local news agencies, social media pages, and publications. The current Thai Fishing Cat distribution seems to be highly fragmented and mostly in coastal wetlands of the Inner Gulf of Thailand and the Thai-Malay Peninsula with one confirmed record from a riverine habitat in central Thailand. No confirmed records came from protected forested areas—perhaps these are marginal habitat for Fishing Cat. Nevertheless, there were no targeted surveys in those areas. Fishing Cat was so far not detected from on-going otters' targeted camera trap surveys along Thailand's Andaman coast. Future surveys should focus on coastal and inland wetlands to expedite the discovery of remaining populations before these are extirpated.

Keywords: Coastal wetland, human-dominated habitat, inland wetland, mangrove forest, persecution, riverine habitat, species distribution, threat assessment.

Abbreviations: DNP - Department of National Park, Wildlife, and Plant Conservation; SRY - Khao Sam Roi Yot National Park; TSL - Thung Salaeng Luang National Park.

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INTRODUCTION

Fishing Cat *Prionailurus viverrinus* has a wide distribution across southern and southeastern Asia. Most populations, however, appear to have declined significantly due to habitat loss, non-targeted hunting, and retaliatory killing associated with livestock depredation and/or damage to aquaculture (e.g., fish ponds; Mukherjee et al. 2016). Known strongholds are Sri Lanka, Bangladesh, West Bengal in India, and the Terai-Duar belt of the Himalayan foothills in India and Nepal (Mukherjee et al. 2016). In southeastern Asia, recent records dating to 2000–2016 are scarce, and the species occurrence is extremely patchy in Vietnam, Cambodia, Thailand, Myanmar, and Indonesia (Java and perhaps Sumatra) (Mukherjee et al. 2016 and references therein). Fishing Cat is listed as Vulnerable on the IUCN Red List of Threatened Species (Mukherjee et al. 2016).

Thailand may be one of the important strongholds for Fishing Cat and a regional priority range country for its conservation—it has few degraded habitats, at least those that are potentially suitable for Fishing Cat, e.g., in coastal mangroves, within large protected areas with a high protection level and law enforcement measures, and populations of ecologically similar species like otters. Nevertheless, between 1996 and 2011, there were only a few targeted surveys for Fishing Cat that yielded confirmed records and these were mainly in and around Khao Sam Roi Yot (SRY) and Thale Noi Non-hunting Area (Cutter & Cutter 2009; Tantipisanuh et al. 2014; Fig. 1). Results of radio telemetry research on 23 radio-collared Fishing Cats in an area of approximately 35km^2 suggested that SRY was a stronghold for the Fishing Cat in Thailand (Cutter & Cutter 2009; Cutter 2015; Patumrattanathan 2015). In the same area, however, negative interaction with people on livestock-raiding led to retribution killings of at least five out of 16 Fishing Cats monitored during this study (Cutter 2015).

In a review of the status of small cats in Thailand (Tantipisanuh et al. 2014), Fishing Cat rarely occurred in protected areas with no significant wetland habitats where most of camera trap surveys were conducted, although none of these surveys had specifically targeted Fishing Cat, except that of Cutter & Cutter (2009). Wetland habitats such as mangrove and peat swamp which were largely under-surveyed may still hold some remaining Fishing Cat populations and other threatened small carnivores and therefore require immediate attention for surveys (Chutipong et al. 2014). These wetlands were heavily used for aquaculture in the past several decades but in many parts are still little degraded, particularly along the west coast of southern Thailand. Given such a paucity of surveys in suitable habitats, Thailand might hold a large Fishing Cat population or, equally, the species might be close to extinction (Appel & Duckworth 2016). This very wide range of possibilities clearly indicates that there is an urgent need for a conservation status assessment in the country.

This article compiles evidence of Fishing Cat occurrence that was not included in the previous review by Tantipisanuh et al. (2014). Some records in this article date to before 2014, but these records are not exhaustive as attempts were not made to review all historic records, e.g., examining specimens in museums. This remains a priority because it has the possibility to indicate a longer-term change in range. Results from a camera trap survey in a coastal mangrove site where wetland-associated species such as otters, Lutrinae, were targeted are also summarized. This present article provides an update on Fishing Cat distribution in Thailand and therefore helps to identify areas for further surveys and conservation efforts in the country. It is also in line with one of the objectives of the Fishing Cat conservation strategy that aims to close information gaps on Fishing Cat distribution and status in range countries (Appel & Duckworth 2016).

METHODS

We compiled Fishing Cat evidence from various sources—personal communications, newspaper articles, social media pages, and publications. We attempted to verify each report by (1) circulating images among experts for confirmation of species identification when images were available, or (2) visiting and taking images and recording narration from owners of the stuffed mounted specimens, reports, and then circulating images for confirmation. Records date from the late 1980s to the late 2010s. Some records are from the same review period in Tantipisanuh et al. (2014) but were overlooked at the time and therefore not included in it.

RESULTS AND DISCUSSION

Records came from Muang District of Phitsanulok Province in north-central Thailand, Bangkhuntian District of Bangkok Province, Muang District of Samut Sakorn Province, Laem Phak Bia Subdistrict in Ban Laem District of Phetchaburi Province located in the Inner Gulf, and Singhanakorn District of Songkhla Province, Muang District and Mai Kaen District of Pattani Province in peninsular Thailand (Fig. 1). Ongoing surveys in mangrove habitats in Ranong, Phang-nga, and Krabi provinces along Thailand's western coast so far failed to detect any evidence of Fishing Cat.

A. Upper Central Thailand

A.1. Sa Khlo Village, Hua Raw Subdistrict, Muang District, Phitsanulok Province

On 24 December 2012, a local news agency reported a male Fishing Cat captured by a group of people at Sa Khlo Village (Anonymous 2012; Fig. 1). The report, however, did not elaborate details on the type of habitat and the animal's capture. It further documented that the cat was reported to a local politician who appeared to recognize the animal as a Fishing Cat. He then asked to keep the animal instead of releasing it to the wild, in fear of the cat being killed and eaten by locals. He convinced the locals that he would report to the authorities, the Department of National Park, Wildlife, and Plant Conservation (DNP), for permission to keep the animal in captivity. There was no further information to validate if the cat was a resident caught in the mentioned area and not an escaped pet. The set of images published with this newspaper article was circulated among six experienced field conservationists/ researchers, and all agreed that the animal was a Fishing Cat, based on its features: small ears in relation to head, short tail in relation to the body, and protruding claws of the front paws. Examination of the habitat (using Google Earth, 16 October 2017; Table 1) where the cat was claimed to be caught, included a small low-lying river, named Sa Khlo, which runs through paddy fields and has a 3–5 m wide scrubby strip dotted with clumps of bamboo situated along both sides. Small and scattered human settlements are situated on both sides of the river in this relatively flat area. Satellite image of the riverine habitat along the Sa Khlo River matches no other habitat where Fishing Cat populations were found in low-lying riverbeds but perhaps similar to those in Pakistan (see Roberts 1977 cited by Appel 2016).

A literature search (published in English) traced no records of Fishing Cat in the nearby Thung Salaeng Luang National Park (TSL; 1,262km^2), located about 20km farther east. TSL is part of the Phu Miang-Phu Thong Conservation Corridor (9,944km^2), which also includes Khao Kho National Park and Wang Pong-Chon Daen Non-hunting Area (Tordoff et al. 2012). According to the GIS database of the Land Development Department 2018 (LDD 2018), TSL consists mainly of evergreen forest (59%) with patches of limestone caves and associated subterranean streams in the Chao Phraya basin and Nan River sub-catchment, and 29% mixed deciduous forest. This habitat is unlikely to harbour Fishing Cats. Since there were no targeted surveys for Fishing Cat anywhere near or in the park, the absence of Fishing Cat there remains uncertain. The park, however, may be of low priority for a Fishing Cat targeted survey due to a lack of significant wetlands.

This inland record in Sa Khlo Village would be a really significant one if it is genuinely of a wild animal since it is almost 400km from the coast where most suitable habitats lie. It would also indicate that Fishing Cat once occurred far away from coastal wetlands. One inland record of 'Fishing Cat' is known from northwestern Thailand, in Tak Province (Duckworth et al. 2010) and another one, a camera trap record from Kulen Promtep Wildlife Sanctuary in northern Cambodia (Rainey & Kong 2010). In the Indian subcontinent, there are many more inland records, e.g., from Terai Arc landscape, Chitwan and Badia NPs, Nepal (Dahal & Dahal 2011; Yadav et al. 2018), India (e.g., Palei et al. 2018), and Sri Lanka (Thudugala 2016). Duckworth et al. (2010) did not, however, examine the specimen from northwestern Thailand, and thus they could not be sure whether the specimen was correctly identified and of certain origin (J.W. Duckworth in litt. 1 July 2017). Due to the intense use of inland wetlands in southeastern Asia, this type of habitat is now much reduced (Davidson 2014). As Fishing Cat is highly adaptable and can persist in degraded habitats (e.g., SRY: Cutter 2015; Pathumratanatarn 2015), all sizes and conditions of inland wetlands need to be identified and surveyed.

B. Inner Gulf of Thailand

B.1. Bangkhuntian District, Bangkok Province

On 10 July 2014, W. Chutipong and D. Ngoprasert interviewed a local school teacher, a former hunter, regarding the historic occurrence of Fishing Cat in Bangkhuntian, a suburb of Bangkok. The person said that he had stuffed 14 Fishing Cats, which were killed by either him or his sibling or sourced from locals in and around his community. He also mentioned that Fishing Cat was opportunistically hunted for meat or as retribution for killing livestock. We traced one stuffed mount stored at a local museum held by the Klong Pittayalongkorn School where he is currently working (Figs. 1; Image 1). This specimen, dated to the late 1980s, was obtained from a local villager who trapped the cat accidentally with a fish trap (Kriangsak Rukngam pers. comm. 10 July 2014).

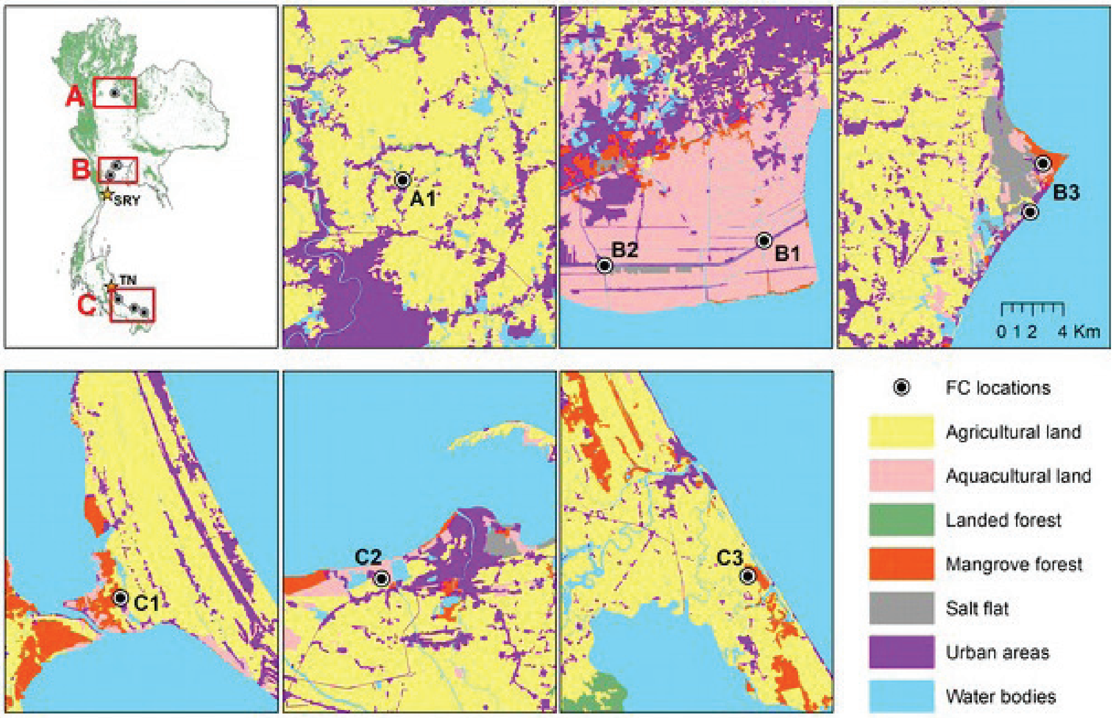

Figure 1. Locations of traced Fishing Cat records. Letters and numbers represent records described in the text and in Table 1. All coordinates are approximate locations based on available information from each record unless otherwise stated.

Table 1. Summary of Fishing Cat and Leopard Cat records in Thailand from the late 1980s to 2016. All coordinates are approximated locations based on available information unless otherwise stated.

Locality	Coordinates	Evidence	Source	Date of image taken	Remarks
A. Upper Central Thailand					
A.1. Sa Khlo, Muang, Phitsanulok	16.883^{0}N, 100.283^{0}E	Images	Local news (Anonymous 2012)	[not indicated]	
B. Inner Gulf of Thailand					
B.1. Bangkhuntian, Bangkok	13.517^{0}N, 100.417^{0}E	Image of stuffed mount specimen	Interviewed the hunter	10 July 2014	The animal was stuffed in the early 1980s and kept at Pittayalongkorn Pittayakhom School; Image 1.
B.2. Phantai Norasing, Khok Kham, Samut Sakorn	13.500^{0}N, 100.317^{0}E	Image of stuffed mount specimen	Wanlop Chutipong, Dusit Ngoprasert	10 July 2014	A road-kill female Fishing Cat found on a road near a school on 14 December 2013 at 5.30h; Image 2.
B.2. Phantai Norasing, Khok Kham, Samut Sakorn	13.483^{0}N, 100.317^{0}E	Image of a cat in a breeding centre	Kitipat Phosri	28 May 2016	It is uncertain whether the photographed cat is from SRY/ Phantai, but it is certain that some Fishing Cats were trapped in Phantai and taken to the breeding centre; Image 3.
B.3. Laem Pak Bia, Ban Laem, Phetchaburi	13.017^{0}N, 100.067^{0}E	Skull	Jonathan Murray (deceased)	2010	Coordinates were taken at the restaurant where the skull of a Leopard Cat was retrieved; Image 4.
B.3. Laem Pak Bia, Ban Laem, Phetchaburi	13.033^{0}N, 100.083^{0}E	Image of a dead animal posted online	Internet search for Fishing Cat	March 2011	Image 5; the URL is no longer available.
C. Peninsular Thailand					
C.1. Singhanakorn, Songkhla	07.250^{0}N, 100.467^{0}E (Pa Khat), 07.250^{0}N, 100.433^{0}E (Pak Ro)	Report with images and VDO link.	Suppakorn Patumrattanathan	2013–2015	https://www.youtube.com/watch?v=aBj7_R-GuxA (YouTube video) The VDO shows the release of a female Fishing Cat as part of the study mentioned in the report (Ramsuti 2014).
C.2. Bangplamor, Pattani	06.850^{0}N, 101.200^{0}E	Image of live-captured animal	Wanchamai Karnthanut	2007	Reported in Buatip et al. 2013; Image 6.
C.3. Mai Kaen, Pattani	06.633^{0}N, 101.667^{0}E	Image of caged animal	Niti Sukumal	2014	The wild-caught Fishing Cat from Mai Kaen District, Pattani Province, was kept as a pet; Image 7.

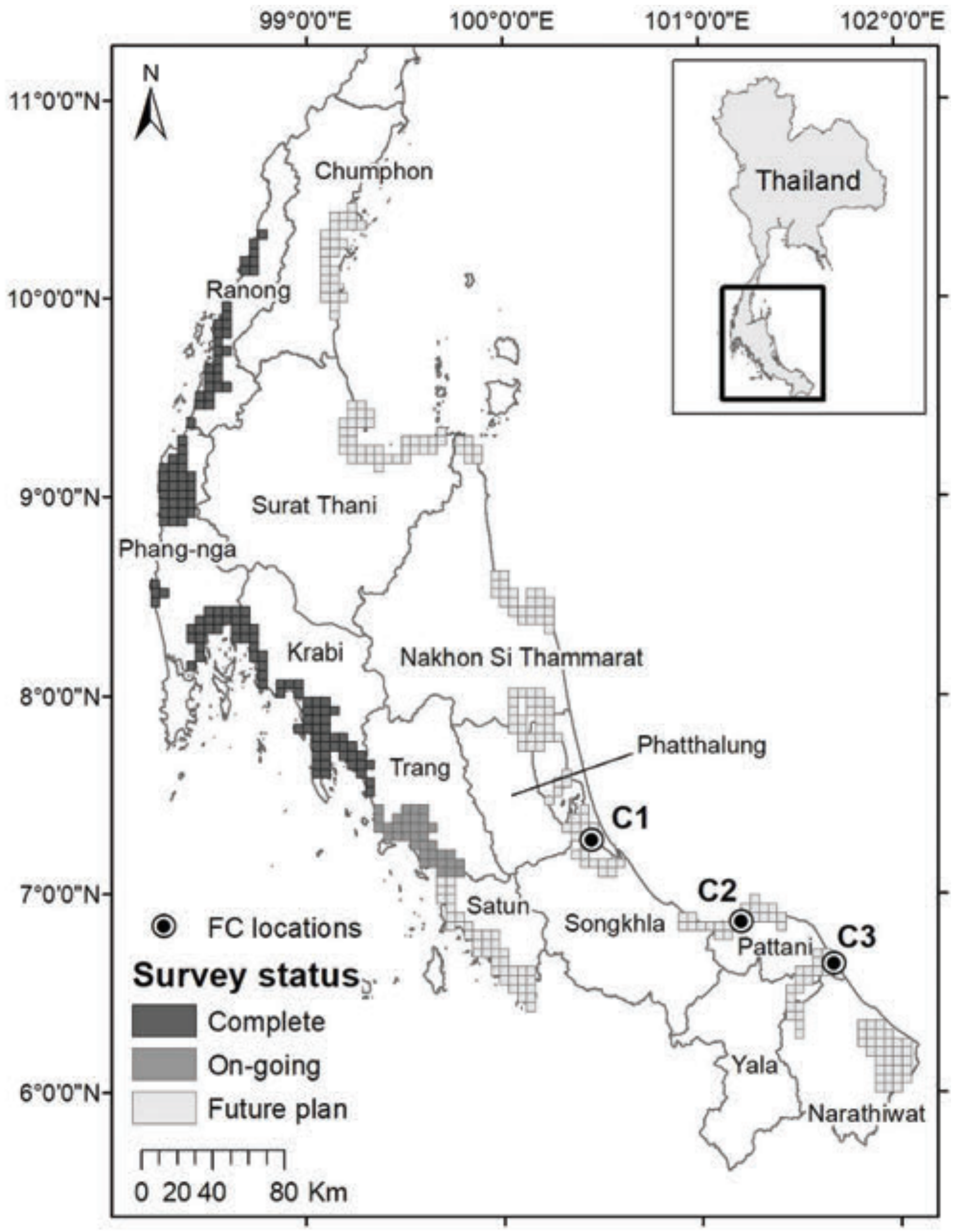

Figure 2. Survey grids used for completed, on-going, and planned otter occupancy surveys in southern Thailand. Approximated locations of records (C.1.–C.3.), as reported in the main text, are shown.

B.2. Phantai Norasing, Khok Kham Subdistrict, Muang District, Samut Sakorn Province

In December 2013, during an occupancy survey for Smooth-coated Otter *Lutrogale perspicillata* and Asian Small-clawed Otter *Aonyx cinereus* in the Inner Gulf of Thailand, A. Kamjing heard of a road-killed Fishing Cat at Phantai Norasing from local landowners when he surveyed their ponds for otter signs. In July 2014, W. Chutipong and D. Ngoprasert examined a stuffed mount of a female road-killed Fishing Cat reported by A. Kamjing (Figs. 1; Image 2) at the Marine and Coastal Resource Conservation Center located close to where the animal was found. The road-killed cat was found dead on a road close to a patch of mangrove forest next to a school by W. Chantong who then reported it to the mangrove conservation centre nearby. The reporter was convinced that the cat was of wild origin since no Fishing Cat was kept as a pet in the area that he was aware of.

In 2012, S. Patumrattanathan, a researcher from DNP, live-trapped four adult Fishing Cats, comprising one male

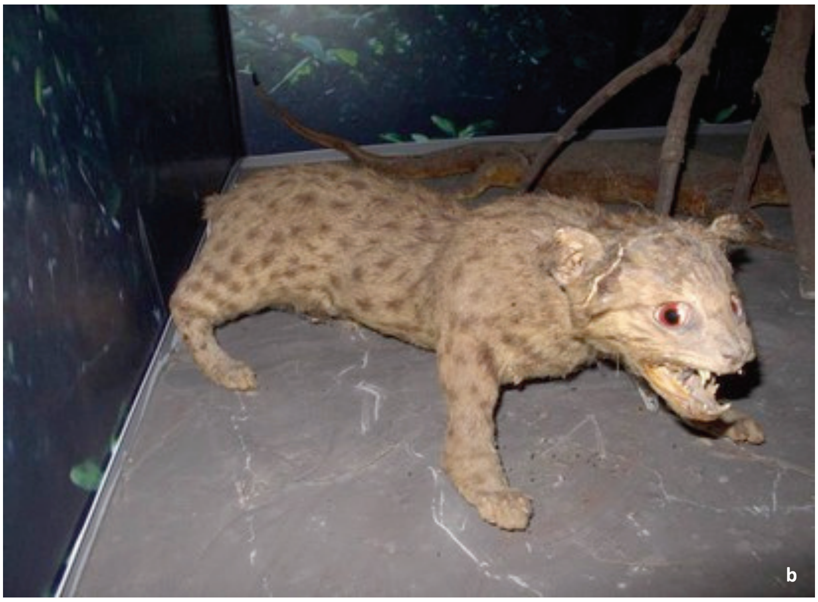

Image 1. A stuffed mount specimen of a Fishing Cat dated back to the 1980s from Bangkhuntian District, Bangkok: a - top view; b - lateral view. © W. Chutipong, 10 July 2014.

and three females close to Phantai Norasing, Khok Kham Subdistrict, Muang District, Samut Sakorn Province. This trapping was part of a three-year project with the aim to increase the genetic diversity of Fishing Cat in Thailand by breeding Fishing Cats from SRY and Phantai Norasing and then releasing the captive-bred individuals at Bueng Boraphet, a wetland of international importance in Nakhon Sawan Province (Suppakorn Patumrattanathan pers. comm. 13 August 2018). All four trapped Fishing Cats from Phantai and the unknown number from SRY were relocated to Khao Prathab Chang Wildlife Breeding Center in Pak Chong Subdistrict, Chom Bueng District, Ratchaburi Province, and gave birth to two kittens. The project, however, was suspended in 2013 before the cats were released. Now only 1–2 pairs of these Fishing Cats remain at the breeding centre. Kitipat Phosri visited the centre in early 2018 and saw the animals (Image 3). No precise information was available about which individuals were caught in SRY and Phantai Norasing. Since S. Patumrattanathan studied Fishing Cats in SRY and Singhanakorn District, Songkhla Province (see C1 in Fig. 1) using radio telemetry and in captivity for 6–7 years (Patumrattanathan 2015; Pathumratanathan et al. 2015), we are confident that he indeed captured Fishing Cats in this area.

B.3. Laem Phak Bia Subdistrict, Ban Laem District, Phetchaburi Province

Two records came from Laem Phak Bia in Ban Laem District of Phetchaburi Province, located in south-central Thailand. The first record was reported by the late Jonathan Murray who obtained at least one skull of a Fishing Cat (Figs. 1; Image 4, but see discussion below) from a restaurant close to Laem Phak Bia in 2010. He questioned the owner to confirm the origin of the skull. The cause of death of this specimen was not reported. Based on DNA analysis of its nasal bone fragments, however, we confirmed that the skull was of a Leopard Cat *Prionailurus bengalensis.* The analysis was done using multilocus DNA barcoding (the combined sequences of partial mtDNA Cytochrome b, 16S, ND5 gene, Control Region, and four Y-chromosome introns including SMCY3, SMCY7, DBY7, and UTY11; Luo et al. 2014), coupled with reference databases of genetic diversity of Fishing Cat and Leopard Cat in Thailand (Klinsawat et al. unpublished data) and other range countries (Luo et al. 2014; Patel et al. 2017). With this example, we strongly recommend that when recovering animal parts without accompanying images of the entire body, one should conduct DNA analysis to verify species identification.

Another record from this area appeared in March 2011. An image of a dead Fishing Cat was posted on the internet (Image 5) by a person who observed the carcass, apparently shot by a worker from a nearby construction site. The cat was shot by a modified slingshot used for fishing. The reporter, however, mistook the animal as a Black Leopard *Panthera pardus*. A description of the post (in Thai) indicated that the cat was shot when the poacher was searching for wild game for a special feast. It was also mentioned that wild game hunting was a common practice among the group of people

Image 2. A stuffed mount specimen of a road-killed female Fishing Cat from Samut Sakorn Province. © W. Chutipong, 10 July 2014.

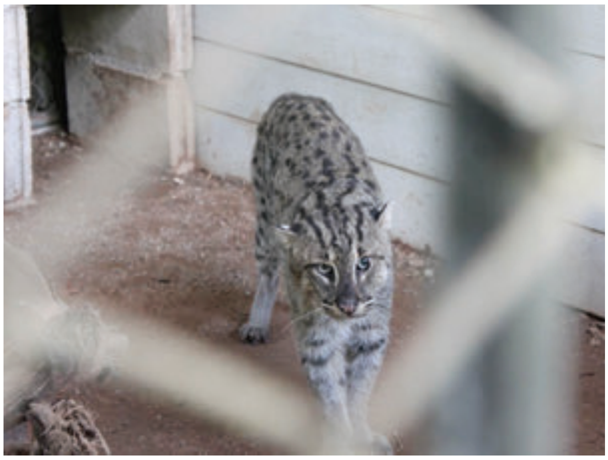

Image 3. A wild-caught Fishing Cat, presumably from either Sam Roi Yot National Park or Phantai, Khok Kham, kept at Khao Prathab Chang Wildlife Breeding Center. © K. Phosri, 28 May 2016.

mentioned in the post. This latter evidence suggested the continued presence of the Fishing Cat in Laem Phak Bia area (at least up to March 2011). On the other hand, threats such as illegal opportunistic hunting were also documented.

C. Peninsular Thailand

C.1. Pa Khat and Pak Ro subdistricts, Singhanakhon District, Songkhla Province

Pathumratanathan et al. (2015) conducted an ecologic study of Fishing Cat in three subdistricts of Singhanakhon District, Songkhla Province, covering an area of approximately 42km^2, between 2013 and 2015 (Fig. 1). Ten Fishing Cats were captured, comprising seven males and three females, in the two subdistricts Pa Khat and Pak Ro. Five males and one female were fitted with VHF radio transmitters. Habitats in these subdistricts consist mainly of paddy fields (52%), degraded peat swamp and mangrove (24%), agriculture areas including shrimp farms (10%) and oil palm plantations (8%), and settlements (6%) (Pathumratanathan et al. 2015). The authors mentioned active hunting of Fishing Cat for meat and persecution due to perceived loss of aquaculture stock such as fish and shrimps, and highly valued fighting roosters that are specially selected and raised for cockfight or gamecocks. The authors, however, do not quantify the intensity of such killings and hunting pressures.

C.2. Bangplamor Village, Rusamilae Subdistrict, Muang District, Pattani Province

In late 2013, evidence of Fishing Cat was uncovered in Pattani Province (Fig. 1), where Buatip et al. (2013) conducted research on predation of Little Egret *Egretta garzetta* nests and mentioned Fishing Cat as a possible nest predator. A follow-up revealed a confirmed record of Fishing Cat occurrence in the area (Image 6). "[In 2007] this cat was trapped in a patchy mangrove around the village named Bangplamor of Muang District, Pattani Province. It is about 15 minutes' drive and close to the [Prince Songkhla] University's [Pattani] campus where the locals earn their living on small scale fishery," said W. Karntanut, one of the article's author. W. Karntanut also reported that two cats were trapped at the same time but one died shortly after. The remaining cat was released after being photographed since it did not take any of the provided food. Further correspondence revealed that Fishing Cats thrived, at least at the time of the report in late 2013, in coastal mangrove habitat close to the campus and local communities. There were also reports of persecution due to loss of livestock. Sometimes, however, "trouble-making" Fishing Cats were trapped and kept as pets instead of being persecuted (Wanchamai Karntanut in litt. 1 October 2013). This record appears to be the southernmost confirmed record in mainland southeastern Asia (Angie Appel in litt. 22 December 2013).

C.3. Mai Kaen Village, Mai Kaen Subdistrict, Mai Kaen District, Pattani Province

Another report of Fishing Cat from Pattani Province came from Mai Kaen District in 2014 (Fig. 1). This cat (Image 7) was caught in mangrove forest close to Saiburi River, but no precise date and location were reported. The person who caught the cat lived there for more than 60 years. He and N. Sukumal, who was born in this area, reported that Fishing Cat was not commonly encountered in the past 20 years, but it was present in

Image 4. A skull of Leopard Cat retrieved from a restaurant near Laem Phak Bia by the late Jonathan Murray in 2010: a - top view; b - lateral view; c - front view. © A.J. Pierce, 2018.

Image 5. A poached Fishing Cat from Laem Phak Bia area. Image posted on the internet in March 2011 by a worker from a nearby construction site.

Image 6. A wild-caught Fishing Cat in captivity in Pattani Province. © W. Karntanut, 5 May 2007.

the area of mangrove forest along Saiburi River and the canals that connect to the main Saiburi River. In the past two decades, Fishing Cats opportunistically entered the areas in this district to prey on poultry (Niti Sukumal personal observation). Some cats were caught and kept as pets, and some were killed (Niti Sukumal personal observation). Fishing Cat is rare in the area at present, although villagers reported in 2016 that two kittens were found in the forested area dominated by *Melaleuca cajuputi*. This report, however, should be treated with caution as species identification could not be validated; the animals were already sold by the time we visited the area in 2016.

C.4. Southwestern coast, Ranong, Phang-nga, and Krabi provinces

Camera trap surveys targeting Smooth-coated Otter and Small-clawed Otter in coastal mangroves in southwestern Thailand have been running since August 2016 (Fig. 2; Tantipisanuh et al. 2018). Grid cells of 5km×5km for camera trapping were initially selected on a basis of a minimum area of mangrove (10%) where Asian Small-clawed Otters were found during a preliminary survey. In each grid cell, we set 3–6 camera trap stations at locations where we found evidence of otter presence like spraints and footprints. Some cameras were also deployed in sites without evidence of otters but which exhibit similar characteristics as habitat used by otters, e.g., the presence of mounds that are well above the highest tide. To avoid inundation, cameras were set 1–3 m above ground but still aimed at the focal areas on the ground, which was large enough to capture large otter groups (Image 8). Cameras were kept at locations for approximately 20 days. Fish oil was used as a lure to attract the focal species to the focal area of cameras, i.e., approximately 3m in front of the camera traps. Fish oil lure appears to attract Fishing Cats to camera traps as observed in a concurrent survey of Fishing Cat in SRY (Kitipat Phosri & Dusit Ngoprasert personal observations).

Eighteen months of surveys in Ranong, Phang-nga, and Krabi provinces covered an area of approximately 2,825km^2 and totalled 11,563 camera trap days across

Image 7. A wild-caught Fishing Cat in captivity in Mai Kaen District, Pattani Province. © N. Sukumal, 2014.

Fishing Cats were recorded in coastal mangroves in other range countries, e.g., the deltaic mangrove forest of Coringa WS in Andhra Pradesh (Mukherjee et al. 2012) and Odisha, both in eastern India (Palei et al. 2018), mangrove forests of southern Cambodia (Thaung et al. 2017), and Ayeyarwady Delta of Myanmar (Naing Lin & Than Zaw, WCS Myanmar Program, in litt. 11 May 2018). Fishing Cat, however, was not detected during surveys conducted along coastal Kerala in southwestern India (Janardhanan et al. 2014). Currently, it is unclear whether Fishing Cat occurs in this part of Thailand and was simply missed in the current surveys or whether it is not present there at all. Despite the non-detection, the entire southwestern coastal wetlands are still priority sites, as they provide potentially suitable habitat, and need targeted surveys for Fishing Cat.

558 camera trap stations. Smooth-coated Otter and Asian Small-clawed Otter were detected in 165 of 558 camera trap stations (30%) and in 71 stations (13%), respectively. Meanwhile, Leopard Cat (0.7%), Large-spotted Civet *Viverra megaspila* (0.2%), Greater Hog Badger *Arctonyx collaris* (0.2%), Small Asian Mongoose *Herpestes javanicus* (0.3%), and Common Palm Civet *Paradoxurus hermaphroditus* (27%) were also recorded, but not a single Fishing Cat (Tantipisanuh et al. unpublished data). Assuming that other small carnivore species that are present were readily detected during the surveys, Fishing Cat either occurs at a very low abundance or does not occur at all in the surveyed area. It is possible that Fishing Cat has very specific habitat requirements, which our otter targeted survey failed to cover.

MANAGEMENT IMPLICATIONS AND CONCLUSIONS

These new localities show that Fishing Cat is more widely distributed along Thailand's coastal wetlands than previously reported—eight records traced were from outside protected areas. The single confirmed record (accepting that the cat's origin is not known) traced from inland and its surrounding habitat, appears to match known inland records from elsewhere in Fishing Cat range. Combined with the previous confirmed records in Tantipisanuh et al. (2014), this evidence strongly suggests that Fishing Cat populations largely occur outside Thailand's protected area system. These results highlight the need to conduct targeted surveys for Fishing Cat in both coastal zones and inland areas with suitable habitat outside protected areas in human-

Image 8. Camera trap images of family groups from Phang-nga Province in 2017: a - Smooth-coated Otter from Kuraburi; b - Asian Small-clawed Otter from Takuapa. © Tantipisanuh et al. 2018.

dominated landscapes, to provide reliable information on the national conservation status and distribution of the species. Due to the difficulty in distinguishing between Fishing Cat and the co-occurring Leopard Cat, particularly in the case of juveniles, species identification should be validated either with photographic evidence and/or DNA analysis of fecal and hair samples or other biologic samples that can yield enough DNA material using the combined mtDNA, Y-linked, and autosomal variants for species identification and detection of hybridization signals. A compilation and identification validation of all purported historic records of Fishing Cat from Thailand, notably including museum specimens, is very important for the cues this might give as to where Fishing Cat occurred and thus suggest sites to look for today. Large-scale habitat protection for Fishing Cat may not be possible in Thailand's fragmented and degraded wetlands; many of these are dominated by people, used as agricultural land and for aquaculture. The next steps in conservation planning for this species are to confirm if the remaining populations are viable and then identify potential source sites, alongside potential threatening factors, and dispersal corridors. Establishment of corridors will help to ensure that the populations remain genetically connected. Restoration, or at least some maintenance of natural habitat, will help to achieve this, as was suggested for Smooth-coated Otter in the Inner Gulf of Thailand (Kamjing et al. 2017), a species which faces similar threats and occupies similar habitats as Fishing Cat. Mitigation and resolutions of human-Fishing Cat negative interactions in areas of high conservation importance, combined with community awareness-raising to understand perceptions, and establishment and promotion of positive attitudes amongst local people and stakeholders towards Fishing Cat persistence, will be crucial in these human-dominated landscapes.

REFERENCES

Anonymous (2012). [Stunned! Big Fishing Cat poked in Phitsanulok's Village. Local people worked together to catch it]. In: *MGR Online* 24 December 2012. Available online at https://mgronline.com/local/detail/9550000155925. Accessed 11 September 2018.

Appel, A. (2016). Fishing Cat and otters in Pakistan, pp61–63. In: Appel, A. & J.W. Duckworth (eds.). Proceedings of the First International Fishing Cat Conservation Symposium, 25–29 November 2015, Nepal. Fishing Cat Working Group, Bad Marienberg, Germany & Saltford, Bristol, United Kingdom, 73pp.

Appel, A. & J.W. Duckworth (eds.) (2016). Proceedings of the First International Fishing Cat Conservation Symposium, 25–29 November 2015, Nepal. Fishing Cat Working Group, Bad Marienberg, Germany & Saltford, Bristol, United Kingdom, 73pp.

Buatip, S., W. Karntanut & C. Swennen (2013). Nesting period and breeding success of the Little Egret *Egretta garzetta* in Pattani province, Thailand. *Forktail* 29: 120–123.

Chutipong, W., N. Tantipisanuh, D. Ngoprasert, A.J. Lynam, R. Steinmetz, K.E. Jenks, L.I. Grassman Jr., M. Tewes, S. Kitamura, M.C. Baker, W. McShea, N. Bhumpakphan, R. Sukmasuang, G.A. Gale, F.K. Harich, A.C. Treydte, P. Cutter, P.B. Cutter, S. Suwanrat, K. Siripattaranukul, Hala-Bala Wildlife Research Station, Wildlife Research Division & J.W. Duckworth (2014). Current distribution and conservation status of small carnivores in Thailand: a baseline review. *Small Carnivore Conservation* 51: 96–136.

Cutter, P. & P. Cutter (2009). Recent sightings of Fishing Cats in Thailand. *Cat News* 51: 12–13.

Cutter, P. (2015). Fishing Cat ecology: food habits, home ranges, habitat use and mortality in a human dominated landscape around Khao Sam Roi Yot area, peninsular Thailand. MSc Thesis. Department of Fisheries, Wildlife and Conservation Biology, University of Minnesota, ix+56pp.

Davidson, N.C. (2014). How much wetland has the world lost? Long-term and recent trends in global wetland area. *Marine and Freshwater Research* 65(10): 934–941; https://doi.org/10.1071/MF14173

Dahal, S.A. & D.R. Dahal (2011). Trapping of Fishing Cat in Chitwan National Park, Nepal. *Cat News* 55: 10–11.

Duckworth, J.W., T. Stones, R. Tizard, S. Watson & J. Wolstencroft (2010). Does the Fishing Cat inhabit Laos? *Cat News* 52: 4–7.

Janardhanan, R., S. Mukherjee, P.V. Karunakaran & R. Athreya (2014). On the occurrence of the fishing cat *Prionailurus viverrinus* Bennet, 1833 (Carnivora: Felidae) in coastal Kerala, India. *Journal of Threatened Taxa* 6(3): 5569–5573; https://doi.org/10.11609/JoTT.o3780.5569-7

Kamjing, A., D. Ngoprasert, R. Steinmetz, W. Chutipong, T. Savini & G.A. Gale (2017). Determinants of Smooth-coated Otter occupancy in a rapidly urbanizing coastal landscape in southeast Asia. *Mammalian Biology* 87: 168–175.

LDD (2018). GIS database http://www.ldd.go.th Electronic version accessed 11 September 2018.

Luo, S.J., Y. Zhang, W.E. Johnson, L. Miao, P. Martelli, A. Antunes, J.L. Smith & S.J. O'Brien (2014). Sympatric Asian felid phylogeography reveals a major Indochinese–Sundaic divergence. *Molecular Ecology* 23(8): 2072–2092.

Mukherjee, S. (2016). Phylogeography of the Fishing Cat in India, pp15–18. In: Appel, A. & J.W. Duckworth (eds.). Proceedings of the First International Fishing Cat Conservation Symposium, 25–29 November 2015, Nepal. Fishing Cat Working Group, Bad Marienberg, Germany & Saltford, Bristol, United Kingdom, 73pp.

Mukherjee, S., T. Adhya, P. Thatte & U. Ramakrishnan (2012). Survey of the Fishing Cat *Prionailurus viverrinus* Bennett, 1833 (Carnivora: Felidae) and some aspects impacting its conservation in India. *Journal of Threatened Taxa* 4(14): 3355–3361; https://doi.org/10.11609/JoTT.o3199.3355-61

Mukherjee, S., A. Appel, J.W. Duckworth, J. Sanderson, S. Dahal, D.H.A. Willcox, V. Herranz Muñoz, G. Malla, A. Ratnayaka, M. Kantimahanti, A. Thudugala, R. Thaung & H. Rahman (2016). *Prionailurus viverrinus*. The IUCN Red List of Threatened Species 2016: e.T18150A50662615. Downloaded on 11 September 2018. https://doi.org/10.2305/IUCN.UK.2016-2.RLTS.T18150A50662615.en

Palei, H.S., U.P. Das & S. Debata (2018). The vulnerable Fishing Cat *Prionailurus viverrinus* in Odisha, eastern India: status and conservation implications. *Zoology and Ecology* 28(2): 69–74; https://doi.org/10.1080/21658005.2018.1468646

Patel, R.P., S. Wutke, D. Lenz, S. Mukherjee, U. Ramakrishnan, G. Veron, J. Fickel, A. Wilting & D.W. Förster (2017). Genetic structure and phylogeography of the Leopard Cat (*Prionailurus bengalensis*) inferred from mitochondrial genomes. *Journal of Heredity* 108(4): 349–360; https://doi.org/10.1093/jhered/esx017

Patumrattanathan, S. (2015). Ecology of Fishing Cat (*Prionailurus viverrinus*) by Community Participation on Its Conservation in Kui Buri District, Prachuap Khiri Khan Province, Thailand [in Thai with English abstract]. PhD Thesis. Sustainable Land Use and Natural Resource Management Special Program, Graduate School of

Kasetsart University, xii+162pp.

Pathumratanathan, S., S. Yimprasert, P. Suwanna, C. Malavanno, A. Neunpang & C. Chaurngtem (2015). Ecology population and distribution of Fishing Cat (*Prionailurus viverrinus*) in natural habitat at Songkhla province, Thailand. Research Report and Wildlife Database, Research Conservation and Animal Health, Songkhla Zoo, Songkhla Province, 129pp.

Rainey, H.J. & K. Kong (2010). A Fishing Cat observation from northern Cambodia. *Cat News* 52: 8–9.

Ramsuti, S. (2014). 10 June [2014] released Fishing Cat. https://www.youtube.com/watch?v=aBj7_R-GuxA Electronic version accessed 11 September 2018.

Tantipisanuh, N., W. Chutipong, D. Ngoprasert, A.J. Lynam, R. Steinmetz, R. Sukmasuang, K.E. Jenks, L.I. Grassman Jr., P. Cutter, S. Kitamura, M.C. Baker, W. McShea, N. Bhumpakphan, G.A. Gale & D.H. Reed (2014). Recent distribution records, threats and conservation priorities of small cats in Thailand. *Cat News Special Issue* 8: 36–44.

Tantipisanuh, N., D. Ngoprasert, W. Chutipong & A. Kamjing (2018). Assessing distribution status of otter species in wetlands and coastal mangrove habitats in west coast of southern Thailand. ASAHI Glass Foundation, Bangkok, Thailand, 11pp.

Thudugala, A. (2016). Fishing Cat conservation in hill country, Sri Lanka, pp29–31. In: Appel, A. & J.W. Duckworth (eds.). Proceedings of the First International Fishing Cat Conservation Symposium, 25–29 November 2015, Nepal. Fishing Cat Working Group, Bad Marienberg, Germany & Saltford, Bristol, United Kingdom, 73pp.

Thaung, R., V.H. Munoz, J. Holden, D. Willcox & N.J. Souter (2017). The Vulnerable Fishing Cat *Prionailurus viverrinus* and other globally threatened species in Cambodia's coastal mangroves. *Oryx* 52(4): 636–640; https://doi.org/10.1017/S0030605317001491

Tordoff, A.W., M.R. Bezuijen, J.W. Duckworth, J.R. Fellowes, K. Koenig, E.H.B. Pollard & A.G. Royo (2012). Ecosystem Profile Indo-Burma Biodiversity Hotspot, 2011 Update. Critical Ecosystem Partnership Fund, Conservation International, Arlington, xxi+360pp.

Yadav, S.K., B.R. Lamichhane, N. Subedi, M. Dhakal, R.K. Thapa, L. Poudyal & B.R. Dahal (2018). Fishing Cat camera trapped in Babai Valley of Bardia National Park, Nepal. *Cat News* 67: 31–33.

Threatened Taxa

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Author contribution: All authors contributed equally to the conception, design, data collection, writing, and revising the manuscript.

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PLATINUM
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The Caracal *Caracal caracal* Schreber, 1776 (Mammalia: Carnivora: Felidae) in Uzbekistan

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Abstract: This article provides information about 27 records of the Caracal *Caracal caracal* in Uzbekistan, particularly in the Kyzylkum Desert and the Ustyurt Plateau. The data collected between 2011 and 2017 were based on information from literary sources, field research, and interviews with local people. At least 11 individuals of the species were killed intentionally and one was run over by a car. Basic threats to the species in Uzbekistan are negative interactions between herders and Caracal, lack of knowledge about its protected status among local people, and lack of conservation measures. The preconditions for the protection of Caracal are the existence of remote unpopulated areas close to state borders between adjacent countries and socio-economic factors that prompt people to move from rural to urban areas. Caracal habitats are protected in Kyzylkum State Reserve, Saigachiy Landscape Sanctuary, and six wildlife sanctuaries. To conserve Caracal, it is necessary to strengthen the network of protected areas in deserts and raise the awareness of local communities and decision-makers in the national government. It is important to continue research on Caracal and develop a government-approved action plan for its conservation.

Keywords: Central Asia, interview survey, Kyzylkum Desert, negative interaction, threat assessment, threatened felid, Ustyurt Plateau.

Russian Abstract: В публикации представлена информация о 27 встречах каракала Caracal caracal в пустыне Кызылкум и на плато Устюрт (Республика Узбекистан). Приведены сведения за период с 2011 по 2017 гг., которые основаны на имеющихся литературных данных, собранном во время экспедиционных выездов материале и сообщениях местного населения. По крайней мере 11 особей каракала были преднамеренно убиты и еще одно животное было сбито машиной. Основными угрозами в Узбекистане представляются существующий конфликт между скотоводами и каракалами, отсутствие знаний об охранном статусе вида среди местного населения и отсутствие должных мер по его охране. Предпосылками для сохранения каракала являются наличие удаленных незаселенных территорий вблизи государственных границ между соседними странами и социально-экономические факторы, которые побуждают людей переезжать из сельской местности в города. Места обитания каракала охраняются в Кызылкумском государственном заповеднике, ландшафтном заказнике «Сайгачий» и еще в шести природных заказниках. Для сохранения каракала необходимо укрепить сеть пустынных охраняемых природных территорий и повысить осведомленность местного населения и лиц, принимающих решения на правительственном уровне. Представляется важным продолжить исследования по каракалу и в дальнейшем разработать одобренный правительством план действий по его сохранению.

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INTRODUCTION

The Caracal *Caracal caracal* is one of the rarest vertebrates in central Asia, where it occurs in Uzbekistan, Kazakhstan, Turkmenistan, northern Iran, and Afghanistan (Heptner & Sludskii 1972). Its range also covers arid regions in Africa, the Arabian Peninsula, the Middle East, Pakistan, and India (Avgan et al. 2016).

The Turkmen Caracal is included as Critically Endangered in the Red Data Books of Uzbekistan (Abdunazarov 2009) and Kazakhstan (Bekenov & Kasabekov 2010) and as Endangered in the Red Data Book of Turkmenistan (Hodzhamuradov & Imamov 2011). The species is included in Appendix I of the CITES (Avgan et al. 2016).

In the 20th Century, the Caracal was recorded on Uzbekistan's Ustyurt Plateau, in Lower Amudarya area, northwestern and southwestern parts of Kyzylkum Desert, and the plains adjoining Surkhan and Zeravshan rivers (Heptner & Sludskii 1972; Mitropolsky 1979; Lesnyak et al. 1984; Bogdanov 1992; Abdunazarov 2009). It inhabits bumpy, well-fixed sands along the Ustyurt Plateau escarpments and on gypsum and stony plains (Sapojnikov 1962; Heptner & Sludskii 1972). Its diet consists primarily of Tolai Hare *Lepus tolai*, Gerbils Gerbellidae, Jerboas Dipodidae, birds, reptiles, and insects. Sometimes it hunts Goitered Gazelle *Gazella subgutturosa*, Red Fox *Vulpes vulpes*, and lambs of Domestic Sheep *Ovis aries* (Sapojnikov 1960, 1962).

Only fragmentary data are available on its current distribution and population size in Uzbekistan. Studies on Caracal were not conducted since the 1980s. Most of the information on recent encounters with Caracal was published in Russian (Lim 2009; Lim & Klichev 2009; Gritsina 2012; Marmazinskaya et al. 2012; Bykova et al. 2015; Gritsina et al. 2016; Marmazinskaya & Mardonova 2016). Thus, this information is poorly available for the international audience and is expedient to provide in this article. This article summarizes all the data on Caracal currently available in Uzbekistan and specifies the existing threats, their causes, and conservation measures that need to be taken.

Study area

Ustyurt Plateau lies between the Mangyshlak Peninsula, Kara-Bogaz-Gol Depression, Aral Sea, and Amudarya Delta. The plateau is an important transboundary region shared by Uzbekistan, Kazakhstan, and Turkmenistan. The Kyzylkum Desert covers the landscape between the Amudarya and Syrdarya rivers, which is bordered by the Aral Sea in the north and the Tien Shan and Pamir-Alai ranges in the southeast. Most of the desert lies in Uzbekistan and Kazakhstan, with a few small portions in Turkmenistan (Fig. 1). The basic landscape of the Ustyurt Plateau is clay desert covered with Wormwood *Artemisia* or mixed Wormwood and Glasswort *Salicornia* communities, with occasional sand areas. The plateau is edged by 'chinks', a regional name for escarpments, which are up to 200m high in some places. Most of the plateau is covered with vegetation, varying from Wormwood and Glasswort in the northern desert subzone to ephemeral plants and Wormwood in the southern desert subzone. The summer is hot and long, lasting from May to September. Average daily temperature in July is 26–28 °C, reaching up to 40–60 °C in some years. In winter it drops to -26°C and even to -41°C.

The Kyzylkum Desert largely consists of fixed and semi-fixed dunes, with occasional patches of unvegetated sand. It includes extensive areas of clay, gypsum, takyr, and saline soils and low sky islands. The plant species prevailing on sandy patches are Sand Sedge *Carex arenaria*, White Saxaul *Haloxylon persicum*, *Calligonum*, and Richter's Saltwort *Salsola arbuscula*; the ones on clay are Wormwood often mixed with shrubs, and *Anabasis salsa* mixed with Saltwort. Average temperature by day in July is between 26°C and 29°C, reaching up to 51°C, and in January between 0°C and 9°C.

MATERIAL AND METHODS

Information was obtained through the collection and analysis of data from literature, field surveys, and interviews. Data collection in the field was carried out during expeditions to the Ustyurt Plateau and Kyzylkum Desert (Fig. 1). During the expeditions, we observed the terrain from elevated points using binoculars or telescope and installed camera traps (Covert UV562HD, Bushnell HD Trophy Camera Camo 119547, and Covert UV552). Using GPS based on WGS 84 datum, we recorded our car and walking routes as well as the points where we encountered wild animals.

For interviews with local people, we designed a questionnaire in Russian. It comprised 10 questions regarding the sex, age, and occupation of respondents, their knowledge about the presence of the species in their environs, their attitudes to wild carnivores, and their perception of interaction with carnivores and of threats to wildlife.

In the villages, we interviewed people who were outside their homes and asked them to recommend

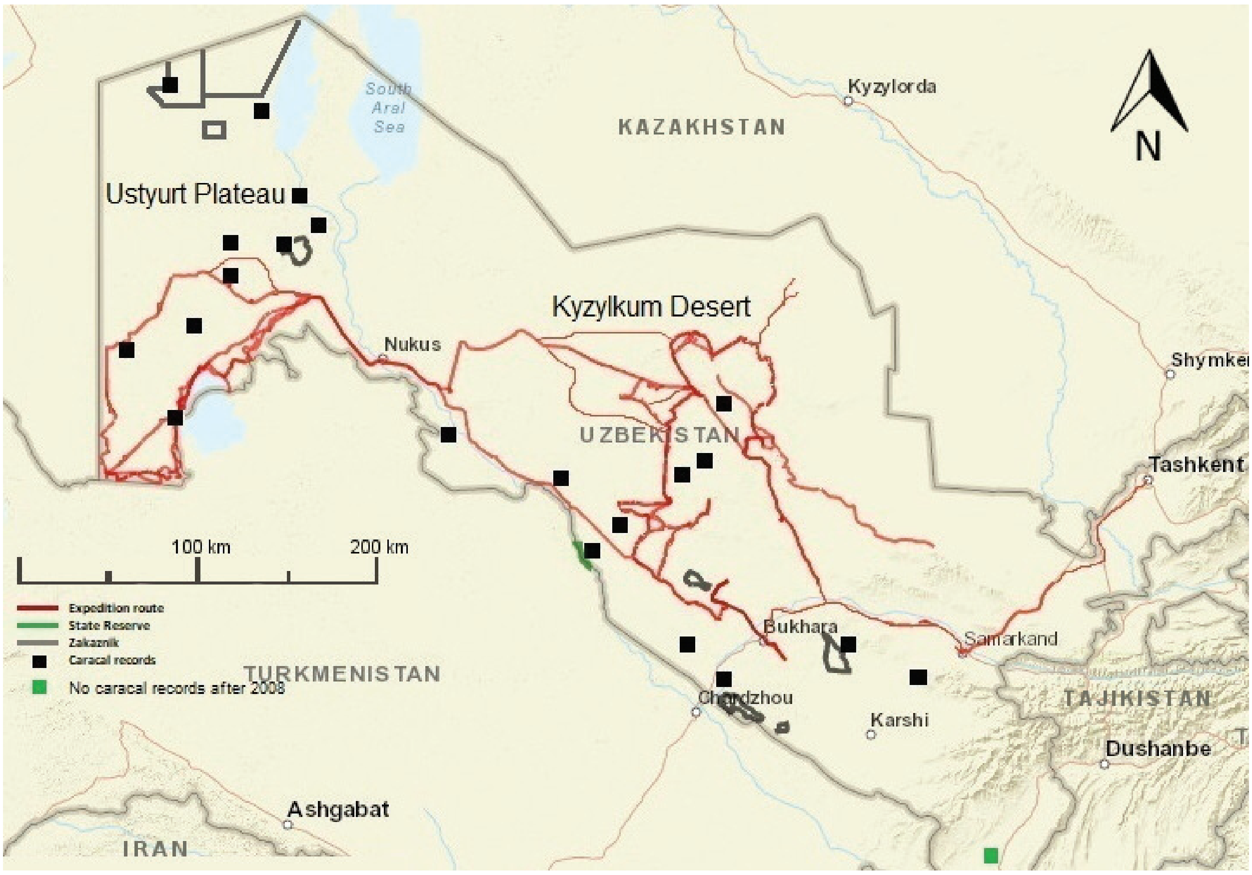

Figure 1. Surveyed areas in Uzbekistan between 2011 and 2017. Expedition routes are marked in red, and international border of Uzbekistan by a solid line.

hunters who were knowledgeable about wildlife. Outside villages, we interviewed all the shepherds that we met during our transits across the desert. We also collected data from the staff of a Bukhara regional nature protection organization and of a compressor station on the Ustyurt Plateau. We recorded the GPS location of each interview and wrote down the responses of the informants. During interviews, we showed them images of wild cats that possibly occur in the area (Asiatic Wildcat *Felis lybica ornata*, Jungle Cat *F. chaus*, Sand Cat *F. margarita*, Manul *Otocolobus manul*, and Caracal), of species that certainly do not occur in Uzbekistan (Andean Cat *Leopardus jacobita* and Fishing Cat *Prionailurus viverrinus*), and of species that historically occurred in the area (Cheetah *Acinonyx jubatus* and Tiger *Panthera tigris*). We noted all the data on Caracal records and attacks of Caracals and other predators on livestock to gain a general understanding of the situation in the region. We assessed threats to Caracal based on previous literature and results of the interview surveys.

RESULTS

The analysis of published Caracal records was an important task for determining routes of our expeditions. Table 1 shows all available information on Caracal presence in Uzbekistan published between 2000 and 2016.

We did not find any record of Caracal in the area of the Surkhan River published later than 2008 (Fig. 1).

Our expeditions took place in the southern and central parts of the Ustyurt Plateau between 2011 and 2015, and in 2017. In 2011, we travelled in the southwestern Kyzylkum Desert. Between 2014 and 2015, we carried out surveys in the northwestern part of this desert, and between 2014 and 2016 in the central part. During the expeditions, we conducted 1,865.5km transect routes by car and 428km on foot and accumulated about 350 observations. Camera traps were set up in 50 locations, including 14 locations on Ustyurt Plateau on 1,080 camera trap days and 36 locations in the Kyzylkum Desert on 3,741 camera trap days.

We interviewed 104 local people from seven villages

Table 1. Caracal records in Uzbekistan published between 2000 and 2016.

Date	Location name	Type of record	Source
Summer 2000	Kyzylkum Reserve in northwestern Kyzylkum, riparian forests of the Tiksuat Section, bank of the Amudarya River in Ostrov Island section	Sightings of two individuals.	Salimov 2004
June 2005	Zeravshan-Uchkuduk Road, 30km from the town of Uchkuduk in central Kyzylkum	An individual killed by a car.	A.S. Nuridjanov pers. comm. June 2005; Gritsina et al. 2016
3.iv.2009	Sura Well, 35km from the Kyzylkum Reserve	An individual killed a few lambs in a sheep herd. Local people killed this individual, probably in retaliation for sheep losses. Later, the dead individual was stuffed and is now exhibited in the Museum of Nature at the Kyzylkum State Reserve (Image 1).	Lim 2009; Lim & Klichev 2009
2009	Ustyurt Plateau	One individual sighted.	Abdunazarov 2009
2011	Karnabchul, southwestern Kyzylkum, 8km southeast of Igrichi	One individual sighted.	Marmazinskaya & Mardonova 2016
2013	16km southeast of Igrichi	One individual sighted.	Marmazinskaya & Mardonova 2016
2014	10km northeast of Igrichi	One individual sighted.	Marmazinskaya & Mardonova 2016
July 2015	Northwestern chink of lake Sarykamysh	One individual captured on a camera trap.	Bykova et al. 2015

and 220 shepherds in the desert, including 278 in group sessions with 2–12 people and the remaining individually. Respondents were shepherds, hunters, farmers, housewives, village elders, and local authorities aged between 14 and 73 years.

Caracal occurrence reported by local people and camera trap records obtained during our field surveys are summarised in Tables 2 and 3. Information on observations and killed Caracals was published in Russian by Gritsina (2012), Marmazinskaya et al. (2012), and Gritsina et al. (2016).

Of the 324 respondents, 28 people (8.5% of total) pointed to the facts of killing Caracal in the past 17 years, either intentionally or as a result of trapping in snares set up for wild predators in general. Local people are completely unaware that Caracal is a law-protected species. Only 58 people identified Caracal correctly from the images. We recorded that the local population were on the whole less aggressive to Caracal than to Wolf. Wolf is considered the main threat to livestock. Eighteen people from the respondents were aggressive towards wild cats and believed that they caused significant damage to sheep and chicken.

Though we did not find any Caracal skins at local markets, we did find the skins and products of other small wild cats, mostly that of Asiatic Wildcat (14 skins and 21 hats) and Jungle Cat (four skins and two hats).

Kyzylkum Desert

In the Kyzylkum area, we interviewed 245 people in five villages and in more than 40 locations. Villagers of Kalaata in central Kyzylkum reported a Caracal killed by herders on 20 March 2014 about 20km southwest of the village. Later, we found the carcass of a young female in the place indicated by the local people (Image 2). The cat was caught in a leg-snare near a sheep pen. Also, the villagers informed us of another Caracal killed by herders in 2012, which used to attack lambs in the calving period, killing up to 10 lambs at one time but leaving them uneaten. This information was confirmed by herders from the village of Jankeldy, 14km from Kalaata. They told us that people from Kalaata killed three individual Caracals between 2012 and 2013. An official of the Bukhara Regional Department of the State Committee for Nature Protection, F. Salimov, observed Caracals several times near the above-mentioned village of Jankeldy and on the shore of lake Zamonbobo in the past 10–15 years. He accounted for the sighting of one individual "several

Image 1. Stuffed Caracal exhibited in the Museum of Nature at the Kyzylkum State Reserve in Uzbekistan. © N. Marmazinskaya.

Table 2. Caracal records collected in Kyzylkum Desert during expeditions between 2011 and 2017.

Date	Location name	Type of record
Between 2000 and 2005	Village of Jankeldy and lake Zamonbobo	Several sightings of individuals.
Autumn 2006	Surroundings of Turtkul	One individual sighted.
March 2011	Shore of lake Dengizkul	Caracal footprints found by M. Gritsina.
Between 2012 and 2013	Surroundings of Kalaata Village	Three individuals killed by herders.
October 2013	Near the town of Gazli	One individual sighted by F. Salimov, an official of the Bukhara Regional Committee for Nature Protection.
Autumn 2013	Lake Dengizkul	One individual sighted by F. Salimov.
20.iii.2014	20km southwest of Kalaata	One individual killed by herders.

Image 2. The carcass of a young female found in Kyzylkum Desert in Uzbekistan on 20.iii.2014. © M. Gritsina.

Image 3. Caracal captured by a camera trap on 22.ix.2017 on Ustyurt Plateau in Uzbekistan. © M. Gritsina & D. Nuridjanov.

dozen kilometres" from the village of Turtkul in 2006. In October 2013, he also saw a Caracal by day near the town of Gazli, and another one in the autumn of the same year not far from lake Dengizkul (Gritsina et al. 2016).

Ustyurt Plateau

In the Ustyurt Plateau area, we interviewed 79 people in four villages.

Footprints of Caracals were recorded in seven places in the southern and central parts of the Karakalpak portion of the Ustyurt Plateau (Marmazinskaya et al. 2012).

In 2014, a hunter from the village of Kubla-Ustyurt killed a Caracal whose skin still remains in the village. We could not estimate the number of animals caught. In late April to early May 2015, the manager of the Kubla-Ustyurt Compressor Plant encountered an individual 5km from the Raushan Ascent on the chink, when he was returning to the village from Kungrad during daytime. The Caracal was lying on the road and only when the driver stopped the car and honked several times did the animal rise unhurriedly and go towards the chink (Gritsina et al. 2016).

In autumn 2010, herders killed an individual that took five lambs from a sheep pen near Churuk Well. According to local people, Caracals frequent the well area. In the same winter, a hunter from Kubla-Ustyurt killed a Caracal near the village. This was not the hunter's first Caracal, as in 1976 this person had killed another one (Gritsina et al. 2016).

On 22 September 2017 at 07.06h, one individual was captured in a camera trap on the eastern chink of Ustyurt Plateau, opposite the western bank of Sarykamysh Lake (Image 3).

Thus, in the years from 2000 to 2017, Caracal was documented in at least 27 localities in Uzbekistan, including 13 dead individuals and 14 live ones. At least 11 individuals were killed intentionally and one was run over by a car. Of the dead and live animals, the presence of Caracal in the area was recognised by its footprints in eight cases.

Table 3. Caracal records collected in Ustyurt Plateau during expeditions between 2011 and 2017.

Date	Location name	Type of record
1976	Kubla-Ustyurt Village	One individual killed.
Winter 2005	40km from Kirkkiz Village towards the chink of the Aral Sea	One individual killed by a hunter.
May 2010	Near Cape Aktumsyk in the Aral Sea village Karateren	One individual observed by workers of Microwave Relay Station 23.
Autumn 2010	Churuk Well Village	One individual killed by herders.
Winter 2010	Amudarya River near the city of Urgench	One individual killed.
Winter 2010	Surroundings of Kubla-Ustyurt Village	One individual killed by a hunter.
Winter 2011	Between the cities of Kungrad and Muynak, Aral Sea area	One individual caught in a trap.
May 2012	Southern and central parts of the Karakalpak portion of the Ustyurt Plateau	Caracal tracks in seven places identified by the survey team.
Spring 2013	Near lake Sudochye	One individual sighted by a respondent.
Winter 2014	Village of Kubla-Ustyurt	One individual killed.
Between 2000 and 2014	Eastern chink of the Aral Sea village	Individuals often caught in traps set for Wolves.
Late April to early May 2015	5km from the Raushan Ascent on the chink village	One individual sighted by respondent.
22.ix.2017	Near Sarykamysh Lake on the eastern chink (Image 3)	One individual captured on a camera trap.

DISCUSSION

Threats to Caracal in Uzbekistan

Analysis of interview surveys revealed that all respondents with the exception of local authorities did not know that Caracal is included as a protected species in the Red Data Book of Uzbekistan (Abdunazarov 2009).

Five Caracals were hunted in retaliation for killing livestock. Another five individuals were killed intentionally by poachers, while two others were caught in traps set for other species.

The main reason for negative interactions between local people and mammalian predators including Caracal is the lack of knowledge of the people on how to properly guard their small livestock. They use traditional, long-established, outdated grazing and breeding methods. The pens built by herders have low walls without solid roofs. Enclosures on grazing grounds are mostly made of thin mesh tied to ordinary wooden sticks and are roofless. In spring and summer, sheep and goats graze and breed without any structures for their protection. Some herds are escorted by a few dogs *Canis familiaris*, usually of Tazy breed, but these dogs are rarely trained to guard and protect the livestock from predators. In addition, they are poorly fed by herders and therefore hunt small wildlife. Due to these circumstances, small livestock is a helpless and easy prey for predators. We did not find any evidence of dogs attacking Caracal.

Results of studies conducted in South Africa indicate that Caracal preys foremost on rodents (Grobler 1981; Palmer & Fairall 1988; Avenant & Nel 2002). The latter authors demonstrated that predation by Caracal in the vicinity of West Coast National Park depended on the availability of wild prey and husbandry techniques; predation on small livestock was limited to the lambing season in spring when rodent densities decreased.

Although Caracal is a non-migratory species, it covers long distances of up to 90km during dispersals and in search of food and mates (Avenant & Nel 1998). For this reason, the fence along the border between Uzbekistan, Turkmenistan, and Kazakhstan poses a certain threat. Caracal habitats are interspersed by heavy-traffic asphalt roads and a network of dirt roads. In view of the Caracal killed in a traffic accident, the road network passing through Caracal habitat is a potential threat. Another potential threat is railways, with a few tracks crossing the feline's habitat.

Ecologic factors possibly impacting Caracal distribution

Abdunazarov (2009) suggested that the quantity of available food impacts Caracal distribution and population size. We do not have any data on Caracal's food resources and its dependency on prey density. A specialized study is required to assess these ecologic variables.

Bekenov & Kasabekov (2010) suggested that cold and snowy winters have a negative effect on Caracal population because the species is not adapted to low temperatures and thick snow cover. Data on the death of Caracals as a result of cold and snowy winters in Uzbekistan for the last 15 years are lacking.

Some parts of Caracal habitats are remote and poorly accessible, which makes patrolling by nature protection agencies problematic and ineffective. The main obstacles are insufficient funding, lack of technically-skilled human resource, and the absence of anti-poaching brigades. Owing to these circumstances, environment protection measures are currently not implemented.

Ecologic factors favouring the conservation of Caracal in Uzbekistan

Caracal occurs only in the desert regions of Uzbekistan. The climate in deserts is characterised by low winter and high summer temperatures alongside other hard natural conditions such as strong winds, poorly accessible areas, and deficiency of fresh water. Some of these areas were brought into use during the Soviet period, but most of them remain unpopulated and are rarely visited by people. Among these unpopulated and unvisited territories are the southern portion of the Ustyurt Plateau, the section of northwestern Kyzylkum next to the border with Kazakhstan, and some parts of central Kyzylkum. These conditions determined by ecogeographic and socioeconomic factors leave many suitable habitats intact and are therefore favourable for Caracal conservation in Uzbekistan.

Socioeconomic factors favouring the conservation of Caracal in Uzbekistan

In the Soviet period, many desert areas were intensively used for large-scale construction of roads, boring of wells, and establishment of rural communities. By now, some villages built in the Soviet times are fully or partly abandoned, and most areas are depopulated due to the migration of people to towns within the country or abroad.

Some of these territories lie close to the borders with Kazakhstan and Turkmenistan, and special permissions must be obtained from border police for visiting these areas.

Formerly, there were a number of small villages in the southern part of the Ustyurt Plateau where people used existent wells as water sources and lands as pastures for their livestock. Currently, no villages exist here any longer and livestock grazing is not practised.

These demographic factors lower human pressures upon wildlife and favour the conservation of biodiversity, including that of Caracal, in the region.

Existing conservation measures and measures that need to be developed

Hunting Caracal is prohibited, as it is included in the Red Data Book of Uzbekistan (Abdunazarov 2009). Species listed therein can only be taken out of their natural environment if there is a sanctioned quota and a permission approved by the Cabinet of Ministers and the Academy of Sciences of the Republic of Uzbekistan, in compliance with the Law of the Republic of Uzbekistan On Protection and Use of Fauna (No. 408, 19 September 2016) (Mirzeev 2016), and the Decree by the Cabinet of Ministers of the Republic of Uzbekistan On Regulation of Use of Biological Resources and On Permission Issuance Procedures in the Use of Natural Resources (No. 290, 20 October 2014) (Mirzeev 2014).

Caracal habitats are conserved in two protected areas, Kyzylkum State Reserve (IUCN Ia) covering 10,311ha, and Saigachiy Wildlife Sanctuary (IUCN Ib) with 219,800ha. The Kyzylkum State Reserve is a well-protected area, mostly because it is situated next to the state border with Turkmenistan. Visits to the reserve and its neighbourhoods are only allowed to local residents and holders of a special permit. The protection of the Saigachy Wildlife Sanctuary founded in 2016 on the Ustyurt Plateau is unsatisfactory because of its vast area that is difficult to manage and is remote from settlements. There are 10 rangers who have four vehicles at their disposal but insufficient funding (fuel and daily allowances) for the continued patrol of the protected area. In addition, there are several smaller protected areas that include Caracal habitats, such as the Sudochy Ornithological Wildlife Sanctuary on the western side of the Amudarya Delta (50,000ha), Dengizkul Wildlife Sanctuary (50,000ha), Karakir Wildlife Sanctuary (30,000ha), Sichankul Wildlife Sanctuary in the Sundukli sands, southwestern Kyzylkum (70,375ha), and Karnabchul Wildlife Sanctuary in southwestern Kyzylkum (25,000ha). All these reserves must be considered 'paper parks' without real protection and management.

We think it is necessary to implement the following activities for Caracal conservation in Uzbekistan: 1) strengthen the protection of Caracal habitats in the existing protected areas and establish new protected areas in the Kyzylkum Desert and on the Ustyurt Plateau, 2) raise local people's awareness and knowledge and inform them about the need for Caracal research and protection, 3) improve the protection of livestock by establishing predator-proof corrals and herding practices, and 4) raise the awareness and knowledge of nature conservation agencies, hunters, and hunters' associations. Much more attention should be paid to scientific research on Caracal, particularly in terms of estimating its current status and range and of developing a functional population monitoring system. It is also important to design, approve, and implement an action plan for Caracal conservation in Uzbekistan and to secure support from conservation authorities.

REFERENCES

Abdunazarov, B.B. (2009). Turkmenskiy karakal *Caracal caracal* (Schreber, 1776) ssp. *michaelis* (Heptner, 1945) (in Russian) [Turkmen Caracal *Caracal Caracal* (Schreber, 1776*)* ssp. *michaelis* (Heptner, 1945)], pp192–193. In: *Krasnaya kniga Respubliki Uzbekistan. Chast' II Zhivotnye [The Red Data Book of the Republic of Uzbekistan. Part II, Animals]*. Chinor ENK, Tashkent.

Avenant, N.L. & J.A.J. Nel (2002). Among habitat variation in prey availability and use by Caracal *Felis caracal*. *Mammalian Biology* 67(1): 18–33.

Avenant, N.L. & J.J. Nel (1998). Home-range use, activity, and density of caracal in relation to prey density. *African Journal of Ecology* 36(4): 347–359.

Avgan, B., P. Henschel & A. Ghoddousi (2016). *Caracal caracal*. The IUCN Red List of Threatened Species: e.T3847A102424310. Downloaded on 2 August 2018. Available online at https://doi.org/10.2305/IUCN.UK.2016-2.RLTS.T3847A50650230.en

Bekenov, A.B. & B.B. Kasabekov (2010). Karakal *Lynx caracal* Schreber, 1776, pp256–257. In: *Krasnaya kniga Respubliki Kazakhstan. Tom 1, Zhivotnye. Chast' 1 Pozvonochnye.* (in Russian) *[The Red Data Book of the Republic of Kazakhstan, Vol. 1, Animals. Part 1, Vertebrates]*. Ministerstvo obrazovaniya i nauki Respubliki Kazakhstan [Ministry for Education and Science of the Republic of Kazakhstan], Almaty.

Bogdanov, O.P. (1992). *Redkie Zhivotnye Uzbekistana. Enciklopedicheskii Spravochnik [Rare animals of Uzbekistan. Encyclopaedic Guide]*. Glavnaya Redaktsiya Enciklopedii, Tashkent, 400pp.

Bykova, E.A., A.V. Esipov & D.E. Golovtsov (2015). K izucheniyu redkikh vidov mlekopitajushchih Uzbekistana pri pomoshi photolovushek (in Russian) [On the study of the rare mammal species of Uzbekistan with the help of camera traps.], pp92–96. In: Azimov, Dj., A. Azimov, K.Sh. Tojibaev, E.A. Lanovenko, E. Shernazarov, D.B. Daminova & U.T. Mirzaev (eds.). *Biologicheskie i Strukturno-phunksional'nie Osnovi Izucheniya i Sokhraneniya Bioraznoobraziya Uzbekistana [The Biological, Structural and Function Principles of the Study and Conservation of Biodiversity in Uzbekistan]*. Tashkent.

Gritsina, M.A. (2012). Predvaritel'nye rezul'tati izucheniya sovremennogo rasprostraneniya ravninnikh vidov semeistva Felidae po territirii Uzbekistana (in Russian) [Preliminary results of the study of contemporary distribution of the flat terrain species of the family Felidae in Uzbekistan], pp92–94. In: Melbekov, A. M., A.B. Bekenov, Yu.A. Grachov, R.J. Baydavletov. S.L. Sklyarenko & N.P. Bodrova (eds.). *Zoologicheskie i Okhotovedcheskie Issledovaniya v Kazakhstane i Sopredel'nych Stranakh [The Study of Zoology and Hunting in Kazakhstan and neighbouring countries]*. Almaty.

Gritsina, M.A., D.A. Nuridjanov, N.V. Marmazinskaya, T.V. Abduraupov, V.A. Soldatov & A.N. Barashkova (2016). Nekotorye redkie phaunisticheskie nahodki mlekopitajushchih na territorii Uzbekistana (in Russian) [Some rare faunistic findings related to the mammals in the Territory of Uzbekistan], pp77–82. In: Tojibaev, K.Sh., E.A. Lanovenko, Dj. A. Azimov, E. Shernazarov, E.V. Vashetko, D.B. Daminova, R.D. Kashkarov, U.T. Mirzaev, Yu.O. Mitropolskaya, B. R. Kholmatov & E.A. Bykova (eds.). *Sovremennye Problemi Sokhraneniya Redkikh, Ischezaiushikh i Maloizuchennikh Jivotnikh Uzbekistana [The Current Issues of Conservation of Rare, Endangered and Little-Studied Animals in Uzbekistan*]. Tashkent.

Grobler, J.H. (1981). Feeding behaviour of the Caracal *Felis caracal* Schreber, 1776 in the Mountain Zebra National Park. *South African Journal of Zoology* 16: 259–262.

Heptner, V.G. & A.A. Sludskii (1972). Karakal (in Russian) [Caracal] *Felis (Lynx) caracal* Schreber, 1776, pp366–384. In: *Mlekopitajushchie Sovetskogo Sojusa Tom 1. Chast' 2. Khishchnye (Gieny i Koshki) [Mammals of the Soviet Union. Vol. 1, Part 2. Carnivora (Hyenas and Cats)]*. Vysshaya Shkola, Moscow.

Hodzhamuradov, Kh.I. & N. Imamov (2011). Karakal (in Russian) *Caracal caracal* Schreber, 1776, pp340–341. In: *Krasnaya kniga Turkmenistana. Tom 2. Bespozvonochnye i pozvonochnye zhivotnye [The Red Data Book of Turkmenistan. Vol. 2. Invertebrate and Vertebrate Animals]*. Ylym, Ashgabat.

Lesnyak, A.P., G.I. Ishunin, A.V. Esipov & L.A. Alimov (1984). Koshki v pushnom promysle Uzbekistana (in Russian) [Cats in the fur production of Uzbekistan.]. *Vol. 3. Okhota i Okhrana Prirody Uzbekistana* [*Hunting and Nature Conservation in Uzbekistan*]: 57–64. Tashkent.

Lim, V.P. (2009). Vozvrashenie turkmenskogo karakala (*Felis caracal michaelis* Heptner, 1945) (in Russian) [The return of the Turkmen Caracal (*Felis caracal michaelis* Heptner, 1945)]. *Ecologicheskii Vestnik [Ecological Bulletin]* 6(99): 23.

Lim, V.P. & M. Klichev (2009). V Uzbekistan vozvrashaetsya turkmeskii karacal (in Russian) [The Turkmen Caracal is back in Uzbekistan]. Available online at www.econews.uz. Accessed on 6 May 2018

Marmazinskaya, N.V. & L.B. Mardonova (2016). Redkie Khishchnye mlekopitajushchie Samarkandskoy oblasti (in Russian) [Rare mammal predators in Samarkand Province], pp130–137. In: Tojibaev, K.Sh., E.A. Lanovenko, Dj. A. Azimov, E. Shernazarov, E.V. Vashetko, D.B. Daminova, R.D. Kashkarov, U.T. Mirzaev, Yu.O. Mitropolskaya, B. R. Kholmatov & E.A. Bykova (eds.). *Sovremennye Problemi Sokhraneniya Redkikh, Ischezaiushikh i Maloizuchennikh Jivotnikh Uzbekistana [The Current Issues of Conservation of Rare, Endangered and Little-Studied Animals in Uzbekistan]*. Tashkent.

Marmazinskaya, N.V., M.A. Gritsina & M.G. Mitropolskiy (2012). Novye dannye po redkim vidam mlekopitajushchih yuga Karakalpakskogo Ustuyrta i severa Sarikamishskoi kotlovini (Uzbekistan) (in Russian) [New Data on the Rare Mammal Species in the Southern Part of the Karakalpak Portion of the Ustyurt Plateau and the Northern Part of the Sarykamysh Depression (Uzbekistan)], pp204–211. In: *Nazemnye Pozvonochnye Zhivotnye Aridnikh Ecosistem* [*Terrestrial Vertebrates of Arid Ecosystems*]. Chinor ENK, Tashkent.

Mirzeev, Sh M. (2014). Ob regulorovanii ispolzovania biologocheskih resursov I o poradke prohozdeniya razreshitelnih procedur v sfere prorodopolzovaniya (in Russian) [Regulation of Use of Biological Resources and On Permission Issuance Procedures in the Use of Natural Resources] pp127–236. In: *Sobranie zakonodatelsva Respubliki Uzkekistan*, *Vipusk* №34 (647) [*Code of Laws of the Republic of Uzbekistan*]. Vol. №43 (647). Tashkent.

Mirzeev, S.M. (2016). O vnesenii izmenenii I dopolnenii v zakon Respubliki Uzbekistan «Ob oxrane I ispolzovanii jivotnogo mira» (in Russian) [About amendments and additions to the law 'On the Protection and Use of the Fauna' in the Republic of Uzbekistan] pp213–232. In: *Sobranie zakonodatelsva Respubliki Uzkekistan*, *Vipusk* №38 (746) [*Code of Laws of the Republic of Uzbekistan*]. Vol. №38 (746). Tashkent.

Mitropolskiy, O.V. (1979). Krasnaya kniga SSSR (in Russian) (Redkie i ischezajushchie vidi zverey i ptits Uzbekistana) [Red Book of the USSR (Rare and endangered species of animals and birds of Uzbekistan)]. *Ochotnik i Rybolov Uzbekistana* [*The Hunter and Fisherman of Uzbekistan*]: 28–36.

Palmer, R. & N. Fairall (1988). Caracal and African Wild Cat diet in the Karoo National Park and the implications thereof for Hyrax. *South African Journal of Wildlife Research* 18: 30–34.

Pavlaniyazov, M. (1974). *Hishchnie zveri pustin Sredney Azii* (in Russian) *[Predators of the Deserts of Central Asia]*. Nukus, 320pp.

Red Data book of the Republic of Uzbekistan. (2009). *Volume. 2. Animals.* (in Russian) Tashkent: Chinor ENK. 215 pp.

Salimov, Kh.V. (2004). Nekotorye izmeneniya v biocenozakh tugaev reki Amudar'i za poslednie chetert' veka (na primere Kizilkumskogo zapovednika) (in Russian) [Some changes in the biocoenoses of the Tugai (riparian forests) of the Amudarya River in the last 25 years (with the Kyzylkum Reserve as a Case Study)], pp324–332. In: *Trudi zapovednokov Uzbekistana, Vipusk 4–5 [The Works of the Reserves of Uzbekistan, Vols. 4–5]*. Tashkent.

Sapojnikov, Yu.F. (1960). Karakal pod Repetekom (in Russian) [Caracal near Repetek]. *Prioda [Nature]* 2: 58–63.

Sapojnikov, Yu.F. (1962). Ob ekologii karakala (*Felis caracal* Mull) v Karakumah (in Russian) [About the ecology of caracal (*Felis caracal* Mull) in the Karakum desert]. Zoologicheskii jurnal *[Zoological journal]* 7(1): 111–1112.

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Small cat surveys: 10 years of data from Central Kalimantan, Indonesian Borneo

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Abstract: We present an update on the photographic detections from camera traps and the activity patterns of Borneo's four small cats, namely, Sunda Leopard Cat *Prionailurus javanensis*, Flat-headed Cat *P. planiceps*, Marbled Cat *Pardofelis marmorata*, and Bay Cat *Catopuma badia*, at two sites in Central Kalimantan, Indonesia. Camera trap survey data of 10 years (2008–2018) from the first site in Sebangau provide details about the temporal partitioning of these small cats from each other but overlap with Sunda Clouded Leopard *Neofelis diardi*. The activity of Flat-headed Cat was higher after midnight and that of Leopard Cat at night with no clear preference before or after midnight. The Marbled Cat is predominantly diurnal, but the remaining three cats have flexible activity periods. While limited data are available from Rungan, the second site, we confirmed the presence of all four small cat species found on Borneo, though we have insufficient data to comment on the Bay Cat. The cat sightings, however, are intermittent and may reflect the unprotected status of this forest. Leopard Cats appear relatively unaffected by habitat disturbance based on encounter rates on camera traps. Conservationists, both NGOs and the government, must pay particular attention to specialists like Flat-headed Cats and Bay Cats when assessing habitat suitability for long-term cat conservation.

Keywords: Activity patterns, camera traps, *Catopuma badia*, diversity, felids, fire, peat-swamp forest, *Pardofelis marmorata*, *Prionailurus javanensis*, *Prionailurus planiceps*.

Bahasa Indonesia Abstract: Kami menyajikan pembaruan pada pendeteksian fotografi dari perangkap kamera dan pola aktivitas empat kucing kecil Borneo yaitu Kucing Kuwuk *Prionailurus bengalensis*, Kucing Batu *Pardofelis marmorata*, Kucing Tandang *Prionailurus planiceps* dan Kucing Merah Cat *Catopuma badia* di dua lokasi di Kalimantan Tengah, Indonesia. Data survei perangkap kamera 10 tahun (2008–2018) dari situs pertama di Sebangau memberikan rincian tentang partisi sementara kucing kecil ini dari satu sama lain tetapi tumpang tindih dengan Macan Dahan *Neofelis diardi*. Aktivitas kucing kepala datar lebih tinggi setelah tengah malam, dan Kucing Kuwuk di malam hari tanpa preferensi yang jelas sebelum atau setelah tengah malam. Kucing Batu didominasi diurnal, tetapi ketiga kucing memiliki periode aktivitas yang fleksibel. Sementara data terbatas tersedia dari situs kedua (Rungan), kami telah mengkonfirmasi keberadaan keempat spesies kucing kecil yang ditemukan di Borneo, meskipun kami tidak memiliki cukup data untuk mengomentari Kucing Merah. Namun, penampakan kucing berselang-seling dan mungkin mencerminkan status hutan yang tidak terlindung. Kucing Kuwuk kembali muncul relatif tidak terpengaruh oleh gangguan habitat berdasarkan pada tingkat pertemuan pada perangkap kamera. Konservasionis (LSM dan pemerintah) harus memberi perhatian khusus kepada spesialis misalnya Kucing Tandang dan Kucing Merah ketika menilai kecocokan habitat untuk konservasi kucing jangka panjang.

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INTRODUCTION

In the absence of Tiger *Panthera tigris*, Borneo's cats represent a fascinating guild, and all are in need of conservation attention. Five species occur on Borneo: the Sunda Clouded Leopard *Neofelis diardi* (Endangered (EN) on the IUCN Red List; Hearn et al. 2016c), the Bay Cat *Catopuma badia* (EN and endemic to Borneo; Hearn et al. 2016a), the Flat-headed Cat *Prionailurus planiceps* (EN; Wilting et al. 2016a), the Marbled Cat *Pardofelis marmorata* (Near Threatened; Ross et al. 2016a), and the Sunda Leopard Cat *Prionailurus javanensis* (Least Concern; Ross et al. 2016). They are all protected under Indonesian law (P.20/MENLHK/SETJEN/KUM.1/6/2018). As they are rare and elusive, it is difficult to study them in the wild. Thus, there is limited knowledge about their ecology despite increased scientific interest.

Since 2008, Borneo Nature Foundation (BNF) and University of Palangka Raya, Centre for the International Management of Tropical Peatlands (UPR-CIMTROP), have been conducting long-term monitoring of the Sunda Clouded Leopard *Neofelis diardi* in Indonesia and, specifically, *N. d. borneensis* in Central Kalimantan. During this time, we also opportunistically obtained images of three of the four small cats in the Sebangau catchment area. Given the disturbed mosaic nature of Sebangau, we also hope to determine which areas are unsuitable for small cats, either due to habitat changes and/or due to human disturbance. Live Leopard Cats are more common in Kalimantan markets for sale as pets than Sunda Clouded Leopards, and their skins are more often found in homes (Rabinowitz et al. 1987). Far less is known about small cat movements, habitat preferences, seasonal movements, breeding patterns, and effects of anthropogenic disturbance across their range. These data are particularly lacking from tropical peat-swamp forests. We present here updated information on temporal activity pattern of four small cats from the Central Kalimantan region of Indonesia.

Study areas

The Sebangau catchment, Central Kalimantan, Indonesia (Fig. 1), is a peat-swamp forest (mixed-swamp forest sub-type) covering an area of ~5,600km^2. This study took place in the 50km^2 research forest located in the northeast. The area was logged under a concession system between 1991 and 1997 followed by illegal logging between 1997 and 2004. The site is at an altitude of about 10m. The area was significantly affected by the forest fires that impacted Indonesia in 2015.

The second research site was established in 2016 in the Rungan Forest, which covers about 1,440km^2 between the Kahayan and Rungan rivers. The forest is a lowland forest mosaic comprising peat-swamp, 'kerangas' (heathland) and the dominant canopy trees are *Palaquium* sp. (nyatoh), *Syzygium* sp. (jambu) and *Shorea* (meranti), (Dipterocarpaceae family). BNF and the Wildlife Conservation Research Unit (WildCRU) of the University of Oxford initiated the Sebangau Felid Project in May 2008, and BNF initiated the Rungan work in 2016.

MATERIAL AND METHODS

Since 2008, a total of 210 camera locations were surveyed across both forest areas with an average of 30 units in each forest area at any one time. Between 2008 and 2012, cameras were set up in pairs in Sebangau and subsequently as single units. In the Rungan site, cameras were all set up as single units. Cameras were set in a stratified random survey design. Cameras were placed 500m to 1,000m apart and were in each location for a minimum of six months; some cameras were in the same location since May 2008. Locations were selected to cover a range of habitats and disturbances within the forests, avoiding streams and slopes wherever present. Camera traps were placed along established human-made trails (more than four years old) and, where possible, watering areas, to maximise the success rate of photographic captures. A combination of camera models were used, including Cuddeback Expert®, Cuddeback Capture IR® (Cuddeback Digital, Non-Typical Inc, WI, USA) Maginon, Crenova, and Bushnell. Cameras were checked every 40 days when batteries were changed and SD cards exchanged. Data were managed in a custom Microsoft Access database. Active behaviour times were calculated using the kernel density method ('href' bandwidth for kernel smoothing; Ridout & Linkie 2009; Meredith & Ridout 2016) to account for average dawn and dusk times in the sites, which are situated almost on the equator (for more information on the Sebangau study site, see Cheyne & Macdonald 2011; Cheyne et al. 2016b). Detection rate was estimated as number of detections/100 trap nights. Weather data were collected daily at each research site and fire data was obtained from the Indonesian Agency of Meteorology, Climatology, and Geophysics. A 30-min interval between photos of the same species was used to determine if photos of were an independent event at the same location and date.

Figure 1. Study sites: circle - Sebangau; star - Rungan.

RESULTS

The number of camera trap (CT) stations at each site varied annually due to broken units (Table 1).

Detailed descriptions of CT locations are in Appendices 1 & 2, including descriptions of the microhabitats, number of trap nights, number of detections, and careful descriptions of the setup around the CT stations. CTs were placed in different habitats across the two sites (Table 2).

The small cats were recorded by 56 of 83 camera traps in Sebangau (67%) and by 16 of 37 camera traps in Rungan (43%) (Table 3).

All small cats in Sebangau were photographed in all main habitat types in the interior forest, <20m from the forest edge and in disturbed areas. All four small cats in Rungan were recorded in the interior forest; only the Flat-headed Cat was recorded near the lake.

Sebangau

Since the cameras were first placed in May 2008, we captured 157 independent images of Sunda Clouded Leopards (Image 1), but only 109 of Sunda Leopard Cats, 54 of Marbled Cats (Image 2), and 33 of Flat-headed Cats (Image 3). Compared to the average detection rates of small cats since the inception of the camera trap study in 2008, there was a decline in the detections of Marbled Cats and Flat-headed Cats (Fig. 2). From 2014 to July 2018, there was an average of 3.9 independent Marbled Cat images/month (min=0, max=16). No Flat-headed Cats were recorded by camera traps between January 2014 and February 2018 (Fig. 2), which coincided with a significant fire event from September to November 2015.

Of the three small cat species, the Sunda Leopard Cat is predominantly nocturnal with no clear preference for time of night. Flat-headed Cats also showed nocturnal activity but with a slight preference for post-midnight hours. Marbled Cats are strongly diurnal. Interestingly, 65% of 115 nocturnal records (18.00–05.59 h) of Sunda Clouded Leopards were between 01.00h and 05.59h (Fig. 3), thus overlapping with the preferred active time for Flat-headed Cats.

Rungan

Three of the small cats were confirmed in Rungan in the first few months of the study but it took 12 months to confirm the presence of the Flat-headed Cat (Table 4).

Bay Cat

With over eight years of long-term camera trap surveying in the peat-swamp forest of the Sebangau

Table 1. Number of camera trap stations per year in the study site.

Year	Sebangau	Rungan
2008	40	0
2009	40	0
2010	40	0
2011	36	0
2012	34	0
2013	30	0
2014	25	0
2015	30	0
2016	30	36
2017	25	50
2018	28	30

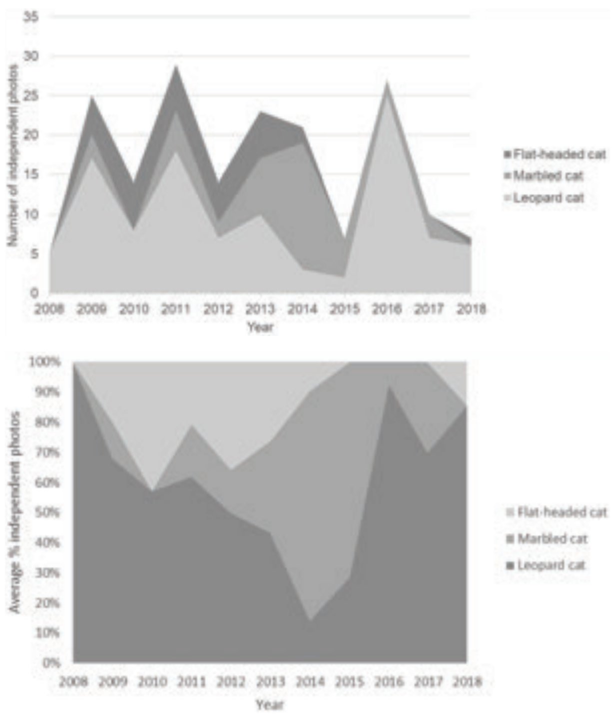

Figure 2. Mean detection of small wild cat species from the inception of the camera trap surveys in Sebangau since 2008.

Table 2. Number of camera trap (CT) locations at each site (NA - habitat type not present in the study site).

Habitat type	Sebangau	Rungan
Burned area	3	NA
Kerangas/ heath	NA	30
Low interior forest	1	4
Mixed swamp forest	74	3
Tall interior forest	5	NA
Total CT locations	**83**	**37**
Total trap nights	**65,261**	**14,642**

catchment, the Bay Cat was not detected, and ongoing work suggests that it is not found in peat-swamp forests. The Bay Cat was confirmed in mosaic heath/ peat-swamp forest habitat for the first time (Sastramidjaja et al. 2015; Cheyne et al. 2016a, 2017). Through the use of camera traps, we present new location information on the distribution of Bay Cat in Kalimantan. This new location is approximately 64km southeast outside the range depicted by Hearn et al. (2016a). Our record of Borneo Bay Cat from the new habitat (heath/ peat-swamp forest) warrants further surveys in different habitat types to fully understand Bay Cat distribution and ecologic needs.

DISCUSSION

The small cats are appearing evenly across the habitat types in both Sebangan and Rungan, with the exception of the Bay Cat that likely does not exist in deep ombrogenous peat-swamp forest (Sebangau). Additionally, we have evidence of breeding in Flat-headed Cat and Marbled Cat in Sebangau (images of kittens) (Images 4 & 5).

Flat-headed Cats have a more irregular capture rate and though they are active throughout the day, more captures are obtained at night and therefore they are predominantly nocturnal. Leopard Cats have a more regular capture rate

Table 3. Camera trap (CT) locations with detections and non-detections of small cats with mean occupancy estimates (Ψ) in the study sites. NA indicates occupancy cannot be calculated due to no small cats being photographed at these locations.

	Sebangau		Rungan	
	Number of CT locations	Ψ	Number of CT locations	Ψ
Leopard Cat	20	21.05	10	26.32
Marbled Cat	20	13.68	2	10.26
Flat-headed Cat	16	11.58	3	6.50
Bay Cat	0	0	1	1.28
No small cats	36	NA	23	NA

Image 1. Sunda Leopard Cat *Prionailurus javanensis* in Sebangau Forest, Central Kalimantan, Indonesian Borneo. © Borneo Nature Foundation, 28 July 2008.

Image 2. Marbled Cat *Pardofelis marmorata* in Sebangau Forest, Central Kalimantan, Indonesian Borneo. © Borneo Nature Foundation, 20 September 2013.

Image 3. Flat-headed Cat *Prionailurus planiceps* in Sebangau Forest, Central Kalimantan, Indonesian Borneo. © Borneo Nature Foundation, 22 February 2013.

Table 4. Capture rate of small cat species from the inception of the camera trap surveys in Rungan between June 2016 and May 2018.

	Jun–Aug 2016	Sep–Nov 2016	Dec 2016–Feb 2017	Mar–May 2017	Jun–Aug 2017	Sep–Nov 2017	Dec 2017–Feb 2018	Mar–May 2018
Flat-headed Cat	0	0	0	0	1	1	0	0
Sunda Leopard Cat	2	2	2	1	0	0	0	0
Marbled Cat	1	4	0	0	1	0	0	0
Bay Cat	1	0	0	0	0	0	0	0

and appear to be active both during the day and night, though they appear to avoid the hottest time of the day (11.00–13.00 h). Marbled Cats have a regular capture rate with the majority of images taken during the day (05.00–16.00 h), suggesting they are diurnal. There is only one image of a Bay Cat taken at 11.17h. These data are similar to those of Hearn et al. (2018), though these authors did not obtain sufficient images of Flat-headed Cats to make a detailed analysis.

Peat-swamp and associated lowland wetlands are postulated to be an important habitat for Flat-headed Cats (Cheyne et al. 2009; Wilting et al. 2010, 2016b; Cheyne & Macdonald 2011; Adul et al. 2015). Marbled Cats are not believed to frequent roads or plantations (Hearn et al. 2016c) and prefer intact forests, though data are lacking on this cat (Rustam et al. 2016).

Peat-swamp and associated lowland wetlands were suggested to be poor or marginal habitat for Sunda Leopard Cat (Mohamed et al. 2016), but our work suggests that Sunda Leopard Cat are far more common (Cheyne & Macdonald 2011; Adul et al. 2015; Cheyne et al. 2016b).

The infrequent capture of the small cats in both sites is likely an artefact of the placing of the cameras (±1km apart) to focus on the wide-ranging Sunda Clouded Leopard. By moving the cameras closer (±500m) we hope to determine the population density for the small cats, determine if the Bay Cat is indeed absent from this forest, and to continue our monitoring of the Sunda Clouded Leopard population. The long period of time required to obtain images of small cats, possibly due to the placement of the cameras targeting Sunda Clouded Leopard, highlights the importance of long-term data and monitoring to avoid false-negative presence data. Sunda Leopard Cat is the most commonly recorded species in the

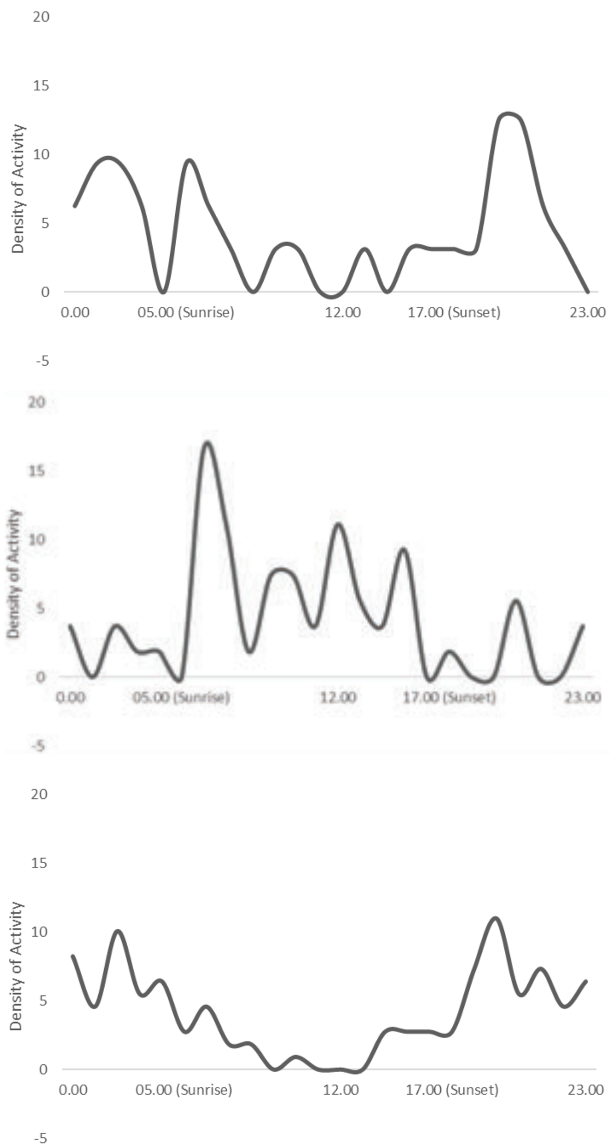

Figure 3. Kernel density estimates of activity patterns of species using alpha of 0.1 smoothing parameter: a - Flat-headed Cat; b - Marbled Cat; c - Sunda Leopard Cat.

study site. Marbled Cat is hard to study and, as many are arboreal, having cameras mainly on the forest floor means we could be missing out on key aspects of their behaviour. Flat-headed Cat is a wetland specialist and prefers forests with water (Wilting et al. 2010). Its diet likely consists of fish, frogs, and small mammals, and it may fill a niche on Borneo filled by the Fishing Cat *Prionailurus viverrinus* elsewhere in Asia (Iwaniuk et al. 2001). Due to this dependence on wetlands, we think that the devastating fires of 2015 may have severely impacted the Flat-headed Cat population, pushing it away from fire-affected areas. Our preliminary results suggest that Flat-headed Cats are returning to these areas, which BNF is actively working to restore. These data could be an artefact of survey effort (a high number of broken cameras) or a genuine reflection of this species behaviour.

Large parts of the peat-swamp are naturally seasonally flooded for up to nine months per year. The flooded nature of Sebangau does not always prevent the animals using the ground; indeed we have evidence of male Orangutans *Pongo pygmaeus* wading through water (Ancrenaz et al. 2014). Keeping a selection of camera trap locations the same over several months or years allows for variations in detection to be accounted for; given the regular flooding of the forest, it is likely that the wildlife is accustomed to this. We do notice animals using our boardwalks more regularly in the wet season. Peatlands and associated forest fires are a crucial conservation concern in Kalimantan (Gaveau et al. 2016; Miettinen et al. 2017). This is especially true during dry years such as in 2015 when a strong El Niño event led to particularly dry conditions. From August to November of that year, MODIS satellites detected over 50,000 fire hotspots in Kalimantan, 53% of which were on peatland (Gaveau et al. 2016; Miettinen et al. 2017). Since 2006, 17.35% of forest in the core Sebangau research area burned down (9.63% in 2015 alone—5.3km^2 of 55km^2). Of particular threat to the Flat-headed Cat are peat drainage and drying out due to logging canals, the loss of permanent water, and increased hydrologic instability (Page et al. 2009; Vanthomme et al. 2013).

Conservation impact

This work represents the first-ever comprehensive and long-term survey of small cats in Central Kalimantan. There is a severe lack of data on these species in non-protected or small forest areas that may also contain viable populations. It is crucial to remember that, while these surveys indicate the continued presence of these cats, habitat loss, wildlife trade, and likely presence of populations in non-protected areas means that more work is needed to understand the impacts of anthropogenic activities on these cats. As detailed in Appendix 1, this project provides extensive and detailed data about many wildlife species in Sebangau and Rungan forests in addition to the cats—an additional 7,959 images (2,765 videos) of 74 species. Of these, two are IUCN Red Listed as Critically Endangered, five as Endangered, 14 as Vulnerable, 12 as Near Threatened, and 41 as Least Concern.

Image 4. Flat-headed Cat *Prionailurus planiceps* kitten

Image 5. Marbled Cat *Pardofelis marmorata* and kitten

REFERENCES

Adul, B. Ripoll, S.H. Limin & S.M. Cheyne (2015). Felids of Sebangau: camera trapping to estimate activity patterns and population abundance in Central Kalimantan, Indonesia. *Biodiversitas* 16(2): 151–155; https://doi.org/10.13057/biodiv/d160208

Ancrenaz, M., R. Sollmann, E. Meijaard, A.J. Hearn, J. Ross, H. Samejima, B. Loken, S.M. Cheyne, D.J. Stark, P.C. Gardner, B. Goossens, A. Mohamed, T. Bohm, I. Matsuda, M. Nakabayasi, S.K. Lee, H. Bernard, J. Brodie, S. Wich, G. Fredriksson, G. Hanya, M.E. Harrison, T. Kanamori, P. Kretzschmar, D.W. Macdonald, P. Riger, S. Spehar, L.N. Ambu & A. Wilting (2014). Coming down from the trees: is terrestrial activity in Bornean orangutans natural or disturbance driven? *Scientific Reports* 4: 1–5.

Cheyne, S.M., Adul, F. Veen, J.F. Van, B.R. Capilla, N. Boyd & S. Maimunah (2017). First record of the Bay Cat in mosaic heath/peat-swamp forest, Kalimantan, Indonesia. *Cat News* 65: 48.

Cheyne, S.M. & D.W. Macdonald (2011). Wild felid diversity and activity patterns in Sabangau peat-swamp forest, Indonesian Borneo. *Oryx* 45(1): 119–124.

Cheyne, S.M., S. Maimunah & F. van Veen (2016a). Camera traps reveal wonders in Ironwood Forests. *Peatlands International* 3: 14–15.

Cheyne, S.M., H. Morrogh-Bernard & D.W. Macdonald (2009). First Flat-headed Cat from Sabangau peat-swamp forest, Indonesian Borneo. *Cat News* 51: 18.

Cheyne, S.M., W.J. Sastramidjaja, Muhalir, Y. Rayadin & D.W. Macdonald (2016b). Mammalian communities as indicators of disturbance across Indonesian Borneo. *Global Ecology and Conservation* 7: 157–173; https://doi.org/10.1016/j.gecco.2016.06.002

Gaveau, D.L.A., D. Sheil, Husnayaen, M.A. Salim, S. Arjasakusuma, M. Ancrenaz, P. Pacheco & E. Meijaard (2016). Rapid conversions and avoided deforestation: examining four decades of industrial plantation expansion in Borneo. *Scientific Reports* 6: 32017.

Hearn, A., J. Brodie, S. Cheyne, B. Loken, J. Ross & A. Wilting (2016a). *Catopuma badia*. In: The IUCN Red List of Threatened Species: e.T4037A112910221. Accessed on 14 October 2018. https://doi.org/10.2305/IUCN.UK.2016-1.RLTS.T4037A50650716.en

Hearn, A.J., S.A. Cushman, J. Ross, B. Goossens, L.T.B. Hunter & D.W. Macdonald (2018). Spatio-temporal ecology of sympatric felids on Borneo. Evidence for resource partitioning? *PLoS One* 13(7): e0200828.

Hearn, A.J., J. Ross, H. Bernard, S.A. Bakar, L.T.B. Hunter & D.W. Macdonald (2016b). The first estimates of Marbled Cat *Pardofelis marmorata* population density from Bornean primary and selectively logged forest. *PLoS One* 11(3): e0151046.

Hearn, A., J. Ross, J. Brodie, S. Cheyne, I.A. Haidir, B. Loken, J. Mathai, A. Wilting & J. McCarthy (2016c). *Neofelis diardi*. In: The IUCN Red List of Threatened Species: e.T136603A97212874. Accessed on 14 October 2018. https://doi.org/10.2305/IUCN.UK.2015-4.RLTS.T136603A50664601.en

Iwaniuk, A.N., W.G. Blankstein & I.Q. Whishaw (2001). Observations of the feeding behaviour of Fishing Cats (*Prionailurus viverrinus*). *Mammalia* 65(1): 89–91.

Meredith, M. & M. Ridout (2016). Overview of the overlap package. In: R Development Core Team, R Package. 3.3.1. Edition. R Foundation for Statistical Computing, Vienna, Austria; https://cran.r-project.org/web/packages/overlap/vignettes/overlap.pdf

Miettinen, J., C. Shi & S. Liew (2017). Fire distribution in peninsular Malaysia, Sumatra and Borneo in 2015 with special emphasis on peatland fires. *Environmental Management* 60(4): 747–757.

Mohamed, A., J. Ross, A.J. Hearn, S.M. Cheyne, R. Alfred, H. Bernard, R. Boonratana, H. Samejima, M. Heydon, D.M. Augeri, J.F. Brodie, A. Giordano, G. Fredriksson, J. Hall, B. Loken, Y. Nakashima, J.D. Pilgrim, Rustam, G. Semiadi, T. van Berkel, J. Hon, N.T.L. Lim, A.J. Marshall, J. Mathai, D.W. Macdonald, C. Breitenmoser-Würsten, S. Kramer-Schadt & A. Wilting (2016). Predicted distribution of the Leopard Cat *Prionailurus bengalensis* (Mammalia: Carnivora: Felidae) on Borneo. *Raffles Bulletin of Zoology, Supplement* 33: 180–185.

Page, S., A. Hoscilo, H. Wosten, J. Jauhiainen, M. Silvius, J. Rieley, H. Ritzema, K. Tansey, L. Graham, H. Vasander & S. Limin (2009). Restoration ecology of lowland tropical peatlands in southeast Asia: current knowledge and future research directions. *Ecosystems* 12(6): 888–905.

Rabinowitz, A., P. Andau & P.P.K. Chai (1987). The Clouded Leopard in Malaysian Borneo. *Oryx* 21: 107–111.

Ridout, M. & M. Linkie (2009). Estimating overlap of daily activity patterns from camera trap data. *Journal of Agricultural, Biological, and Environmental Statistics* 14(3): 322–337.

Ross, J., J. Brodie, S. Cheyne, A. Datta, A. Hearn, B. Loken, A. Lynam, J. McCarthy, C. Phan, A. Rasphone, P. Singh & A. Wilting (2016a). *Pardofelis marmorata*. In: The IUCN Red List of Threatened Species: e.T16218A97164299. Accessed on 14 October 2018. https://doi.org/10.2305/IUCN.UK.2016-1.RLTS.T16218A97164299.en

Ross, J., J. Brodie, S. Cheyne, A. Hearn, M. Izawa, B. Loken, A. Lynam, J. McCarthy, S. Mukherjee, C. Phan, A. Rasphone & A. Wilting (2016b). *Prionailurus bengalensis*. In: The IUCN Red List of Threatened Species: e.T18146A50661611. Accessed on 14 October 2018. https://doi.org/10.2305/IUCN.UK.2015-4.RLTS.T18146A50661611.en

Rustam, R., A.J. Hearn, J. Ross, R. Alfred, H. Samejima, M. Heydon, S.M. Cheyne, J.F. Brodie, A.J. Giordano, H. Bernard, R. Boonratana, B. Loken, A. Mohamed, M.-A. Jayasilan, D.M. Augeri, J. Eaton, J. Hon, A.J. Marshall, J. Mathai, G. Semiadi, D.W. Macdonald, C. Breitenmoser-Würsten, S. Kramer-Schadt & A. Wilting (2016). Predicted distribution of the Marbled Cat *Pardofelis marmorata* (Mammalia: Carnivora: Felidae) on Borneo. *Raffles Bulletin of Zoology, Supplement* 33: 157–164.

Sastramidjaja, W.J., S.M. Cheyne, B. Loken & D.W. Macdonald (2015). The Bay Cat in Kalimantan, new information from recent sightings. *Cat News* 62: 10–12.

Vanthomme, H., J. Kolowski, L. Korte & A. Alonso (2013). Distribution of a community of mammals in relation to roads and other human disturbances in Gabon, central Africa. *Conservation Biology* 27(2): 281–291.

Wilting, A., J. Brodie, S. Cheyne, A. Hearn, A. Lynam, J. Mathai, J. McCarthy, E. Meijaard, A. Mohamed, J. Ross, S. Sunarto & C. Traeholt (2016a). *Prionailurus planiceps*. In: The IUCN Red List of Threatened Species: e.T18148A50662095. Accessed on 14 October 2018. https://doi.org/10.2305/IUCN.UK.2015-2.RLTS.T18148A50662095.en

Wilting, A., S.M. Cheyne, A. Mohamed, A.J. Hearn, J. Ross, H. Samejima, B. Boonratana, A.J. Marshall, J.F. Brodie, A. Giordiano, J.A. Eaton, J. Hall, J.D. Pilgrim, M. Heydon, G. Semiadi, E. Meijaard, D.W. Macdonald, C. Breitenmoser-Würsten & S. Kramer-Schadt (2016b). Predicted distribution of the Flat-headed Cat *Prionailurus planiceps* (Mammalia: Carnivora: Felidae) on Borneo. *Raffles Bulletin of Zoology, Supplement* 33: 173–179.

Wilting, A., A. Cord, A.J. Hearn, D. Hesse, A. Mohamed, C. Traeholdt, S.M. Cheyne, S. Sunarto, M.-A. Jayasilan, J. Ross, A.C. Shapiro, S. Dech, C. Breitenmoser, J.W. Duckworth, J. Sanderson & J. Hofer (2010). Modelling the species distribution of Flat-Headed Cats (*Prionailurus planiceps*), an Endangered south-east Asian small felid. *PLoS One* 5(3): e9612.

Appendix 1. Summary of camera trap (CT) locations in Sebangau, Central Kalimantan Indonesian Borneo. LC - Leopard Cat, MC - Marbled Cat, FHC - Flat-headed Cat.

No. of CT days	Location of camera	Habitat class	Additional habitat information	Altitude (m)	LC	MC	FhC
372	T 1.3E x TY 2015	Burned area	Interior forest	16–20	X		
375	T 1B East 975m 2015	Burned area	Forest edge (<20m)	16–20		X	
180	T SC East x TY 2015	Burned area	Forest edge (<20m)	16–20	X		
1475	JE1	Mixed swamp forest	Forest edge (<20m)	16–20			X
2399	Km2 x Railway	Mixed swamp forest	Interior forest	16–20			
2399	Km3 x Railway	Mixed swamp forest	Interior forest	16–20	X		
2399	Km4 x Railway	Mixed swamp forest	Interior forest	16–20	X		
2447	Old Railway 400m	Mixed swamp forest	Disturbed logging railway	16–20		X	X
241	Old Railway x T2E	Mixed swamp forest	Disturbed logging railway	16–20			
724	Old Railway x TX	Mixed swamp forest	Disturbed logging railway	16–20		X	
849	OR x T0.8E 2013	Mixed swamp forest	Disturbed logging railway	16–20			
346	OR1150m	Mixed swamp forest	Disturbed logging railway	16–20			
382	Ottercam T1B Canal	Mixed swamp forest	Interior forest	16–20			
375	P.Jelotung x TD 2015	Mixed swamp forest	Interior forest	16–20		X	X
52	Railway 1450m	Mixed swamp forest	Disturbed logging railway	16–20			
835	Secret Transect	Mixed swamp forest	Forest edge (<20m)	16–20		X	
262	T 0.4 East End 2015	Mixed swamp forest	Interior forest	16–20		X	
740	T 0.4 X TD 2015	Mixed swamp forest	Interior forest	16–20	X		
374	T 0.8 x TB 2015	Mixed swamp forest	Interior forest	16–20	X	X	
465	T 0.8 x TE 2015	Mixed swamp forest	Interior forest	16–20	X		X
372	T 0.8E x ORW 2015	Mixed swamp forest	Interior forest	16–20			
2395	T 1.6 x P.owa-owa 2015	Mixed swamp forest	Interior forest	16–20		X	X
436	T 1.6 x T E	Mixed swamp forest	Interior forest	16–20		X	
372	T 1.6E x TW 2015	Mixed swamp forest	Interior forest	16–20		X	
375	T 16 x TB 2015	Mixed swamp forest	Interior forest	16–20			
375	T 1A x Railway 2015	Mixed swamp forest	Disturbed logging railway	16–20			
375	T 2 700m 2015	Mixed swamp forest	Interior forest	16–20		X	
375	T 2 x TE 2015	Mixed swamp forest	Interior forest	16–20			
372	T 2E x ORW 2015	Mixed swamp forest	Disturbed logging railway	16–20			X
372	T 2E x TX 2015	Mixed swamp forest	Interior forest	16–20			
649	T 2km 700m	Mixed swamp forest	Interior forest	16–20			
2450	T CC 25m di atas pohon	Mixed swamp forest	Canopy 10m	10	X		
802	T DD 400m	Mixed swamp forest	Forest edge (<20m)	16-20	X		
248	T FF 125m 2015	Mixed swamp forest	Forest edge (<20m)	16–20	X		X
261	T SC 1412m 2015	Mixed swamp forest	Forest edge (<20m)	16–20			
64	T SC 530m 2016	Mixed swamp forest	Forest edge (<20m)	16–20			
965	T SC 610m 2015	Mixed swamp forest	Forest edge (<20m)	16–20			X
841	T SC East 275m	Mixed swamp forest	Forest edge (<20m)	16–20		X	
935	T SC East 275m 2015	Mixed swamp forest	Forest edge (<20m)	16–20			X
843	T.Secret 1412m	Mixed swamp forest	Forest edge (<20m)	16–20		X	
880	T.Secret 610m	Mixed swamp forest	Forest edge (<20m)	16–20		X	
566	T0 950m di atas pohon	Mixed swamp forest	Canopy 10m	10		X	
436	T0 x T F	Mixed swamp forest	Interior forest	16–20		X	

No. of CT days	Location of camera	Habitat class	Additional habitat information	Altitude (m)	LC	MC	FhC
2154	T0 x TC	Mixed swamp forest	Interior forest	16–20			X
907	T0 x TC 2013	Mixed swamp forest	Interior forest	16–20	X		
907	T0 x TG 2013	Mixed swamp forest	Interior forest	16–20			X
437	T0 x TH	Mixed swamp forest	Interior forest	16–20			X
379	T0.4E END	Mixed swamp forest	Interior forest	16–20			
904	T0.8 x TG 2013	Mixed swamp forest	Interior forest	16–20			X
427	T0.8 x THH	Mixed swamp forest	Interior forest	16–20	X		
2154	T0.8E x TX	Mixed swamp forest	Interior forest	16–20			
616	T0.8E x TY	Mixed swamp forest	Interior forest	16–20			
841	T1.3E x TY 2013	Mixed swamp forest	Interior forest	16–20		X	
55	T1.6 375m	Mixed swamp forest	Interior forest	16–20	X		
2395	T1.6 x Pondok Owa-Owa	Mixed swamp forest	Interior forest	16–20		X	X
2395	T1.6 x Railway	Mixed swamp forest	Interior forest	16–20			
881	T1.6 x TC 2013	Mixed swamp forest	Interior forest	16–20			
435	T1.6E x TZ	Mixed swamp forest	Interior forest	16–20		X	
2395	T1A x Railway	Mixed swamp forest	Interior forest	16–20	X		
436	T1A x TD	Mixed swamp forest	Interior forest	16–20			
83	T1B x Railway	Mixed swamp forest	Interior forest	16–20			
649	T2 700m 2013	Mixed swamp forest	Interior forest	16–20			
5	T2 x TA	Mixed swamp forest	Interior forest	16–20			
2446	T2 x TB	Mixed swamp forest	Interior forest	16–20			
699	T2 x TD	Mixed swamp forest	Interior forest	16–20	X		
62	T2 x THH	Mixed swamp forest	Interior forest	16–20			
905	T2E x OR 2013	Mixed swamp forest	Interior forest	16–20			
435	T2E x TY	Mixed swamp forest	Interior forest	16–20			
2450	TD x Jelutong Pondok	Mixed swamp forest	Interior forest	16–20		X	X
1007	Tower Path	Mixed swamp forest	Interior forest	16–20	X		
260	TREE Railway 1350m 2015	Mixed swamp forest	Canopy 10m	10			
258	TREE T 0.8 412m 2015	Mixed swamp forest	Canopy 10m	10			
116	TREE T 0.8E x TX 2015	Mixed swamp forest	Canopy 10m	10			
247	TREE T 1B 350m 2016	Mixed swamp forest	Canopy 10m	10	X		
257	TREE T SC 685m 2015	Mixed swamp forest	Canopy 10m	10			
81	TS x TBB 525m	Mixed swamp forest	Forest edge (<20m)	16–20	X		
81	TS x TCC	Mixed swamp forest	Forest edge (<20m)	16–20			
131	TP 0 650m	Tall interior forest	Interior forest	16–20	X		X
131	TP 1 1200m	Tall interior forest	Interior forest	16–20			
130	TP A 800m	Tall interior forest	Interior forest	16–20			
130	TP A x TP 1	Tall interior forest	Interior forest	16–20			
131	TP B 1700m	Tall interior forest	Interior forest	16–20			
2399	Km5 x Railway	Low interior forest	Interior forest	16–20	X		

Appendix 2. Summary of camera trap (CT) locations in Rungan, Central Kalimantan Indonesian Borneo. LC - Leopard Cat, MC - Marbled Cat, FHC - Flat-headed Cat.

No. of CT days	Location of camera	Habitat class	Additional habitat information	Altitude (m)	LC	MC	FhC	BC
107	Mungku Baru Cam 13 Frank	Kerangas/ heath	Interior forest	50	X			
107	Mungku Baru Cam 15 Frank	Kerangas/ heath	Interior forest	50				
107	Mungku Baru Cam 16 Frank	Kerangas/ heath	Interior forest	50	X			
106	Mungku Baru Cam 18 Frank	Kerangas/ heath	Interior forest	50				
106	Mungku Baru Cam 19 Frank	Kerangas/ heath	Interior forest	50				
682	Mungku Baru Cam 2 Frank	Kerangas/ heath	Interior forest	50				
316	Mungku Baru Cam 3 Frank	Kerangas/ heath	Interior forest	50	X			
274	Mungku Baru Cam 4 Frank	Kerangas/ heath	Interior forest	50				
682	Mungku Baru Cam 5 Frank	Kerangas/ heath	Interior forest	50	X	X		
682	Mungku Baru Cam 6 Frank	Kerangas/ heath	Interior forest	50				
64	Mungku Baru Cam 7 Frank	Kerangas/ heath	Interior forest	50	X			
63	Mungku Baru Cam 8 Frank	Kerangas/ heath	Interior forest	50				
63	Mungku Baru Cam 9 Frank	Kerangas/ heath	Interior forest	50			X	
661	Mungku Baru CAM BNF 1+2	Kerangas/ heath	Interior forest	50	X			
661	Mungku Baru CAM BNF 11+12	Kerangas/ heath	Interior forest	50	X			
661	Mungku Baru CAM BNF 13+14	Kerangas/ heath	Interior forest	50	X			X
660	Mungku Baru CAM BNF 17+18	Kerangas/ heath	Interior forest	50	X			
660	Mungku Baru CAM BNF 19+20	Kerangas/ heath	Interior forest	50				
659	Mungku Baru CAM BNF 21+22	Kerangas/ heath	Interior forest	50				
659	Mungku Baru CAM BNF 23+24	Kerangas/ heath	Interior forest	50				
660	Mungku Baru CAM BNF 25+26	Kerangas/ heath	Interior forest	50				
497	Mungku Baru CAM BNF 27+28	Kerangas/ heath	Interior forest	50				
660	Mungku Baru CAM BNF 29+30	Kerangas/ heath	Interior forest	50			X	
498	Mungku Baru CAM BNF 3+4	Kerangas/ heath	Interior forest	50				
660	Mungku Baru CAM BNF 31+32	Kerangas/ heath	Interior forest	50				
660	Mungku Baru CAM BNF 33 TREE	Kerangas/ heath	12m in canopy	70				
355	Mungku Baru CAM BNF 34 TREE	Kerangas/ heath	10m in canopy	70				
296	Mungku Baru CAM BNF 5+6	Kerangas/ heath	Interior forest	70		X		
498	Mungku Baru CAM BNF 7+8	Kerangas/ heath	Interior forest	70	X			
62	Mungku Baru Cam 1 Frank	Kerangas/ heath	Interior forest	70				
63	Mungku Baru Cam 10 Frank	Low interior forest	Interior forest	70				
109	Mungku Baru Cam 11 Frank	Low interior forest	Interior forest	70				
109	Mungku Baru Cam 12 Frank	Low interior forest	Interior forest	70				
107	Mungku Baru Cam 17 Frank	Low interior forest	Interior forest	70				
107	Mungku Baru Cam 14 Frank	Mixed swamp forest	Interior forest	70				
660	Mungku Baru CAM BNF 15+16	Mixed swamp forest	Interior forest	70				
661	Mungku Baru CAM BNF 9+10 Danau	Mixed swamp forest	Edge of a lake	40			X	

Appendix 3. Scientific, common, and Indonesian names and IUCN Red List status of species from Central Kalimantan, Indonesian Borneo.

Scientific name	Common name	Local name	Recent IUCN status
Pongo pygmaeus	Bornean Orangutan	Kahiu	Critically Endangered
Manis javanica	Sunda Pangolin	Trenggiling, Peusing	Critically Endangered
Prionailurus planiceps	Flat-headed Cat	Kucing dampak	Endangered
Cynogale bennettii	Otter Civet	Musang air	Endangered
Catopuma badia	Bay Cat	Kucing merah	Endangered
Hylobates albibarbis	Bornean White-bearded Gibbon	Kalaweit/ Owa-owa	Endangered
Ciconia stormi	Storm's Stork	Unknown	Endangered
Neofelis diardii	Sunda Clouded Leopard	Macan dahan/ Harimau dahan	Vulnerable
Lophura erythrophthalma	Malay Crestless Fireback	Manok himba	Vulnerable
Helarctos malayanus	Sun Bear	Beruang	Vulnerable
Arctictis binturong	Binturong	Binturong	Vulnerable
Aonyx cinerea	Asian Small-clawed Otter	Unknown	Vulnerable
Sus barbatus	Bearded Pig	Babi hutan	Vulnerable
Cervus unicolor	Sambar	Rusa	Vulnerable
Presbytis rubicunda	Red langur	Kelasi/ Lutung merah	Vulnerable
Macaca nemestrina	Pig-tailed Macaque	Beruk	Vulnerable
Tarsius bancanus borneanus	Horsfield's Tarsier	Inkir/ Binatang hantu	Vulnerable
Petinomys setosus	Temminck's Flying Squirrel	Unknown	Vulnerable
Mulleripicus Pulverulentus	Great Slaty Woodpecker	Balatuk	Vulnerable
Setornis criniger	Hook-billed Bulbul	Unknown	Vulnerable
Melanoperdix niger	Black Partridge	Unknown	Vulnerable
Pardofelis marmorata	Marbled Cat	Kuwuk	Near Threatened
Hemigalus derbyanus	Banded Civet	Musang	Near Threatened
Herpestes semitorquatus	Collared Mongoose	Unknown	Near Threatened
H. brachyurus	Short-tailed Mongoose	Unknown	Near Threatened
Muntiacus atherodes	Bornean Yellow Muntjac	Kijang/ Kidang, Muncak	Near Threatened
Anthracoceros malayanus	Black Hornbill	Tingang/ Enggang	Near Threatened
Carpococcyx radiatus	Bornean Ground-cuckoo	Unknown	Near Threatened
Strix leptogrammica	Brown Wood-owl	Unknown	Near Threatened
Lophura ignita	Bornean Crested Fireback	Unknown	Near Threatened
Harpactes diardii	Diard's Trogon	Unknown	Near Threatened
Trichixos pyrropygus	Rufous-tailed Shama	Unknown	Near Threatened
Trichastoma rostratum	White-chested Babbler	Unknown	Near Threatened
Prionailurus javanensis	Leopard Cat	Kucing hutan, Meong congkok	Least Concern
Trichys fasciculata	Long-tailed Porcupine	Landak	Least Concern
Hystrix brachyura	Malayan Porcupine	Landak	Least Concern
Prionodon linsang	Banded Linsang	Musang congkok	Least Concern
Paradoxurus hermaphroditus	Common Palm Civet	Unknown	Least Concern
Viverra tangalunga	Malay Civet	Unknown	Least Concern
Arctogalidia trivirgata	Small-toothed Palm Civet	Civet	Least Concern
Martes flavigula	Yellow-throated Marten	Unknown	Least Concern
Mustela nudipes	Malay Weasel	Unknown	Least Concern
Muntiacus muntjak	Southern Red Muntjac	Unknown	Least Concern
Macaca fascicularis	Long-tailed Macaque	Monyet ekor panjang (Kra)	Least Concern

Scientific name	Common name	Local name	Recent IUCN status
Nannosciurus melanotis	Black-eared Squirrel	Hantitik	Least Concern
Sundasciurus lowii	Low's Squirrel	Unknown	Least Concern
Echinosorex gymnura	Moonrat	Unknown	Least Concern
Ptilocercus Lowii	Pen-tailed Treeshrew	Unknown	Least Concern
Callosciurus notatus	Plantain Squirrel	Unknown	Least Concern
C. prevostii	Prevost's Squirrel	Unknown	Least Concern
Maxomys surifer	Indomalayan Maxomys	Unknown	Least Concern
Tupaia glis	Common Treeshrew	Tupai	Least Concern
T. splendidula	Ruddy Treeshrew	Tupai	Least Concern
T. picta	Painted Treeshrew	Tupai	Least Concern
T. tana	Large Treeshrew	Tupai	Least Concern
T. gracilis	Slender Treeshrew	Tupai	Least Concern
T. minor	Lesser Treeshrew	Tupai	Least Concern
Exilisciurus whiteheadi	Tufted Pygmy Squirrel	Hantitik	Least Concern
Pellorneum capistratum	Black-capped Babbler	Unknown	Least Concern
Pitta moluccensis	Blue-winged Pitta	Unknown	Least Concern
Ketupa ketupu	Buffy Fish-owl	Unknown	Least Concern
Stachyris erythroptera	Chestnut-winged Babbler	Unknown	Least Concern
Phaenicophaeus curvirostris	Chestnut-breasted Malkoha	Unknown	Least Concern
Centropus bengalensis	Lesser Coucal	Unknown	Least Concern
Accipiter trivirgatus	Crested Goshawk	Unknown	Least Concern
Spilornis cheela	Crested Serpent-eagle	Unknown	Least Concern
Rhipidura javanica	Pied Fantail	Unknown	Least Concern
Caprimulgus affinis	Savanna Nightjar	Unknown	Least Concern
Pelargopsis capensis	Stork-billed Kingfisher	Bakaka	Least Concern
Sitta frontalis	Velvet-fronted Nuthatch	Unknown	Least Concern
Amaurornis phoenicurus	White-breasted Waterhen	Baburak	Least Concern
Copsychus malabaricus	White-rumped Shama	Murai	Least Concern
Spizaetus melanoleucus	Black-and-white Hawk-eagle	Antang	Least Concern
Varanus salvator	Common Water Monitor	Biawak	Least Concern

Author details: Karen Jeffers is the Sebangau Research Project Manager of the Borneo Nature Foundation. She has over 10 years' experience in Indonesia studying biodiversity, policy and has been researching small felids in Sebangau for some years, providing unique insights into their behaviour. Mr. Adul is the Senior Camera Trap Coordinator for BNF. Adul has worked with the camera trap project since its inception and has travelled to several other conservation projects to share his knowledge and skills in running camera trap projects. Adul presented BNF's work at the Indonesian Carnivore Conference in 2017. Susan Cheyne has worked in Southeast Asia since 1997 and in Indonesia since 2002. She is a co-director of BNF and has carried out long-term gibbon and mammal population monitoring in eight sites across Indonesian Borneo. She is a vice-chair of the IUCN Primate Specialist Group Section on Small Apes and a member of the IUCN Cat Specialist Group.

Author contribution: Karen Jeffers carried out the field research under RISTEK permit number 8/TKPIPA/E5/Dit.KI/VIII/2018. She contributed to data collection with Adul and analysis and writing with SMC. Adul designed the camera study grid with KAJ and SMC and assisted the fieldwork. He contributed to data analysis with KAJ and SMC. Susan Cheyne conceived of the study and assisted in the field design. Along with KAJ and Adul she analysied the data and wrote the paper.

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Insights into the feeding ecology of and threats to Sand Cat *Felis margarita* Loche, 1858 (Mammalia: Carnivora: Felidae) in the Kyzylkum Desert, Uzbekistan

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Abstract: Little is known about the ecology of the Sand Cat *Felis margarita* throughout its range in the deserts of northern Africa to central Asia. We present observations of the Sand Cat in the southern Kyzylkum Desert, Uzbekistan, potentially preying upon a large bird and returning to the kill on subsequent nights. This record contributes to the knowledge about the feeding ecology and varied diet of the Sand Cat and its opportunistic hunting strategy.

Keywords: Asian Houbara, Bukhara region, camera trapping, *Chlamydotis macqueenii*, conservation needs, opportunistic feeding, scavenging.

The distribution of the Sand Cat *Felis margarita* ranges from northern Africa to central Asia across which it almost exclusively inhabits sandy and stony deserts (Schauenberg 1974). Very little is known about its ecology and while some aspects have been studied in Israel (Abbadi 1991), Morocco (Sliwa et al. 2013; Breton et al. 2016; Sliwa et al. 2017; Breton & Sliwa 2018), and Iran (Ghafaripour et al. 2017), the Central Asian Sand Cat *F. m. thinobius* remains particularly understudied. Burnside et al. (2014) confirmed a breeding population to be still present in the southern Kyzylkum Desert, Uzbekistan (Fig. 1), aligning modern data with the species distribution reported by Heptner & Sludskii (1992).

Felis margarita is classified as Least Concern in the IUCN Red List (Sliwa et al. 2016). In Uzbekistan, while *F. m. thinobius* is not listed in the Red Data Book of the country (Khassanov 2009), it has been recommended for inclusion in the next edition of the book, which is yet to be published (Gritsina pers. comm. 18 April 2018). Apart from local knowledge and anecdotal evidence, nothing is known about the ecology, distribution, population sizes, or trends of the species in Uzbekistan (Gritsina 2014) nor anywhere in central Asia. Therefore, any new observation contributes to the knowledge base on this species. Here we present opportunistic observations on the feeding ecology of a Sand Cat in Uzbekistan.

Materials and Methods

As part of long-term research into the ecology of Asian Houbara *Chlamydotis macqueenii* in the southern Kyzylkum Desert west of Bukhara, field research teams have been spending 3.5 months in the study area each year from 2012–2018 as described in Burnside et al. 2014. During this fieldwork, they occasionally observe Sand Cat, but as the work is diurnal it does not overlap well with the nocturnal activity of Sand Cat, which reduces the probability of detecting the species. The

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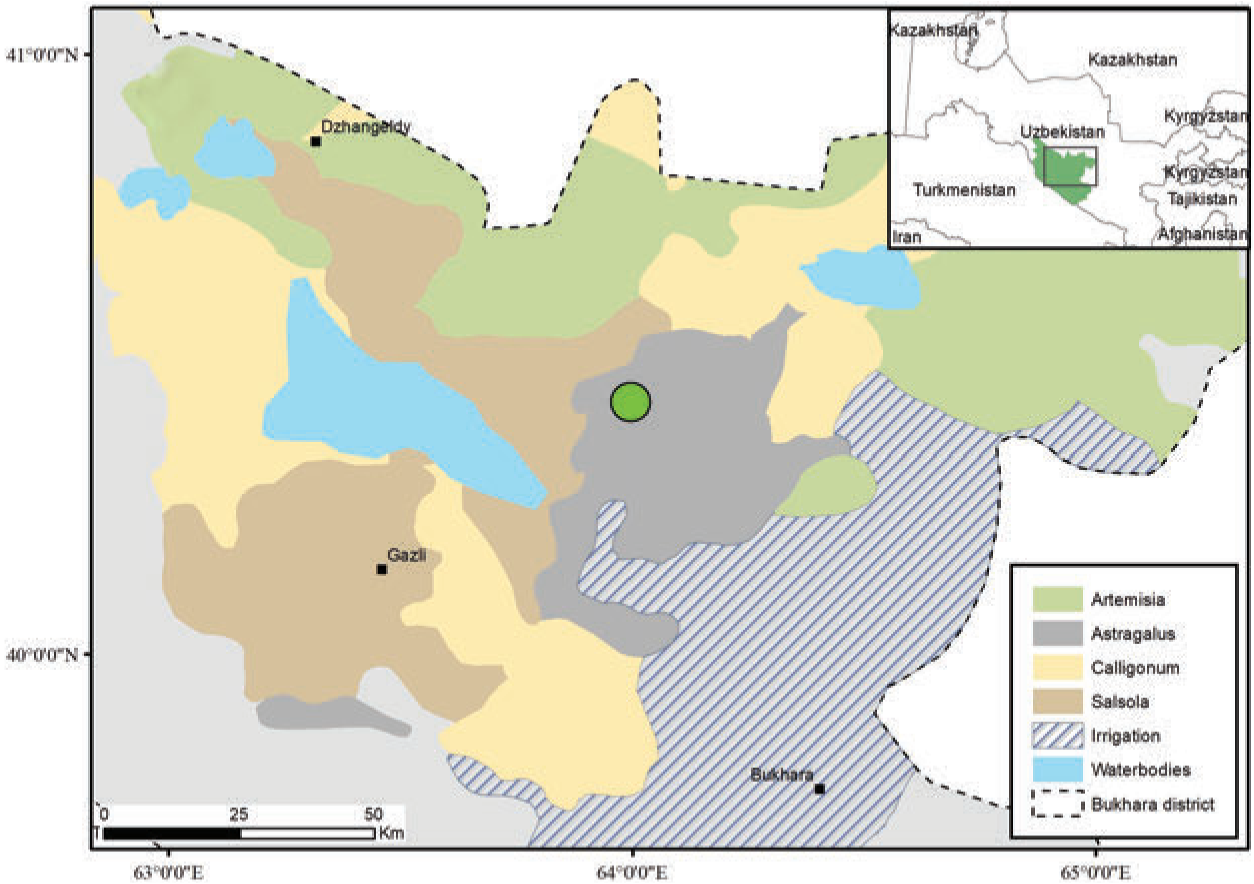

Figure 1. Study area, *C. macqueeni*i Research Project, Kyzylkum Desert, Uzbekistan, showing Sand Cat observation (green dot) and the different vegetation zones. © R. Burnside.

data is thus generally limited to opportunistic diurnal observations. This equivalent field effort in each field season resulted in an average of one Sand Cat report per year, with the exception of 2014 (Burnside et al. 2014) and 2018 (this article) when the species was also recorded through camera traps.

Part of our work is to monitor the survival of released captive-bred *C. macqueenii* and establish causes of its mortality in the field. In the period after their release, captive-bred birds are more susceptible to predation than their wild counterparts (Burnside et al. 2016). On 26 March 2018, we located a freshly-killed and partially-eaten *C. macqueenii*, identified by its leg rings as a recently released captive-bred yearling male. The evidence found around the carcass suggested that the predator was a cat. We deployed a trail camera (Bushnell Trophy Cam HD Essential, model #119836) 2m from the kill, low to the ground and concealed in a shrub, for three nights. We set it to record motion-triggered, 15s-long videos both during the day and night (PIR sensor) and then returned to collect it three days later.

Results

The carcass of *C. macqueenii* was found on a small hill of consolidated sand with low shrubs dominated by *Astragalus villosissimus* and *Salsola* spp. and sparse grass cover. The discovery was made after sighting feathers distributed in shrubs up to 10m around the kill at 40.423^{0}N & 63.986^{0}E. Feathers did not show signs of chewing but had been plucked. The pectoral muscles were partially eaten and the entire head and neck were missing. The legs and wings were intact and undamaged. This is unlike a kill by Red Fox *Vulpes vulpes*, another common predator of released captive-bred *C. macqueenii* in the area (Burnside et al. 2016). A Red Fox usually chews the limbs, removing and caching them, while leaving chewed feather quill tips as opposed to plucking them at kill sites (Robert J. Burnside, unpublished data).

Pounce marks found close to the carcass, approximately 4m away, were identified as that of a Sand Cat. Erasil Khaitov, an experienced tracker in the research team who has worked extensively in the

Image 1. Camera trap footage of a Sand Cat feeding on the carcass of a captive-bred Asian Houbara in the Kyzylkum Desert, Uzbekistan. © A. Brighten.

Image 2. Sand Cat pounce marks left during a hunt, with four paw-prints (highlighted with white dashed boxes) in the Kyzylkum Desert, Uzbekistan. © A. Brighten & R. Burnside.

Kyzylkum Desert, identified the species' prints without hesitation. Tracks leading up to the kill site showed a slow, creeping approach indicating that the cat was moving low to the ground. In two areas, the tracks deepened with the force of a pounce (Image 2), with all four paws visible; drag marks of approximately 6m were seen nearby leading to where the carcass was found.

The camera trap recorded footage of a Sand Cat returning to the carcass on 26 March 2018 (Image 1). It arrived after dark at 20.55h and spent 15min at the kill where it was seen to feed on the *C. macqueenii* (Video 1).

A Sand Cat was recorded on the camera trap visiting the kill once more at 21.24h on 28 March 2018, after which there were no more observed visits by the cat or other vertebrate scavengers. The footage showed the Sand Cat to be a male. The morning after the second visit by the cat, however, the carcass had been removed. There was a single night trigger on 28 March, the second visit by a cat, suggesting there to be a battery failure limiting the firing of the infra-red flash. The removal of the carcass was, therefore, not caught on camera as the next trigger was 29 March at 10.32h showing the *C. macqueenii* to have been taken away. We were unable to confirm which scavenger removed the carcass.

Discussion

Very little is known about the Sand Cat's feeding ecology. Components of its diet were described in Uzbekistan in the 1960s from stomach contents of hunted cats (Schauenberg 1974), which mainly consisted of small burrowing rodents. Other studies from central Asia summarised by Heptner & Sludskii (1992), using stomach contents, faecal samples, or a combination of both, found Sand Cat diet dominated by gerbils *Gerbillus* and jerboa species like *Allactaga, Dipus*, *and Paradious*; however, this also varied, comprising of other mammals such as Tolai Hare *Lepus tolai* and Souslik *Spermophillus leptodactilus*, reptiles such as snakes *Spalerosophis diodema* and *Coluber karelini* and gecko *Teratoscincus,* birds such as Turtle Dove *Streptopelia turtur*, Crested Lark *Galerida cristata*, Saxaul Jay *Podoces panderi*, and Desert Sparrow *Passer simplex*, a single observation of a Pallas Sand Grouse *Syrrhaptes paradoxus*, and arthropods such as *Coleoptera*, *Phalangids*, and *Scorpiones*. Sand Cats were observed preying on gecko *Stenodactylus* in Israel (Abbadi 1991), and on Cape Hare *Lepus capensis*, viper *Cerastes*, Greater Hoopoe Lark *Alaemon alaudipes*, and Domestic Fowl in the Sahara (Dragesco-Joffé 1993).

The southern Kyzylkum Sand Cat diet likely comprises fauna found in our Bukhara study area, such as small rodents, including several *Gerbillus* species, Long-clawed Souslik *Spermophillus leptodactilus* and Yellow Souslik *S. fulvus*, 30 reptile species including Toad-headed Agama *Phrynocephalus*, and four amphibian species (Showler 2017). Small bird species are also numerous in the area, Alaudidae in particular, including the abundant Crested Lark *Galerida cristata*, which are also probable prey of the Sand Cat. The accounts of Abbadi (1991) and Dragesco-Joffé (1993) both describe Sand Cat hunting strategy as opportunistic and our observations in the Kyzylkum Desert presented here support this assertion.

From the evidence presented, it seems likely that the *C. macqueenii* was killed by the Sand Cat. The average weight of a captive-bred *C. macqueenii* yearling male is 1.5–2 kg, whereas Central Asian Sand Cats weigh on average 3.125kg for males (2.65–3.40 kg, n=6) and 2.194kg for females (1.35–3.10 kg, n=5) (Heptner & Sludskii 1992). The *C. macqueenii* was, therefore, large prey for a small cat. The species may not form a significant part of Sand Cat diet, but this predator-naïve, recently-released *C. macqueenii* may have offered an easy opportunity for the Sand Cat.

Our record is the first of a Sand Cat returning to a kill in the Kyzylkum Desert, and it did not cover the carcass. In Niger's Ténéré Desert, Dragesco-Joffé (1993) observed Sand Cats burying their prey in the sand when they killed more than what they could eat, later returning to feed on the carcasses. Returning to kills and scavenging has been documented in only a few small wild cat species. Sliwa (1994) observed Black-footed Cats *Felis nigripes* killing and caching Southern Black Bustards *Afrotis afra* in South Africa and a scavenging event on a Springbok *Antidorcas marsupialis* lamb, while Avenant & Nel (2002) reported Caracal *Caracal caracal* feeding on the carcasses of Springbok that it had presumably killed.

In Uzbekistan and other parts of central Asia, the Sand Cat is likely threatened by increasing degradation and encroachment of its desert habitat through anthropogenic activities, both industrial and private. Particularly in the Bukhara region, this encroachment includes expanding industry and infrastructure, mainly construction of railways, roads, and pipelines, as well as mining for natural resources such as gas, oil, gold, sand, and gravel. Unlike large businesses, local communities in Uzbekistan still have limited access to reliable fuel resources due to the government's policies on gas export. The result is that the gathering of fuelwood continues on a large scale in the Bukhara region. Historically, this was limited to Saxaul *Haloxylon persicum*, but recently we have seen the collection become less discriminating, uprooting other woody shrubs. We encountered tractors undertaking such activities on an almost daily basis in the spring between 2016 and 2018 in the region. This resulted in changes to the shrub structure and increase in drifting sand (Robert J. Burnside, unpublished data).

Pastoralism is the most widespread anthropogenic activity in the desert. In general, it seems to have a low impact on vegetation communities and structure at the landscape-level and is at a stable level in the Bukhara region (Koshkin et al. 2014). As with other rangeland systems, however, there is a general mistrust of mammalian predators among the local people. We have first-hand reports of the prevalent negative perceptions and direct persecution of cats in general, both of Sand Cat and Asian Wildcat *Felis lybica ornata*, by the rangeland inhabitants in our study area. One recent account (Erasil Khaitov, pers. comm. 20 May 2018) involved the destruction of a Sand Cat den and killing of kittens by a shepherd in retaliation for the loss of a lamb, supposedly killed by a Sand Cat. The evidence was that the lamb was killed by a bite to the neck, which is indicative of a cat, although other cats and carnivores inhabit the area (Caracal, Asian Wildcat, Jungle Cat *Felis chaus*, Red Fox, Corsac Fox *Vulpes corsac*, and Grey Wolf *Canis lupus*).

Another threat to Sand Cat is human-introduced mammals such as the Domestic Dog *Canis familiaris*, which are potential predators of cats (Cole & Wilson

2015). In the Kyzylkum Desert, many rangeland farmers keep shepherding dogs. The killing of Sand Cats by these dogs was reported from the Moroccan Sahara (Sliwa 2013; Sliwa et al. 2013). Sliwa et al. (2013) identified an additional threat of disease transmission from Domestic Cat *Felis catus* to Sand Cat. While this may not currently threaten the Sand Cat population in the Bukhara study area, as there is a low density of human settlements and presumably low density of Domestic Cat, it may affect Sand Cat in rangelands or sandy deserts closer to larger human settlements of Uzbekistan.

The first steps in conservation action needed for the Sand Cat are two-fold. Firstly, assessment of the population status and improved understanding of its ecology to quantify the impacts of human activity on the population are needed. Secondly, education, changing perceptions, and resolving human-predator negative interactions are necessary to reduce persecution. As understanding the species' ecology is the first step to better quantifying the conservation status of Sand Cat and mitigating anthropogenic impacts on it in Uzbekistan, the observations presented here represent important information for understanding Sand Cat ecology, specifically the variability in the diet of this potentially threatened small wild cat.

References

Abbadi, M. (1991). Israel's elusive feline: Sand Cats. *Israel Land and Nature* 16(3): 111–115.

Avenant, N.L. & J.A.J. Nel (2002). Among habitat variation in prey availability and use by Caracal *Felis caracal*. *Mammalian Biology* 67(1): 18–33; https://doi.org/10.1078/1616-5047-00002

Breton, G., A. Sliwa, S. Azizi & A. Essalhi (2016). Sand Cats in the Moroccan Sahara – preliminary results of a new study. *Cat News* 63: 7–10.

Breton, G. & A. Sliwa (2018). Sand Cat research and conservation in Morocco, pp14–15. In: Appel, A., S. Mukherjee & S.M. Cheyne (eds.). Proceedings of the First International Small Wild Cat Conservation Summit, 11–14 September 2017, United Kingdom. Wild Cat Network, Bad Marienberg, Germany, Sálim Ali Centre for Ornithology and Natural History, Coimbatore, India and Borneo Nature Foundation, Oxford, United Kingdom, 42pp.

Burnside, R.J., M.A. Koshkin & P.M. Dolman (2014). Breeding population of Sand Cat in the southern Kyzylkum Desert, Uzbekistan. *Cat News* 60: 25–26.

Burnside, R.J., N.J. Collar, K.M. Scotland & P.M. Dolman (2016). Survival rates of captive-bred Asian Houbara *Chlamydotis macqueenii* in a hunted migratory population. *IBIS* 158(2): 353–361; https://doi.org/10.1111/ibi.12349

Cole, R.F. & D.E. Wilson (2015). *Felis margarita* (Carnivora: Felidae). *Mammalian Species* 47(924): 63–77; https://doi.org/10.1093/mspecies/sev007

Dragesco-Joffé, A. (1993). Le chat des sables, un redoutable chasseur de serpents [The Sand Cat, a formidable snake hunter], pp119–126. In: *La Vie Sauvage du Sahara. Delachaux et Niestlé, Lausanne, Switzerland*, 240pp

Ghafaripour, S., M. Naderi & H.R. Rezaei (2017). Investigating abundance, density and potential threats of Sand Cat in the southeastern parts of Iran. *Journal of Wildlife and Biodiversity* 1(1): 47–55.

Gritsina, M. (2014). Sand cats in Uzbekistan. Sand Cat Working Group. Available online at http://www.sand-cat.wild-cat.org. Accessed on 22 May 2018.

Heptner, V.G. & A.A. Sludskii (1992). Sand Cat *Felis (Otocolobus) margarita* Loche, 1858, pp636–665. In: Hoffmen, R.S., V.G. Heptner & A.A. Sludskii (eds.). *Mammals of the Soviet Union. Vol. II, Part 2: Carnivora (Hyaenas and Cats)*. Smithsonian Institution Libraries and the National Science Foundation, Washington, D.C., 784pp.

Khassanov, F. (2009). *The Red Data Book of the Republic of Uzbekistan, Vol. 2. Animals.* Chinor ENK, Tashkent, 215pp.

Koshkin, M.A., N.J. Collar & P.M. Dolman (2014). Do sheep affect distribution and habitat of Asian Houbara *Chlamydotis macqueenii*? *Journal of Arid Environments* 103: 53–62; https://doi.org/10.1016/j.jaridenv.2014.01.002

Schauenberg, P. (1974). Données nouvelles sur le Chat des sables *Felis margarita* Loche, 1858. *Revue Suisse de Zoologie* 81(4): 949–969.

Showler, D.A. (2017). *Guide to the Amphibians & Reptiles of the Kyzylkum Desert, Uzbekistan*. Self-published PDF, Norwich, UK, pp. 112

Sliwa, A. (1994). Diet and feeding behaviour of the Black-footed Cat (*Felis nigripes* Burchell, 1824) in the Kimberley region, South Africa. *Der Zoologische Garten* 64: 83–96.

Sliwa, A. (2013). *Felis margarita*, pp199–202. In: Kingdon, J.S. & M. Hoffmann (eds.). *The Mammals of Africa, Vol. V (Carnivores, Pangolins, Equids and Rhinoceroses*). Academic Press, Amsterdam, The Netherlands, 560pp.

Sliwa, A., G. Breton & F. Chevalier (2013). Sand Cat sightings in Moroccan Sahara. *Cat News* 59: 28–30.

Sliwa, A., T. Ghadirian, A. Appel, L. Banfield, M.S. Shah & T. Wacher (2016). *Felis margarita*. In: The IUCN Red List of Threatened Species: e.T8541A50651884. Downloaded on 20 May 2018; https://doi.org/10.2305/IUCN.UK.2016-2.RLTS.T8541A50651884.en

Sliwa, A., S. Azizi, E. Alifal, A. Essalhi, M. Endichi & G. Breton (2017). First Sand Cat kittens sighted in the Moroccan Sahara. *Cat News* 66: 19–20.

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SHORT COMMUNICATION

First photographic evidence of Fishing Cat *Prionailurus viverrinus* Bennett, 1833 and Clouded Leopard *Neofelis nebulosa* Griffith, 1821 (Carnivora: Felidae) in Parsa National Park, Nepal

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Abstract: Twelve cat species were recorded in Nepal including the largest, Tiger *Panthera tigris*, and the smallest, Rusty-spotted Cat *Prionailurus rubiginosus*. There is more research on the *Panthera* species than on small wild cats; consequently, the conservation status, distribution, and ecology of small cat species are poorly known. In this article, we report on the first photographic evidence of Clouded Leopard *Neofelis nebulosa* and Fishing Cat *Prionailurus viverrinus* in Parsa National Park in southern central Nepal during a camera trap survey targeted at the tiger between 2014 and 2016. There were only single detections of each species; this does not give enough information to establish distribution or conservation status of either of the species in Parsa National Park. Further targeted surveys are needed to establish the significance of this protected area for the conservation of these two species.

Keywords: Camera trapping survey, small wild cats, southern central Nepal, Terai.

Nepal is home to 12 cat species including both the largest, Tiger *Panthera tigris*, and the smallest, Rusty-spotted Cat *Prionailurus rubiginosus*, of the world (Lamichhane et al. 2016; Lama et al. 2019). Distribution and ecology of large charismatic cats like Tiger, Snow Leopard *Panthera uncia*, and Leopard *Panthera pardus* are researched considerably in Nepal (see Jackson 1996; Smith et al. 1998; Thapa et al. 2014; Karki et al. 2015) in comparison to small felids. There are huge information gaps on the distribution and status of smaller felids in Nepal. Most of the existing information on small cat species are based on historic references and specimens, anecdotal

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records, and sign surveys carried out in protected areas for large felids (Lamichhane et al. 2016; Taylor et al. 2016). These efforts detected common and large felids but may have missed rare and elusive smaller felids (Tempa et al. 2013). Increased use of camera trapping in recent years aided in the discovery of rare species like Clouded Leopard *Neofelis nebulosa* and Fishing Cat *Prionailurus viverrinus* in new areas and provided verifiable records (see Appel et al. 2012; Lamichhane et al. 2016; Taylor et al. 2016; Ghimirey & Acharya 2018; Yadav et al. 2018; Lama et al. 2019). The latest addition is the discovery of Marbled Cat *Pardofelis marmorata* in the eastern Himalayas of Nepal (Lama et al. 2019).

Among the cat species, Clouded Leopard receives less attention from the conservation community in Nepal and is threatened by illegal wildlife trade and degrading habitat (Ghimirey & Acharya 2018). Though Hodgson (1853) reported its presence in Nepal already in the mid-18th Century, it was recorded in different parts of the country only since the late 1980s (Dinerstein & Mehta 1989), such as in Dhanusa, Nawalparasi, and Kaski districts (Dinerstein & Mehta 1989), Annapurna Conservation Area (Appel et al. 2012; Ghimire et al. 2019), Shivapuri Nagarjun NP (Pandey 2012), and Chitwan NP (Ghimirey et al. 2014; Lamichhane et al. 2014). In recent years, Fishing Cat was recorded in Chitwan NP (Dahal & Dahal 2011; Mishra et al. 2018), Koshi Tappu Wildlife Reserve (Taylor et al. 2016), Bardia NP (Yadav et al. 2018), Shuklaphanta NP (NTNC survey records, unpublished), and Jagadishpur Reservoir in Kapilvastu area of southwestern Nepal (Dahal 2016).

We report Clouded Leopard and Fishing Cat recorded for the first time in Parsa NP in southern central Nepal during a monitoring survey targeting tiger. These are the first confirmed records for the presence of both species in Parsa NP.

Study area

Parsa NP is located in southern central Nepal (27.306^{0}N & 84.781^{0}E) (Fig. 1), covering an area of 627km^2 (Thapa et al. 2014; Lamichhane et al. 2018). It is contiguous with Chitwan NP in the west and is a critical region in the Chitwan-Parsa-Valmiki trans-boundary forest complex in the Terai Arc landscape (Chanchani et al 2014). The park is dominated by subtropical dry deciduous forest with colonizing *Saccharum spontaneum* and *Imperata cylindrica* on the dry riverbeds and floodplains to a climax Sal *Shorea robusta* forest on Bhabhar and hillsides (Thapa et al. 2014). The streams running off the Churia Hills permeates the porous sediment and flows underground, reappearing south of the park and restricting water availability in more than 70% of its area throughout the dry months (Lamichhane et al. 2017). The protected area supports diverse mammalian fauna including Tiger, Leopard, Dhole *Cuon alpinus,* Striped Hyena *Hyaena hyaena*, Golden Jackal *Canis aureus*, Bengal Fox *Vulpes bengalensis*, and Honey Badger *Mellivora capensis* (Thapa et al. 2014). The major prey species are Spotted Deer *Axis axis*, Barking Deer *Muntiacus muntjak*, Gaur *Bos gaurus*, Nilgai *Bosephalus tragocamelus*, Wild Boar *Sus scrofa*, and Sambar *Rusa unicolor*. The combined ungulate density was estimated to be 25.33 (SE±3.9) ungulates/km^2 in 2013 (Dhakal et al. 2014).

Materials and Methods

The study was primarily designed for tiger monitoring, deploying camera traps in continuous cells of 2kmx2km during the cool and dry seasons of November 2014 to January 2015 and February to April 2016, covering the core area of Parsa NP during the first survey period and the new extension area during the 2016 survey period (Fig. 1). A pair of camera traps (model: Panthera V5) was placed in each cell. All the camera traps were active for 24 hours for a minimum of 21 days during both survey periods. Following completion of the field survey, images were checked manually for the species recorded.

Results

Camera traps were deployed in 130 and 167 locations during the first and second survey period, with a total survey effort of 7,230 trap nights, including 3,549 and 3,681 trap nights, respectively. We obtained a single image of Clouded Leopard and four images of a Fishing Cat.

Clouded Leopard

A single Clouded Leopard was photographed on 30 November 2014 at 00.26h at 27.312°N & 84.961°E (Fig. 1) on the eastern edge of Parsa NP. The species was identified by comparing the pelt pattern with the image of a Clouded Leopard provided in the IUCN Red List (Grassman et al. 2016). The age and sex of the individual, however, could not be determined. The Clouded Leopard was camera trapped in Sal-dominated mixed forests (Image 1).

Fishing Cat

Four images of Fishing Cat were obtained from three camera trap stations (27.235°N & 84.892°E; 27.234°N & 84.914°E; 27.246°N & 84.946°E) on the southeastern edge of Parsa NP during the 2016 survey (Fig. 1). Comparison of the pelage on both flanks from the paired cameras confirmed that all three stations recorded the same individual. We could not confirm its sex from the images. These three camera trap stations were in a Sal-dominated

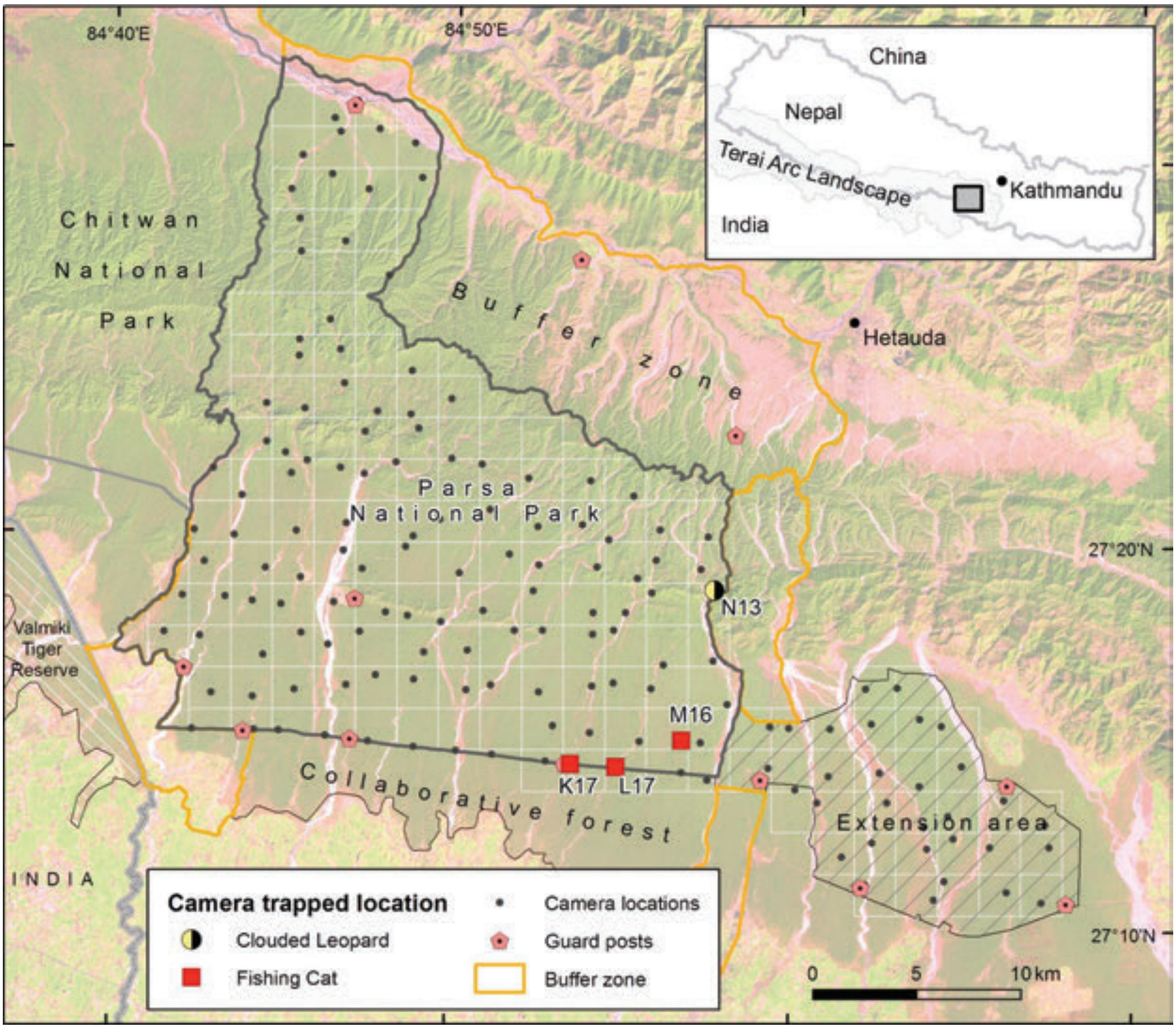

Figure 1. Study area with camera trap locations in Parsa National Park, Nepal.

forest (Image 2).

Discussion

Our records confirm that both Clouded Leopard and Fishing Cat occur in Parsa NP. Thus, both species were documented in all three protected areas within the Chitwan-Parsa-Valmiki trans-boundary forest complex (Clouded Leopard: Ghimirey et al. 2014; Lamichhane et al. 2014; Kamlesh Maurya pers. comm. 2017; Fishing Cat: Dahal & Dahal 2011; Mishra 2016; Mukherjee et al. 2016).

Borah et al. (2014) reported frequent captures of the Clouded Leopard by camera traps set up on paths and animal trails in Manas NP. Also, Lamichhane et al. (2014) reported records of the species on the forest floor in Chitwan NP. The camera locations in Parsa NP were selected after an intensive search for signs such as scratch marks to maximize the probability of capturing the tiger. Our protocol of checking camera traps every alternate day may have impacted encounter rates of shy and elusive small wild cats.

Large intact and interconnected forest patches of this complex (ca. 3,000km^2) might have provided an opportunity for the dispersal of the Clouded Leopard. Such interconnected forest habitats are important for sustaining viable populations of large carnivores such as Tiger, Leopard, and Clouded Leopard, which in turn also protect the functionality of the ecosystem (Borah et al. 2014; Chanchani et al. 2014). To maintain its ecological integrity, the Chitwan-Parsa-Valmiki protected area complex should also be kept intact by avoiding the construction of linear infrastructure such as roads and railways that fragment the forests, or by establishing wildlife-friendly corridors.

Across its range, the Fishing Cat is associated with wetlands such as coastal and inland wetlands, rivers

Image 1. Clouded Leopard *Neofelis nebulosa* in a dry riverbed in Parsa National Park, Nepal. © Department of National Parks and Wildlife Conservation, National Trust for Nature Conservation, Zoological Society of London, 16 November 2014.

Image 2. Fishing Cat *Prionailurus viverrinus* on a forest road in Parsa National Park, Nepal. © Department of National Parks and Wildlife Conservation, National Trust for Nature Conservation, Zoological Society of London, 08 March 2016.

Table 1. Details of Clouded Leopard and Fishing Cat capture events in Parsa National Park, Nepal.

Particulars	Fishing Cat	Clouded Leopard
Grid ID (GPS Locations)	K17 (27.235^{0}N & 84.892^{0}E), L17 (27.234^{0}N & 84.914^{0}E), M16 (27.246^{0}N & 84.946^{0}E)	N13 (27.312^{0}N & 84.961^{0}E)
Elevation	201–255 m	458m
Number of detections	3	1
Date of capture	8.iii.2016	30.xi.2014
Time of capture	04.48h (K17), 05.37h (L17) & 19.43h (M16)	00.26h
Flank image	Both	Right
	Forest road	Riverbed
Habitat surrounding the location	Sal forest	Sal forest
Distance to nearest settlement	4.5–5.6 km	5.7km
Distance to nearest perennial water source	4.2–5.7 km	0.5km

and streams, marsh areas, reed beds, tidal creeks, and mangrove forests (Mukherjee et al. 2016). Parsa NP is a relatively dry area with limited water sources, especially during the dry rainless season between October and April. Perennial water sources here are confined to small streams coming from the Churia Hills and flowing partly underneath the surface, which limits the availability of water in the park (Israil et al. 2006; Thapa et al. 2014).

The location where the Fishing Cat was recorded is a dry forest road in Bhabar Forest, which contrasts with records in wetlands across southern and southeastern Asia (e.g., Cutter & Cutter 2009 in Thailand; Mukherjee et al. 2012 in West Bengal, India; Islam et al 2015 in Pakistan; Taylor et al. 2016 in eastern Nepal; Palei et al. 2018 in Odisha, India; Thaung et al. 2018 in coastal Cambodia). A targeted survey for Fishing Cat by Sharma (2016) did not record the species in Parsa NP. This survey covered only a small area (~20km^2), targeting two sites close to rivers and streams. Our record is at a distance of ~20km from the survey area of Sharma (2016) and well away from wetland sites or water sources (>5km). Looking at the linear movement and the single record of the species, we assume that the individual might have arrived incidentally at the location or been passing through it while migrating to another habitat.

While the global ranges of Fishing Cat and Clouded Leopard are declining due to various anthropogenic factors (Grassman et al. 2016; Mukherjee et al. 2016), the current records in an additional protected area would help in their conservation.

These records, however, also indicate that more in-depth surveys on their distribution, abundance, and habitat use are necessary and warranted. In addition, such targeted surveys will also contribute to understanding the dynamics between larger carnivores, like tiger and leopard, and small wild cats. Hence, we recommend a targeted survey covering the current capture locations to ascertain whether these individuals were transiting or are resident.

References

Appel, A., Y. Ghimirey & R. Acharya (2012). Status Assessment of Wild Felids with a Special Focus on Clouded Leopard and Asian Golden Cat in the Hugu-Kori Forest, Annapurna Conservation Area, Nepal. Friends of Nature, Kathmandu, Nepal, 24pp.

Borah, J., T. Sharma, D. Das, N. Rabha, N. Kakati, A. Basumatary & J. Vattakaven (2014). Abundance and density estimates for common Leopard *Panthera pardus* and Clouded Leopard *Neofelis nebulosa* in Manas National Park, Assam, India. *Oryx* 48(1): 149–155; https://doi.org/10.1017/S0030605312000373

Chanchani, P., B.R. Lamichhane, S. Malla, K. Maurya, A. Bista, R. Warrier, S. Nair, M. Almeida, R. Ravi, R. Sharma, M. Dhakal, S.P. Yadav, M. Thapa, S.R. Jnawali, N.M.B. Pradhan, N. Subedi, G.J. Thapa, H. Yadav, Y.V. Jhala, Q. Qureshi, J. Vattakaven & J. Borah (2014). Tigers of the Transboundary Terai Arc Landscape: Status, Distribution and Movement in the Terai of India and Nepal. National Tiger Conservation Authority, Government of India, and Department of National Park and Wildlife Conservation, Government of Nepal, 98pp.

Cutter, P. & P. Cutter (2009). Recent sightings of Fishing Cats in Thailand. *Cat News* 51: 12–13.

Dahal, S. (2016). Fishing Cats outside protected areas in Nepal Terai, pp27–28. In: Appel, A. & J.W. Duckworth (eds.). Proceedings of the First International Fishing Cat Conservation Symposium, 25–29 November 2015, Nepal. Fishing Cat Working Group, Bad Marienberg, Germany and Saltford, Bristol, United Kingdom, 75pp.

Dahal, S. & D.R. Dahal (2011). Trapping of Fishing Cat in Chitwan National Park, Nepal. *Cat News* 55: 10–11.

Dhakal, M., M. Karki, S.R. Jnawali, N. Subedi, N.M.B. Paradhan, S. Malla, B.R. Lamichhane, C.P. Pokheral, G.J. Thapa, J. Oglethorpe, S.A. Subba, P.R. Bajracharya & H. Yadav (2014). Status of Tigers and Prey in Nepal. Department of National Parks and Wildlife Conservation, Kathmandu, Nepal, 74pp.

Dinerstein, E. & J.N. Mehta (1989). The Clouded Leopard in Nepal. *Oryx* 23(4): 199–201; https://doi.org/10.1017/S0030605300023024

Ghimirey, Y. & R. Acharya (2018). The Vulnerable Clouded Leopard *Neofelis nebulosa* in Nepal: an update. *Oryx* 52(1): 166–170; https://doi.org/10.1017/S0030605316000582

Ghimirey, Y., K. Yadav, J. Rai, R. Baral & R. Acharya (2019). Clouded Leopard in Sikles-Bhujung landscape, Annapurna Conservation Area, Nepal. *Cat News* 61: 13–15.

Ghimirey, Y., R. Acharya & S. Dahal (2014). An undocumented record of a Clouded Leopard captured in Chitwan District, Nepal. *Cat News* 60: 27–28.

Grassman, L., A. Lynam, S. Mohamad, J.W. Duckworth, J. Borah, D. Willcox, Y. Ghimirey, A. Reza & H. Rahman (2016). *Neofelis nebulosa*. In: The IUCN Red List of Threatened Species: e.T14519A97215090. Accessed on 15 August 2018; https://doi.org/10.2305/IUCN.UK.2016-1.RLTS.T14519A97215090.en

Hodgson, B.H. (1853). *Felis macrosceloides*. *Proceedings of the Zoological Society of London* 21: Plate XXXVIII.

Islam, S., R. Nawaz & M. Moazzam (2015). A survey of Smooth-coated Otter (*Lutrogale perspicillata sindica*) and Fishing Cat (*Prionailurus viverrinus*) in Chotiari Reservoir, Sanghar, Pakistan, using camera traps. *International Journal of Biology and Biotechnology* 12(4): 579–584.

Israil, M., M. Al-hadithi & D.C. Singhal (2006). Application of a resistivity survey and geographical information system (GIS) analysis for hydrogeological zoning of a piedmont area, Himalayan foothill region, India. *Hydrogeology Journal* 14(5): 753–759.

Jackson, R.M. (1996). Home range, movements and habitat use of Snow Leopard (*Uncia uncia*) in Nepal. PhD Thesis. University of London, United Kingdom, 233pp.

Karki, J.B., B. Pandav, S.R. Jnawali, R. Shrestha, N.M.B. Pradhan, B.R. Lamichane, P. Khanal, N. Subedi & Y.V. Jhala (2015). Estimating the abundance of Nepal's largest population of tigers *Panthera tigris*. *Oryx* 49(1): 150–160; https://doi.org/10.1017/S0030605313000471

Lama, S.T., J.G. Ross, D. Bista, A.P. Sherpa, G.R. Regmi, M.K. Suwal, P. Sherpa, J. Weerman, S.S. Lama, M. Thapa, L.P. Poudyal & A.M. Paterson (2019). First photographic record of Marbled Cat *Pardofelis marmorata* Martin, 1837 (Mammalia, Carnivora, Felidae) in Nepal. *Nature Conservation* 32: 19–34; https://doi.org/10.3897/natureconservation.32.29740

Lamichhane, B.R., C.P. Pokheral, S. Poudel, D. Adhikari, S.R. Giri, S. Bhattarai, T.R. Bhatta, R. Pickles, R. Amin, K.P. Acharya, M. Dhakal, U.R. Regmi, A.K. Ram & N. Subedi (2018). Rapid recovery of tigers *Panthera tigris* in Parsa Wildlife Reserve, Nepal. *Oryx* 52(1): 16–24; https://doi.org/10.1017/S0030605317000886

Lamichhane, B.R., M. Dhakal, N. Subedi & C.P. Pokheral (2014). Clouded Leopard co-exist with other five felids in Chitwan National Park, Nepal. *Cat News* 61: 30–32.

Lamichhane, B.R., R. Kadariya, N. Subedi, B.K. Dhakal, M. Dhakal, K. Thapa & K.P. Acharya (2016). Rusty-spotted Cat: 12th cat species discovered in western Terai of Nepal. *Cat News* 64: 30–33.

Mishra, R., K. Basnet, R. Amin & B.R. Lamichhane (2018). Fishing Cat *Prionailurus viverrinus* Bennett, 1833 (Carnivora: Felidae) distribution and habitat characteristics in Chitwan National Park, Nepal. *Journal of Threatened Taxa* 10(11): 12451–12458; https://doi.org/10.11609/jott.3426.10.11.12451-12458

Mukherjee, S., A. Appel, J.W. Duckworth, J. Sanderson, S. Dahal, D.H.A. Willcox, V. Herranz Muñoz, G. Malla, A. Ratnayaka, M. Kantimahanti, A. Thudugala, R. Thaung & H. Rahman (2016). *Prionailurus viverrinus*. In: The IUCN Red List of Threatened Species: e.T18150A50662615. Accessed on 15 August 2018; https://doi.org/10.2305/IUCN.UK.2016-2.RLTS.T18150A50662615.en

Mukherjee, S., T. Adhya, P. Thatte & U. Ramakrishnan (2012). Survey of the Fishing Cat *Prionailurus viverrinus* Bennett, 1833 (Carnivora: Felidae) and some aspects impacting its conservation in India. *Journal of Threatened Taxa* 4(14): 3355–3361; https://doi.org/10.11609/JoTT.o3199.3355-61

Palei, H.S., U.P. Das & S. Debata (2018). The Vulnerable Fishing Cat *Prionailurus viverrinus* in Odisha, eastern India: status and conservation implications. *Zoology and Ecology* 28(2): 69–74; https://doi.org/10.1080/21658005.2018.1468646

Pandey, B.P. (2012). Clouded Leopard in Shivapuri Nagarjun National Park, Nepal. *Cat News* 57: 24–25.

Sharma, B. (2016). Status of Fishing Cat in Parsa Wildlife Reserve, central Nepal, pp. 61–63. In: Appel, A. & J.W. Duckworth (eds.). Proceedings of the First International Fishing Cat Conservation Symposium, 25–29 November 2015, Nepal. Fishing Cat Working Group, Bad Marienberg, Germany and Saltford, Bristol, United Kingdom, 75pp.

Smith, J.L.D., S.C. Ahearn & C. McDougal (1998). Landscape analysis of Tiger distribution and habitat quality in Nepal. *Conservation Biology* 12(6): 1338–1346.

Taylor, I.R., H.S. Baral, P. Pandey & P. Kaspal (2016). The conservation status of the Fishing Cat *Prionailurus viverrinus* Bennett, 1833 (Carnivora: Felidae) in Koshi Tappu Wildlife Reserve, Nepal. *Journal of Threatened Taxa* 8(1): 8323–8332; https://doi.org/10.11609/jott.2034.8.1.8323-8332

Tempa, T., M. Hebblewhite, L.S. Mills, T.R. Wangchuk, N. Norbu, T. Wangchuk, T. Nidup, P. Dendup, D. Wangchuk, Y. Wangdi & T. Dorji (2013). Royal Manas National Park, Bhutan: a hot spot for wild felids. *Oryx* 47(2): 207–210; https://doi.org/10.1017/S0030605312001317

Thapa, K., R. Shrestha, J. Karki, G.J. Thapa, N. Subedi, N.M.B. Pradhan & M.J. Kelly (2014). Leopard *Panthera pardus fusca* density in the seasonally dry, subtropical forest in the Bhabhar of Terai Arc, Nepal. *Advances in Ecology* 2014(286949): 1–12; https://doi.org/10.1155/2014/286949

Thaung, R., V.H. Muñoz, J. Holden, D. Willcox & N.J. Souter (2018). The Vulnerable Fishing Cat *Prionailurus viverrinus* and other globally threatened species in Cambodia's coastal mangroves. *Oryx* 52(4): 636–640; https://doi.org/10.1017/S0030605317001491

Yadav, S.K., B.R. Lamichhane, N. Subedi, M. Dhakal, R.K. Thapa, L. Poudyal & B.R. Dahal (2018). Fishing Cat camera trapped in Babai Valley of Bardia National Park, Nepal. *Cat News* 67: 31–33.

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First photographic evidence of polymorphic Asiatic Golden Cat *Catopuma temminckii* Vigors & Horsfield, 1827 (Mammalia: Carnivora: Felidae) in Buxa Tiger Reserve, West Bengal, India

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Abstract: During a camera trap survey in Buxa Tiger Reserve in West Bengal, India, individuals of Asiatic Golden Cat *Catopuma temminckii* were photographed between 13 and 26 February 2018. The images provide the first photographic evidence of the species presence in this protected area. Both golden and spotted individuals were recorded.

Keywords: Camera trapping, eastern Himalaya, spotted morph, subtropical wet hill forest, Temminck's Cat.

The Asiatic Golden Cat *Catopuma temminckii*, also known as the Temminck's Cat, is a medium-sized elusive wild cat distributed from eastern Nepal (Ghimirey & Pal 2009) to southeastern Asia (Holden 2001; Johnson et al. 2009; Gray et al. 2014; Tantipisanuh et al. 2014; Willcox et al. 2014; Zaw et al. 2014). In India, it was recorded in the protected areas of Sikkim, Assam, Arunachal Pradesh, Meghalaya, and Mizoram (Choudhury 2007; Bashir et al. 2011; Lyngdoh et al. 2011; Gouda et al. 2016; Nadig et al. 2016; Mukherjee et al. 2018). It is listed as Near Threatened by the IUCN (McCarthy et al. 2015) and as Scheduled I species in the Indian Wildlife (Protection) Act 1972 (Menon 20014).

The Asiatic Golden Cat is the largest wild cat among the oriental Felinae (Bashir et al. 2011) It is remarkably polymorphic in its pelage and is also known as "a feline of many costumes" (Dhendup 2016). The most common coat colour is golden or red-brown, less frequently also dark brown (Jutzeler et al. 2010), grey, or black (Jigme 2011). The spotted morph was previously known only from China (Smith & Xie 2008) and Bhutan (Wang 2007; Wang & Macdonald 2009).

Study area

Buxa Tiger Reserve is situated in Alipurduar District, West Bengal, India, covering an area of 760.87km^2. It lies between 26.500–26.702 ^{0}N and 89.333–89.860 ^{0}E, nestled between the international boundary to Bhutan in the north, the state boundary to Assam in the east, Jaldapara Wildlife Division in the west, and Cooch Behar District in the south (Fig. 1). The reserve is located at the confluence of three major biogeographic zones, namely, central Himalaya, Brahmaputra Valley, and

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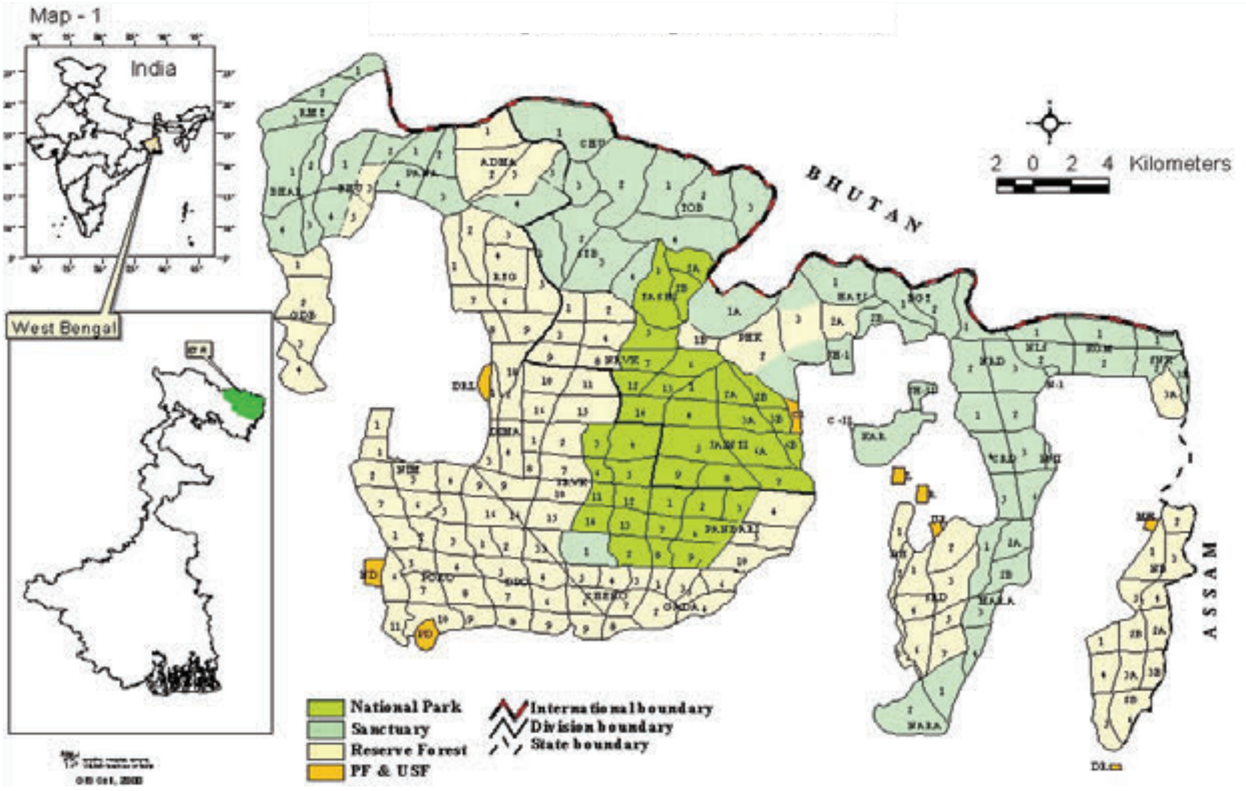

Figure 1. Buxa Tiger Reserve, West Bengal, India (Source: Tiger Conservation Plan 2013).

Figure 2. Boundary of Buxa Tiger Reserve in West Bengal, India.

Figure 3. Locations where Asiatic Golden Cats were recorded in February 2018 (yellow pins).

lower Gangetic plains. Altitude ranges between 53m and 1,735m and constitutes the eastern Himalayan subtropical wet hill forest (Tiger Conservation Plan 2013). Notable tree species in the study area are *Quercus*, *Acer, Castanopsis, Magnolia cathcartii*, *Alnus nepalensis, Phoebe attenuate, Betula cylindrostachys*, and various bamboo Bambusoideae species (Tiger Conservation Plan 2013).

This camera trap survey was conducted between January and March 2018 using 182 Cuddeback C series camera traps with colour strobe module. We recorded

Table 1. Details of camera trap images of Asiatic Golden Cat in Buxa Tiger Reserve, West Bengal, India.

Image	Location	Date	Time	Altitude	Morph
1, 2	26.770°N & 89.577°E	17.ii.2018	13.19h	1,025m	Golden
3, 4, 5	26.781°N & 89.611°E	13.ii.2018	09.22–09.23 h	1,355m	Golden and spotted
6	26.781°N & 89.611°E	26.ii. 2018	15.28h	1,355m	Golden

Images 1 & 2. Golden morph of Asiatic Golden Cat recorded at 1,025m on 17 February 2018. © Camera Trap Buxa Tiger Reserve, placed by Mayukh Ghose.

Images 3, 4 & 5. Spotted and golden morphs of Asiatic Golden Cat recorded at 1,355m on 13 February 2018. © Camera Trap Buxa Tiger Reserve, placed by Mayukh Ghose.

Image 6. Golden morph of Asiatic Golden Cat recorded at 1,355m on 26 February 2018. © Camera Trap Buxa Tiger Reserve, placed by Mayukh Ghose.

coordinates using a Garmin E-trex 10 GPS, based on WGS 84 datum, and a digital altimeter for recording elevation of camera trap locations.

The study area was divided into a grid with cells of 1.414×1.414 sqkm each in two blocks of 240km². The cameras were placed opposite each other, keeping a minimum distance of 0.7km to the next pair. The 91 camera trap pairs were active all throughout 24 hours.

Results

Camera traps were active on 26 days for a total of 2,366 station days in 195 locations. Asiatic Golden Cats were recorded in six images on three different days in two locations, both located in the high altitude zone of the Buxa Tiger Reserve. These locations are separated by 450sqkm. All six images show Asiatic Golden Cats during the day (Images 1–6).

Golden and spotted morphs were recorded at the same location, interacting with each other in a single frame (Images 3 & 4).

Discussion

Our records provide the first photographic evidence for the presence of Asiatic Golden Cat in the Buxa Tiger

Reserve. This is also the first instance of golden and spotted morphs of Asiatic Golden Cat being recorded together in the reserve.

The spotted morph, also known as ocelot morph, of the Asiatic Golden Cat was long thought to be more common in China than elsewhere in the species global range (Jutzeler et al. 2010). In the Himalaya, this morph was first recorded in Bhutan's Jigme Singye Wangchuck National Park at an elevation of 3,738m (Wang 2007). Four colour morphs of Asiatic Golden Cat were recorded in the eastern Himalaya. Ghimirey & Pal (2009) reported a melanistic morph in a *Schima-Castanopsis* forest in Nepal's Makalu-Barun National Park. Bashir et al. (2011) reported melanistic and dark grey morphs co-occurring in temperate and subalpine forests of Khanchendzonga Biosphere Reserve, Sikkim. Golden, dark red, grey, and black morphs were recorded above 1,500m in Bhutan (Jigme 2011; Vernes et al. 2015; Dhendup 2016), in Myanmar (Zaw et al. 2014), and in and around Eaglenest Wildlife Sanctuary, Arunachal Pradesh, India (Mukherjee et al. 2018).

In contrast, only golden morphs were reported south of the Isthmus of Kra in peninsular Malaysia (Gumal et al. 2014) and in Sumatra (Holden 2001; Haidir et al. 2013; Pusparini et al. 2014). The occurrence of diverse colour morphs of Asiatic Golden Cat seems to be limited to the eastern Himalaya, China, and Indo-China (Patel et al. 2016). The latter authors suggested that this phenomenon indicates a long adaptation process to diverse habitats in the species northern range while only golden morphs colonized the Sunda shelf during its southward expansion.

References

Bashir, T., T. Bhattacharya, K. Poudyal & S. Sathyakumar (2011). Notable observations on the melanistic Asiatic Golden Cat (*Pardofelis temminckii*) of Sikkim, India. *NeBIO* 2(1): 1–4.

Choudhury, A. (2007). Sighting of Asiatic Golden Cat in the grasslands of Assam's Manas National Park. *Cat News* 47: 29.

Dhendup, T. (2016). Status of Asiatic Golden Cat *Catopuma temminckii* Vigors & Horsfield, 1827 (Carnivora: Felidae) in Bhutan. *Journal of Threatened Taxa* 8(4): 8698–8702; https://doi.org/10.11609/jott.2560.8.4.8698-8702

Ghimirey, Y. & P. Pal (2009). First camera trap image of Asiatic Golden Cat in Nepal. *Cat News* 51: 19.

Gouda, J., J. Sethy & N.P.S. Chauhan (2016). First photo capture of Asiatic Golden Cat in Dampa Tiger Reserve, Mizoram, India. *Cat News* 64: 26–27.

Gray, T.N.E., P. Channa, P. Chanrattanak & P. Sovanna (2014). The status of Jungle Cat and sympatric small cats in Cambodia's eastern plains. *Cat News Special Issue* 8: 19–23.

Gumal, M., A.B.B.M. Salleh, M.N. Yasak, L.S. Horng, B.P.Y.H. Lee, L.C. Pheng, H. Hamzah, D. Kong, D. Magintan, D.T.C. Yung, A.Z.B. Zalaluddin, A.B. Azmi, N.B. Khalid, T.P. Yen, V. Mufeng, F.C.F. Meng & S. Ng (2014). Small-medium wild cats of Endau Rompin landscape in Johor, peninsular Malaysia. *Cat News Special Issue* 8: 10–18.

Haidir, I.A., Y. Dinata, M. Linkie & D.W. MacDonald (2013). Asiatic Golden Cat and Sunda Clouded Leopard occupancy in the Kerinci Seblat landscape, west-central Sumatra. *Cat News* 59: 7–10.

Holden, J. (2001). Small cats in Kerinci Seblat National Park, Sumatra, Indonesia. *Cat News* 35: 11–14.

Jigme, K. (2011). Four colour morphs of and the altitudinal record of Asiatic Golden Cat in Bhutan. *Cat News* 55: 12–13.

Johnson, A., C. Vongkhamheng & T. Saithongdam (2009). The diversity, status and conservation of small carnivores in a montane tropical forest in northern Laos. *Oryx* 43(4): 626–633.

Jutzeler, E., Y. Xie & K. Vogt (2010). Asiatic Golden Cat in China. *Cat News Special Issue* 5: 40–41.

Lyngdoh, S., K.M. Selvan, G.V. Gopi & B. Habib (2011). First photographic evidences of two rare cats from Pakke Tiger Reserve, western Arunachal Pradesh. *Current Science* 101(10): 1284–1286.

McCarthy, J., S. Dahal, T. Dhendup, T.N.E. Gray, S. Mukherjee, H. Rahman, P. Riordan, N. Boontua & D. Willcox (2015). *Catopuma temminckii*. In: The IUCN Red List of Threatened Species: e.T4038A97165437. Accessed on July 2018. https://doi.org/10.2305/iucn.uk.2008.rlts.t4038a10316334.en

Menon, V. (2014). *Indian Mammals: A Field Guide*. Hachette Boo Publishing India Pvt. Ltd., Gurgaon, India, 528pp.

Mukherjee, S., P. Choudhary, R. Arthreya & P.V. Karunakaran (2018). A tale of tails — an attempt to decipher small cat distributions by tail lengths, pp11–12. In: Appel, A., S. Mukherjee & S.M. Cheyne (eds.). Proceedings of the First International Small Wild Cat Conservation Summit, 11–14 September 2017, United Kingdom. Wild Cat Network, Bad Marienberg, Germany, Sálim Ali Centre for Ornithology and Natural History, Coimbatore, India, and Borneo Nature Foundation, Oxford, United Kingdom, 40pp.

Nadig, S., R. Navya & A.P. Silva (2016). Small cats in the Himalayan foothills: the Asian Golden Cat of Nongkhyllem Wildlife Sanctuary, India. *Small Wild Cat Conservation News* 2: 23.

Patel, R.P., D.W. Förster, A.C. Kitchener, M.D. Rayan, S.W. Mohamed, L. Werner, D. Lenz, H. Pfestorf, S. Kramer-Schadt, V. Radchuk, J. Fickel & A. Wilting (2016). Two species of southeast Asian cats in the genus *Catopuma* with diverging histories: an island endemic forest specialist and a widespread habitat generalist. *Royal Society Open Science* 3(10): 160350; https://doi.org/0.1098/rsos.160350

Pusparini, W., H.T. Wibisono, G.V. Reddy, Tarmizi & P. Bharata (2014). Small and medium-sized cats in Gunung Leuser National Park, Sumatra, Indonesia. *Cat News Special Issue* 8: 4–9.

Smith, A.T. & Y. Xie (2008). *A Guide to the Mammals of China*. Princeton University Press, New Jersey, 544pp.

Tantipisanuh, N., W. Chutipong, D. Ngoprasert, A.J. Lynam, R. Steinmetz, R. Sukmasuang, K.E. Jenks, L.I. Grassman Jr., P. Cutter, S. Kitamura, M.C. Baker, W. McShea, N. Bhumpakphan, G.A. Gale & D.H. Reed (2014). Recent distribution records, threats and conservation priorities of small cats in Thailand. *Cat News Special Issue* 8: 36–44.

Tiger Conservation Plan (2013). Buxa Tiger Conservation Foundation Trust, Buxa Tiger Reserve, Deptartment of Forests Government of West Bengal.

Vernes, K., T. Sangay, R. Rajaratnam & R. Singye (2015). Social interaction and co-occurrence of colour morphs of the Asiatic Golden Cat, Bhutan. *Cat News* 62: 18–20.

Wang, S.W. (2007). A rare morph of the Asiatic Golden Cat in Bhutan's Jigme Singye Wangchuk National Park. *Cat News* 47: 27–28.

Wang, S.W. & D.W. Macdonald (2009). The use of camera traps for estimating tiger and leopard populations in the high altitude mountains of Bhutan. *Biological Conservation* 142(3): 606–613.

Willcox, D., T.Q. Phuong, H.M. Duc & N.T.T. An (2014). The decline of non-Panthera cat species in Vietnam. *Cat News Special Issue* 8: 53–61.

Zaw, T., T. Myint, S. Htun, S.H.T. Po, K.T. Latt, M. Maung & A.J. Lynam (2014). Status and distribution of smaller cats in Myanmar. *Cat News Special Issue* 8: 24–30.

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First photographic record of the Rusty-spotted Cat *Prionailurus rubiginosus* (I. Geoffroy Saint-Hilaire, 1831) (Mammalia: Carnivora: Felidae) in Horton Plains National Park, Sri Lanka

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Abstract: The Rusty-spotted Cat *Prionailurus rubiginosus* is thought to be present in most forested areas of Sri Lanka. Though it was suggested that the species may occur in montane regions, there was no photographic evidence to date. Here we present the first photographic record of the Rusty-spotted Cat in Horton Plains National Park. Individuals including cubs were photo-captured on 15 separate occasions during a 5,538 camera trap days study. These photo-captures were made both during the day and night, and indicate the presence of a breeding population in this protected area.

Keywords: Camera trap, carnivore, Felidae, montane forest, protected area.

The Rusty-spotted Cat *Prionailurus rubiginosus* (I. Geoffroy Saint-Hilaire, 1831) is native to India, Nepal, and Sri Lanka (Nekaris 2003; Mukherjee et al. 2016). It is currently listed by the IUCN as Near Threatened (Mukherjee et al. 2016) and is considered nationally Endangered in Sri Lanka (Ministry of Environment 2012). Its main threats are habitat loss and fragmentation (Mukherjee et al. 2016).

In Sri Lanka, the Rusty-spotted Cat is thought to be

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present in most forested areas (Philips 1980 cited in Nekaris 2003). Direct evidence of its presence below 170m in arid scrub forests, dry forests, and monsoon forests was presented by Nekaris (2003) and Kittle & Watson (2004). Indirect or anecdotal evidence suggests its presence in wet forests near montane regions (Nekaris 2003). Photographic evidence, however, is scarce, particularly in the montane region. Here we report the first photographic record of the Rusty-spotted Cat above 2,000m in Horton Plains National Park (HPNP), located in Sri Lanka's montane zone, from a series of photo-captures made over a 15-month period.

Study area

HPNP is a protected area covering 31.6km^2 of grassland and montane forest; it was designated as a national park in 1988 (IUCN 1990) and is part of the Central Highlands of Sri Lanka World Heritage Site (World Heritage Convention 2018). It is located within the wet and cool highlands (Fernanado 1968) between 6.783–6.833 °N and 80.767–80.850 °E at an altitude of 2,100–2,300 m (Fig. 1). It receives an annual rainfall of 2,000–5,000 mm (Werner 1988). The vegetation consists of tropical montane forest interspersed with a mosaic of large grasslands and forest patches; extensive grasslands and terraces indicate areas of former farmland (Padmalal & Kikuchi 1993). HPNP is surrounded by natural forests, pine and eucalyptus plantations, and tea plantations with an associated village.

Material and Methods

During the initial phase of a camera trapping project focusing on Sri Lankan Leopard *Panthera pardus kotiya* in HPNP, we established 18 survey points in the core of the national park, next to and surrounding the grassland (Fig. 1). Survey points were located within each cell of a 1km^2 systematic grid. At each survey point, paired Reconyx™ HC500 camera traps were set up facing each other 45cm above the target level. The cameras were deployed from 3 December 2015 to 3 March 2017, for a total of 5,538 camera trap days. Each camera was in operation for 24 hours daily in Rapidfire™ mode, with no delay between image sets, taking three images per trigger.

The retrieved images were sorted into incidents; we define an incident as an image or a series of images of a species or individual separated by intervals of less than one hour. The timings of the incidents were analysed using the overlap package (Ridout & Linkie 2009) in R v. 3.5.1 (R Core Team 2018). The Rusty-spotted Cat was

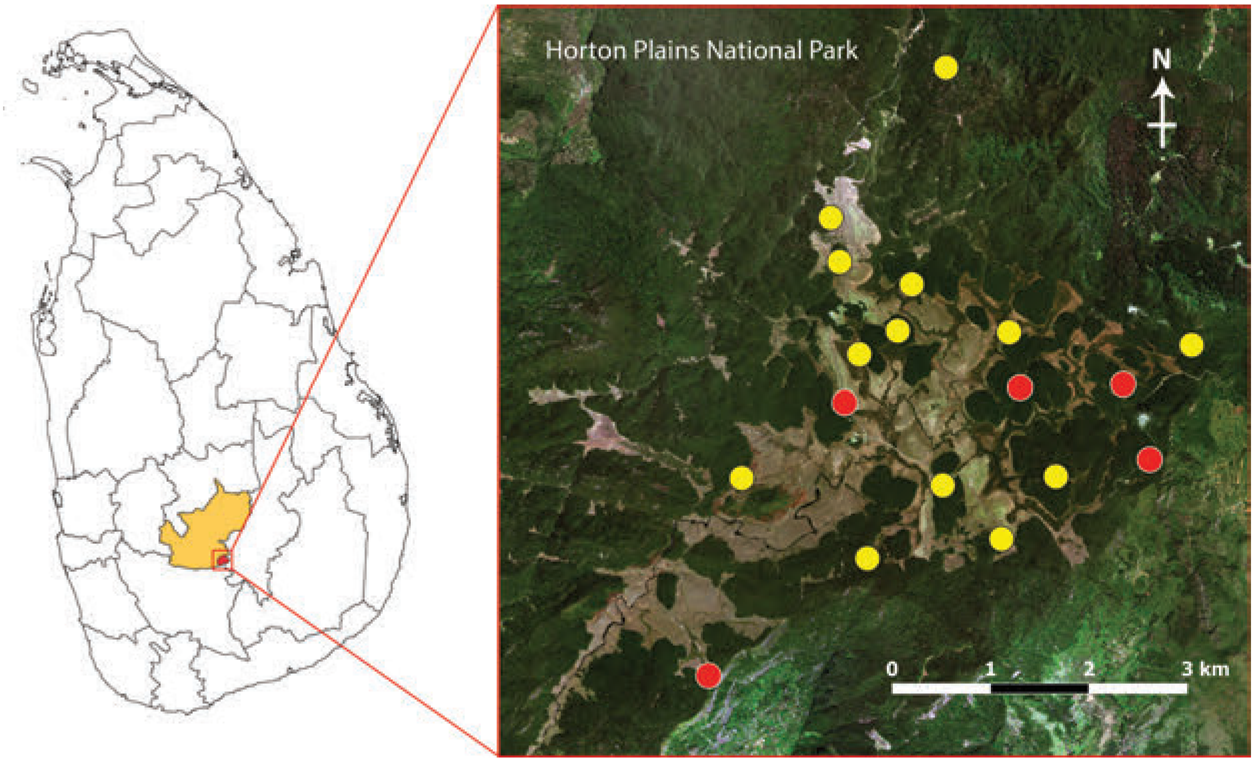

Figure 1. The study site in Horton Plains National Park (HPNP; marked in red on the map of Sri Lanka), located within Nuwara Eliya District (orange). The circles on the satellite image of HPNP represent camera trap locations; Rusty-spotted Cat was recorded in locations marked in red. Administrative map of Sri Lanka obtained from GADM v. 2.8 (2015).

identified by its reddish-grey fur in daytime images, reddish-brown spots that ran longitudinally along its body and head, and by the dark stripes on the inner sides of its front legs (Sunquist & Sunquist 2009). Because of the poor contrast between the cat's spots and coat in our infrared images, we were not able to distinguish among individuals.

Results

Over the survey period, the Rusty-spotted Cat was captured in 15 incidents at five locations, of which two incidents (13.3%) occurred during the day (Table 1; Image 1). These locations were separated by distances of 0.8–5.1 km. In the first incident on 26 March 2016, two adult individuals were recorded in the same image. The last incident was recorded on 16 October 2016. One notable incident shows an adult female with a kitten during the day on 16 June 2016. On 22 July 2016, an adult individual was photographed with a rodent in its jaws. Overall, most photo-captures occurred between sunset and sunrise (Fig. 2).

Discussion

Our findings make an important extension to the documented range of the species, as previously it was only documented below 2,100m (Nekaris 2003; Kittle & Watson 2004). Further, the record of an adult female Rusty-spotted Cat with a kitten indicates the presence of a breeding population in Horton Plains National Park. This also indicates that the Rusty-spotted Cat possibly maintains a reproductive population in montane forest regions.

Given the nationally Endangered status of the species, these findings highlight the conservation value of HPNP and may have implications for managing tourism in the national park. HPNP is one of the most highly visited national parks in Sri Lanka (Sri Lanka Tourist Board 2017) with strict legal protection and enforcement; therefore, the wildlife populations therein are likely adequately protected. Outside HPNP, however, the montane forest is one of the most threatened habitats in Sri Lanka (Kittle et al. 2017). More research needs to be carried out in high-altitude habitats throughout Sri Lanka to determine the importance of montane forest habitats and to assess the impact of forest fragmentation and land use change for the cat's survival.

Table 1. Records of Rusty-spotted Cat in Horton Plains National Park, Sri Lanka, in 2016.

Camera trap station (CT) and elevation	Date and time of records	Remarks
CT02 (2,135m)	6.vi.2016, 01.37h	
	13.vi.2016, 23.37h	
	26.vi.2016, 23.59h	
	27.vi.2016, 20.29h	
	27.vi.2016, 23.30h	
	30.vi.2016, 23.24h	
CT10 (2,162m)	16.vi.2016, 09.44h	Daytime capture; one adult individual observed with cub.
	20.vii.2016, 22.03h	
	22.vii.2016, 04.07h	One adult individual observed with a rodent in its jaws.
	13.x.2016, 00.37h	
CT11 (2,084m)	26.iii.2016, 18.11h	Two adult individuals captured in the same image.
CT14 (2,154m)	31.viii.2016, 14.25h	Daytime capture.
CT17 (2,151m)	23.iv.2016, 04.16h	
	10.v.2016, 00.09h	
	16.x.2016, 05.54h	

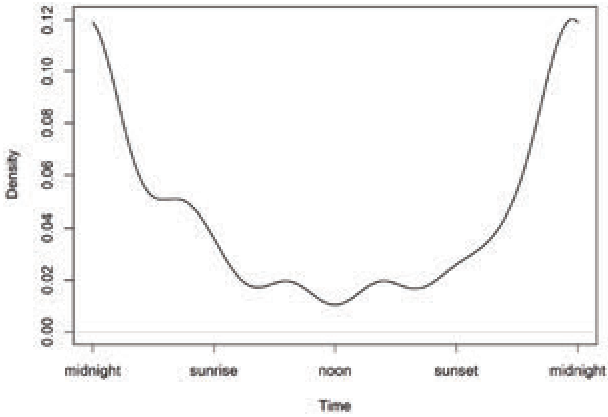

Figure 2. Patterns in photo-capture timings (n=15) of the Rusty-spotted Cat in Horton Plains National Park, Sri Lanka

References

Fernando, S.N.U. (1968). *The Natural Vegetation of Ceylon*. Lake House Bookshop, Colombo, 85pp.

GADM (2015). Database of Global Administrative Areas, Version 2.8. Available online at https://gadm.org/maps/LKA.html. Downloaded on 31 October 2017.

IUCN (1990). Directory of South Asian Protected Areas. IUCN, Gland, Switzerland & Cambridge, U.K., xxiv+294pp.

Kittle, A. & A. Watson (2004). Rusty-spotted Cat in Sri Lanka: observations of an arid zone population. *Cat News* 40: 17–19.

Kittle, A.M., A.C. Watson, S.A. Cushman & D.W. Macdonald (2017). Forest cover and level of protection influence the island-wide distribution of an apex carnivore and umbrella species, the Sri Lankan Leopard (*Panthera pardus kotiya*). *Biodiversity and Conservation* 27(1): 235–263; https://doi.org/10.1007/s10531-017-1431-8

Ministry of Environment (2012). The National Red List of Sri Lanka: Conservation Status of the Fauna and Flora. Ministry of Environment,

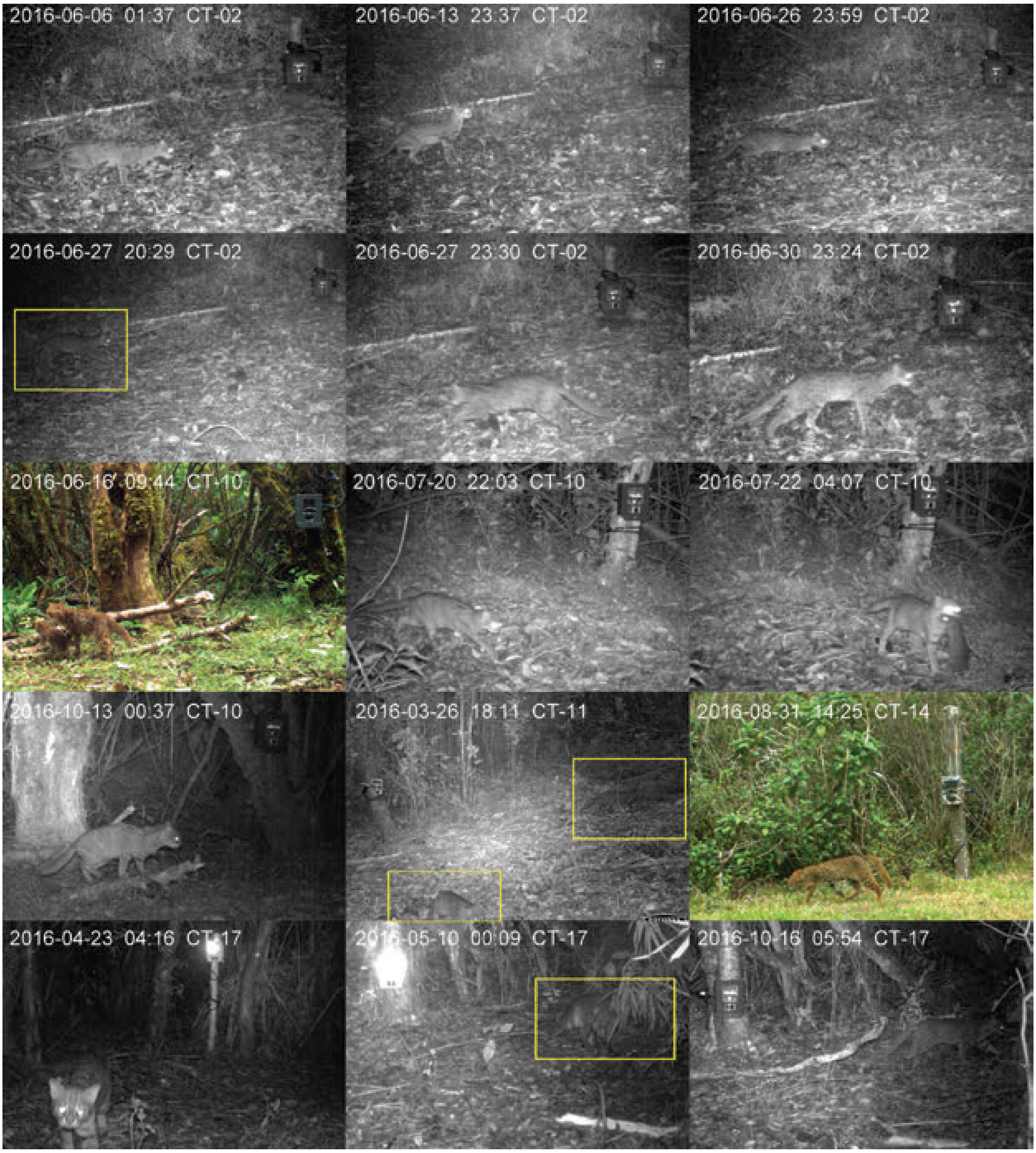

Image 1. Photographic evidence of the Rusty-spotted Cat *Prionailurus rubiginosus* in montane forest of Horton Plains National Park, montane forest of Sri Lanka. Yellow boxes indicate the location of the cat in the image if it is not easily observable. Notable features of these images include the presence of a cub, predation behaviour, and up to two individuals in the same image.

Sri Lanka.

Mukherjee, S., J.W. Duckworth, A. Silva, A. Appel & A. Kittle (2016). *Prionailurus rubiginosus*. In: The IUCN Red List of Threatened Species: e.T18149A50662471. Downloaded on 28 November 2017; https://doi.org/10.2305/IUCN.UK.2016-1.RLTS.T18149A50662471.en

Nekaris, K.A.I. (2003). Distribution and behaviour of three small wild cats in Sri Lanka. *Cat News* 38: 30–32.

Padmalal, U.K.G.K. & T. Kikuchi (1993). A phytosociological survey on grassland in Horton Plains National Park, Sri Lanka. *Ecological Review = Seitaigaku Kenkyu* 22(4): 159–174.

Phillips, W.W.A. (1980). *Manual of the Mammals of Sri Lanka*. Wildlife and Nature Protection Society of Sri Lanka, Colombo, Sri Lanka, 116pp.

R Core Team (2018). The R Project for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. Available online at https://www.R-project.org/. Accessed on 22 July 2018.

Ridout, M. & M. Linkie (2009). Estimating overlap of daily activity patterns from camera trap data. *Journal of Agricultural, Biological, and Environmental Statistics* 14(3): 322–337; https://doi.org/10.1198/jabes.2009.08038

Sri Lanka Tourist Board (2017). Annual Statistical Report 2016. Sri Lanka Tourism Development Authority ASR, 106pp. http://www.sltda.lk/sites/default/files/annual-statical-report-2017.pdf

Sunquist, M.E. & F.C. Sunquist (2009). Family Felidae (cats), pp54–168. In: Wilson, D.E. & R.A. Mittermeier (eds.) *Handbook of the Mammals of the World, Vol. 1. Carnivores*. Lynx Edicions, Barcelona, Spain, 728pp.

Werner, W.L. (1988). Canopy dieback in the upper montane rain forests of Sri Lanka. *GeoJournal* 17(2): 245–248; https://doi.org/10.1007/BF02432929

World Heritage Convention (2018). Central Highlands of Sri Lanka. In: UNESCO World Heritage Centre, World Heritage List. Available online at http://whc.unesco.org/en/list/1203. Accessed on 22 February 2018.

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