The African golden cat *Caracal aurata* in Tanzania: first record and vulnerability assessment

Ilaria Greco and Francesco Rovero

Abstract We report on the first population found in Tanzania of the Vulnerable African golden cat *Caracal aurata*, extending its documented range c. 200 km to the south and south-east. This is one of the least-known and truly forest-dependent felines in Africa, ranging across the Guinea–Congolian forest block. We recorded the new population in Minziro Nature Forest Reserve, north-west Tanzania, during a 3-month survey in 2018. We deployed 70 camera traps on a regular grid and obtained 33 detection events of the golden cat at 26% of sites, with a minimum of 10 individuals across 257 km². We estimated occupancy and detection probability and modelled these in relation to the distance of sampling sites to the forest edge, which coincides with both the Reserve boundary and proximity to human settlements surrounding the Reserve. Mean estimated occupancy was 0.41 ± SE 0.12 (mean detectability = 0.13 ± SE 0.05), with occupancy increasing significantly with distance from the forest edge. Detectability did not vary significantly with distance from the forest edge, but was higher for camera models that had a shorter trigger time. Our findings add to the scant data available for this species. It appears threatened by human activity, which we recorded both outside and within the Reserve, and the presence of the species indicates Minziro Forest is an important site for its conservation.

Keywords African golden cat, camera trapping, *Caracal aurata*, detection probability, edge effect, Minziro, occupancy modelling, Tanzania

Supplementary material for this article is available at doi.org/10.1017/S003060532000040X

The African golden cat *Caracal aurata* is an elusive, medium-sized felid categorized as Vulnerable on the IUCN Red List, regarded as the least-known wildcat in Africa and one of the least-studied felines (Bahaa-El-Din et al., 2015b). As the only truly forest-dwelling feline in Africa, it is threatened by deforestation, habitat destruction and snaring (Bahaa-El-Din et al., 2016). Although the population is believed to be decreasing (Bahaa-El-Din et al., 2015a), robust knowledge of the species is scant. The golden cat occurs in West and Central Africa, with an easternmost population recently confirmed in Kenya from a roadkill in the Aberdare Mountains (Hatfield et al., 2019). Western Tanzania has been regarded as potentially suitable for the species (Butynski et al., 2012), but no records have previously been reported. Here, we present the first record and results of habitat association modelling for a population of golden cat found in Tanzania in the course of a biodiversity survey in Minziro Nature Forest Reserve. We used a camera-trap survey, and occupancy analysis, to determine the distribution of the golden cat and its association with habitat edges and human disturbance.

Camera trapping was conducted in Minziro Nature Forest Reserve, north-west Tanzania, during 3 October–28 December 2018. Established in 2016 and formerly a reserve with lower protection status, it comprises 257 km² of flat, moist forest at a mean altitude of 1,150 m (Rovero et al., 2019). The northern boundary is the country border, merging with the Sango Bay Forest Reserve in Uganda. All other boundaries adjoin human-modified areas with settlements, plantations and patches of drier woodland and grassland (Fig. 1), with Kagera river and seasonal flooding to the east, and a paved road and several villages to the west. The Reserve is the easternmost extension in Tanzania of the Congo–Guinea forest, with fauna typical of West and Central Africa. The Reserve is heavily disturbed by illegal logging, burning, livestock grazing and fishing occurring in the area (Rovero et al., 2019). We found evidence of bushmeat hunting: we encountered hunters with dogs on one occasion and found a number of snares, presumably set for ungulates but potentially a threat to the golden cat and other species.

We surveyed 70 sites across the Reserve using a regular grid of 1–2 km² cell size, firstly surveying 40 camera sites and then 30 (Fig. 1), for a minimum of 30 days (mean 32 days) each. We used Browning (Morgan, USA), Cuddleback (Green Bay, USA) and UOVision (Shenzhen, China) cameras, with infrared flash and motion-activated sensor. The trigger speed was 0.15 s for Browning, and 1–2 s for Cuddleback and UOVision. Cameras were unbaited and attached to trees at c. 50 cm from the ground, facing a presumed animal trail.

The survey yielded 2,219 camera-days from 68 camera traps (two were stolen). We annotated images using *Wild.ID* and ran analyses using *R 3.6* (R Core Team, 2019). We calculated

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Received 12 December 2019. Revision requested 18 February 2020. Accepted 6 May 2020. First published online 12 November 2020.

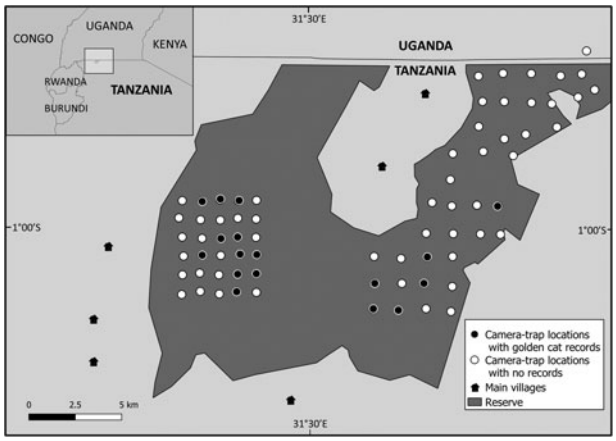

FIG. 1 Minziro Nature Forest Reserve, Tanzania, with camera-trap sites and records of the African golden cat *Caracal aurata*.

the number of golden cat detections per day, and used them to derive a relative abundance index. We plotted the species' daily activity pattern using hourly events. We then used single-season occupancy modelling (MacKenzie et al., 2002) to estimate golden cat occupancy (ψ) and detection probability (p) and their association with presumed covariates. We arranged golden cat detections/non-detections into a site-by-sampling occasion matrix; we chose 5 days as the resolution of the occasions as with poorly detected species this provides the best estimation of detectability, and hence occupancy (Rovero & Spitale, 2016). We built parsimonious models using the distance from each site to the closest Reserve border (i.e. forest edge) as a covariate. We derived these distances using *QGIS* (QGIS Development Team, 2019) and a 1:100,000 scale map. Based on our survey of human disturbance, we considered greater distance to the border as a proxy for increasing habitat quality and decreasing human disturbance. We assumed that both ψ and p increase with distance to border. For detection probability we also considered that camera-trap model could potentially influence detection. Using *unmarked* (Fiske & Chandler, 2011), we built all model combinations and ranked them according to the Akaike information criterion (AIC). We considered statistically supported models with $\Delta AIC < 2.00$ and used *AICcmodavg* (Mazerolle, 2019) to average parameter estimates.

After discarding 3,297 blank and set-up images, camera trapping yielded 4,244 photographs of 23 species of medium to large wild mammals (Supplementary Table 1), including 169 images of golden cats. These corresponded to 33 independent detection events of the species within 24-hour intervals at 17 sites (naïve occupancy = 0.26; Fig. 1). Based on individual pelage marks, we identified a minimum of 10 individuals. Pelage colouration varied from dark brown to sandy and golden (Plate 1). Animals were mainly active at night, with activity peaking at 19.00, 22.00 and 3.00, but were also detected in daylight (Supplementary Fig. 1). Based on occupancy model ranking (Table 1), we averaged the two most supported models, and the resultant mean estimated occupancy was 0.41 ± SE 0.12. Occupancy increased significantly with distance to the Reserve border (1.30 ± SE 0.54; Table 2, Fig. 2). Mean detection probability was 0.13 ± SE 0.05 and did not vary significantly with distance to the Reserve border but did vary between camera models, with Browning cameras having significantly higher values (Supplementary Table 2).

Our findings suggest that habitat intactness and human disturbance affect golden cat occurrence, with increased occupancy with increasing distance from the Reserve border

PLATE 1 African golden cat *Caracal aurata* photo-trapped in Minziro Nature Forest Reserve, Tanzania. The survey revealed golden/brown-reddish (a, c) and dark/light grey (b, d) morphotypes.

TABLE 1 Model ranking for occupancy (ψ) and detection probability (*p*) of the African golden cat *Caracal aurata* detected by camera trapping in Minziro Nature Forest Reserve (Fig. 1), Tanzania.

Models	No. of parameters	AIC[1]	Δ AIC	AIC weight	R^2
p (Camera model) ψ (Distance from closest edge)	5	198.88	0.00	0.59	0.27
p (Camera model + Distance from closest edge) ψ (Distance from closest edge)	6	200.50	1.62	0.26	0.27
p (.) ψ (Distance from closest edge)	3	203.44	4.56	0.06	0.16
p (Distance from closest edge) ψ (Distance from closest edge)	4	204.18	5.31	0.04	0.18
p (Camera model) ψ (.)	4	204.83	5.95	0.03	0.17
p (Camera model + Distance from closest edge) ψ (.)	5	205.68	6.80	0.02	0.18
p (.) ψ (.)	2	212.82	13.95	< 0.01	0.00
p (Distance from closest edge) ψ (.)	3	213.16	14.28	< 0.01	0.03

[1]Models were ranked according to the Akaike information criterion (AIC), with ΔAIC < 2 considered supported.

TABLE 2 Parameter estimates from the averaging of the two best supported models testing the effect of covariates on detection probability (*p*) and occupancy (ψ) of the African golden cat in Minziro Nature Forest Reserve (Fig. 1).

Model	Estimate ± SE	*Z*	P (>|*z*|)
ψ Distance from closest edge	1.30 ± 0.54	2.38	0.02
p Camera model—Browning	1.51 ± 0.64	2.36	0.02
p Camera model—UOVision	−0.57 ± 1.23	−0.47	0.64
p Distance from closest edge	−0.18 ± 0.30	0.61	0.54

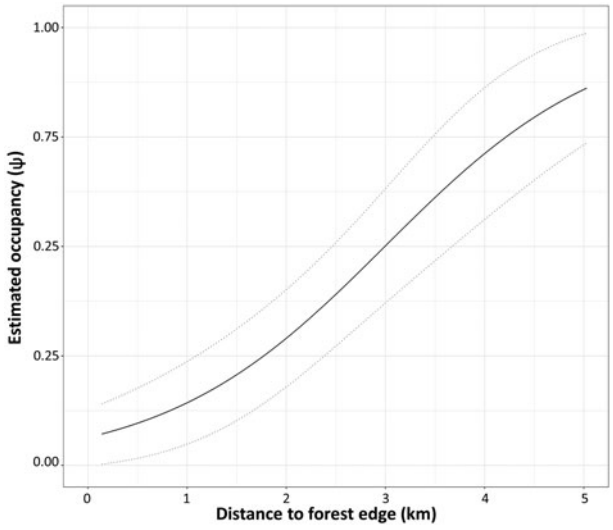

FIG. 2 Estimated occupancy (dotted lines show SE) of the golden cat in Minziro Nature Forest Reserve in relation to distance from the closest forest edge.

and human settlements. This matches the feline's known sensitivity to anthropogenic disturbance and its vulnerability in human-disturbed areas (Martinez Marti, 2011; Bahaa-El-Din et al., 2016). We documented a high incidence of human activities around and within the Reserve, potentially explaining the species' relatively higher occurrence in areas with dense, closed-canopy, continuous forests. A similar pattern has also been reported in Uganda (Mugerwa et al., 2012). Detection probability was greater with faster cameras, highlighting the importance of standardizing camera models in wildlife surveys: the best performing devices increase the probability of detecting elusive species. Although not exclusively nocturnal, the golden cat activity pattern showed peaks at night, mirroring the cathemeral behaviour reported by Bahaa-El-Din et al. (2015a). Peaks of golden cat activity may overlap with periods of low human presence and higher prey activity. The minimum number of 10 individual cats detected gives a naïve density of 4 per 100 km², suggesting that this population may not be as abundant as in other areas. Densities of 16 individuals per 100 km² have been reported in pristine habitats in Gabon, and densities similar to our estimates have been reported in highly disturbed and hunted areas (Bahaa-El-Din et al., 2016). It is possible that the presence of seasonally flooded forest and swamps, mainly on the eastern side of Minziro Nature Forest Reserve, make this habitat type suboptimal for the golden cat.

This is the first record of the little-known golden cat in Tanzania, c. 200 km east-south-east from the closest known populations in Uganda and Rwanda, potentially confirming anecdotal reports of the species in the contiguous Sango Bay Forest in Uganda in the mid 1990s (T. Davenport, pers. comm., 2019). Pelage pattern suggests the population in Tanzania may be the subspecies *Caracal aurata aurata*, with spots only on the abdomen and limbs (Bahaa-El-Din et al., 2015a). Given its isolation and the heavily modified habitat, we assume this population is genetically isolated, and thus Minziro Nature Forest Reserve may be an important site for the species' conservation. We also recorded the tree pangolin *Phataginus tricuspis* and giant pangolin *Smutsia gigantea*, both Endangered, and the first record in Tanzania of the fire-footed rope squirrel *Funisciurus pyrropus*. Considering the human encroachment we detected, and ineffective law enforcement, these findings indicate the need for appropriate protection of this forest.

Acknowledgements We thank Tim Davenport and an anonymous reviewer for their constructive comments; Italy's Provincia Autonoma di Trento, MUSE–Science Museum, and the Italian NGO ACAV for funding; COSTECH and the Tanzanian Forest Service for research permission and assistance; Chief Conservator Bernard Mwigulu along with Hassan Omary, Twaha Mponzi and Alfred Mlenge for support; Michele Menegon for the loan of some cameras; and Andrew Perkin, Steven Shinyambala, Ruben Mwakisoma, Wilbrod Bayona and other assistants for field support.

Author contributions Study design, data collection: FR; data analysis: IG; writing: IG, FR.

Conflicts of interest None.

Ethical standards This research abided by the *Oryx* guidelines on ethical standards.

References

Bahaa-El-Din, L., Henschel, P., Butynski, T., Macdonald, D.W., Mills, D., Slotow, R. & Hunter, L. (2015a) The African golden cat *Caracal aurata*: Africa's least known feline. *Mammal Review*, 45, 63–77.

Bahaa-El-Din, L., Mills, D., Hunter, L. & Henschel, P. (2015b) *Caracal aurata*. In *The IUCN Red List of Threatened Species* 2015: e.T18306A50663128. dx.doi.org/10.2305/IUCN.UK.2015-2.RLTS.T18306A50663128.en [accessed 8 July 2020].

Bahaa-El-Din, L., Sollmann, R., Hunter, L., Slotow, R., Macdonald, D.W. & Henschel, P. (2016) Effects of human land-use on Africa's only forest-dependent feline: the African golden cat *Caracal aurata*. *Biological Conservation*, 199, 1–9.

Butynski, T.M., Douglas-Dufresne, H. & de Jong, Y.A. (2012) Identification, distribution and conservation status of the African golden cat *Caracal aurata* in Kenya. *Journal of East African Natural History*, 101, 3–16.

Fiske, I. & Chandler, R. (2011) *unmarked*: an *R* package for fitting hierarchical models of wildlife occurrence and abundance. *Journal of Statistical Software*, 43, 10.

Hatfield, R.S., Mwaura, J., Musila, S. & O'Meara, L. (2019) The first confirmed record of African golden cat *Caracal aurata* from Kenya since 1946. *Journal of East African Natural History*, 108, 49–55.

MacKenzie, D.I., Nichols, J.D., Lachman, G.B., Droege, S., Royle, J.A. & Langtimm, C.A. (2002) Estimating site occupancy rates when detection probabilities are less than one. *Ecology*, 83, 2248–2255.

Martinez Marti, C. (2011) *The Leopard (*Panthera pardus*) and the Golden Cat (*Caracal aurata*) in Equatorial Guinea: A National Assessment of Status, Distribution and Threat*. Conservation International & Panthera, New York, USA.

Mazerolle, M.J. (2019) *Model Selection and Multimodel Inference Based on (Q)AIC(c)*. R package version 2.2-1. cran.r-project.org/package=AICcmodavg [accessed 13 July 2020].

Mugerwa, B., Sheil, D., Ssekiranda, P., van Heist, M. & Ezuma, P. (2012) Camera trap assessment of terrestrial vertebrates in Bwindi Impenetrable National Park, Uganda. *African Journal of Ecology*, 51, 21–31.

QGIS Development Team (2019) *QGIS Geographic Information System. Open-Source Geospatial Foundation Project*. qgis.org [accessed July 2020].

R Core Team (2019) *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing, Vienna, Austria.

Rovero, F. & Spitale, D. (2016) Species-level occupancy analysis. In *Camera Trapping for Wildlife Research. Data in the Wild* (eds F. Rovero & F. Zimmermann), pp. 68–64. Pelagic Publishing, Exeter, UK.

Rovero, F., Shinyambala, S., Perkin, A. & Greco, I. (2019) *Minziro Nature Reserve Biodiversity Surveys 2018*. figshare.com/articles/Minziro_Nature_Reserve_Biodiversity_surveys_2018/10283822/1 [accessed 8 July 2020].