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Patch-occupancy survey of elephant (*Loxodonta africana*) surrounding Livingstone, Zambia

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Wild elephants represent the biggest human–wildlife conflict issue in Livingstone, Zambia. However, little is known about their movements. This survey investigated elephants' habitat use outside a core protected and fenced zone that forms part of Mosi-oa-Tunya National Park, Zambia. Using 'patch-occupancy' methodology, indications of elephant presence (feeding behaviour, dung and tracks) were surveyed. The survey aimed to assist proposed future monitoring exercises by defining the geographical extent that should be considered to improve accuracy in species abundance estimates. Results were supplemented using collected indications of elephant presence from prior monitoring exercises, and during this survey. Elephant presence was confirmed up to 8 km from the boundary of the protected core habitat, focussed in: (1) an unfenced zone of the national park, (2) along a road leading from the national park to the Dambwa Forest to the north and (3) along two rivers located to the west (Sinde River) and east (Maramba River) of the core area. Detection probability of elephant presence was high using these methods, and we recommend regular sampling to determine changes in habitat use by elephants, as humans continue to modify land-use patterns.

Conservation implications: Identification of elephant ranging behaviour up to 8 km outside of the Mosi-oa-Tunya National Park in southern Zambia will assist in managing human–elephant conflict in the area, as well as in assessing this seasonal population's abundance.

Introduction

In fragmented land-use mosaics, the home ranges of African elephants (*Loxodonta africana*) cover a combination of protected and unprotected areas (Douglas-Hamilton, Krink & Vollrath 2005; Graham et al. 2007; Karidozo & Osborn 2015). The ranging by elephants in human-dominated landscapes inevitably leads to interaction, and therefore conflict, with communities. Most notably, conflict occurs with farmers as a result of crop-raiding, but also includes destroying water supplies, demolishing grain stores and houses, and sometimes injuring and killing people and livestock (Dublin & Hoare 2004; Graham et al. 2007; Sitati et al. 2003). Wild elephants represent the biggest human–wildlife conflict issue in Livingstone, Zambia. However, little is known about their movements. Understanding elephants' use of land outside of protected areas is considered important to the future conservation and management of African elephant populations (Graham et al. 2007; Hoare 2000; Okello et al. 2015).

The Mosi-oa-Tunya National Park (MoT NP) on the outskirts of Livingstone in southern Zambia supports a seasonal population of elephants, peaking in the months of May to October (African Lion & Environmental Research Trust [ALERT] 2012). A fenced section of the MoT NP, known as the 'Old Zoological Park' (OZP), appears to be the core habitat used by elephants in the area. However, at least some elephants are also known to utilise the protected Dambwa Local Forest No. 22, to the north of the MoT NP, as well as entering surrounding unprotected, human-dominated habitats (ALERT 2012), causing significant conflict with communities (Chishika 2010).

No robust survey has been performed to date to assess habitat use by elephants outside the MoT NP. Further, the scope of long-term population monitoring in the region is difficult to define without knowledge of the species' ranging behaviour. Elephants are known to move out of the OZP only after dark (Zambia Department of National Parks and Wildlife, pers. comm., n.d.), whilst much of the land outside of the OZP is heavily forested. As such, direct observation of elephants from the ground or air, to assess ranging behaviour, in this area is problematic. 'Patch-occupancy' or 'presence–absence' methodology is well established and provides an effective

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technique to monitor elephants' ranging behaviour over large geographic areas (Buij et al. 2007; MacKenzie et al. 2002, 2003). This survey therefore aims to use the patch-occupancy method for elephants outside of the core area of the OZP to assist planning of long-term monitoring efforts in the region.

Aerial surveys conducted between September and December 2008 recorded an elephant population for MoT NP of 31 individuals (Simukonda 2009). However, monitoring of elephants both within the OZP and in the surrounding areas between 2010 and 2012 identified 409 individuals that were either resident or transient at some point during the survey period (ALERT 2012), suggesting a more robust survey of the elephant population is needed. At present, elephants' ranging behaviour outside of the OZP is unconfirmed. Additionally, whether the OZP forms the core habitat for all elephants in the region, is unknown. For more accurate estimates of species abundance and density in the region, it is important to include areas outside the OZP in a robust survey design. However, the necessary geographic extent of any survey for improved survey accuracy, whilst also remaining cost-efficient, can currently only be postulated. Results from this survey aim to address knowledge gaps in the ranging behaviour of elephants in Livingstone to assist future population and conflict management in this area.

Methods

Located in the southern province of Zambia, outside the town of Livingstone, is the MoT NP that lies between 17° 48.897′–17° 58.300′ S and 25° 45.040′–25° 53.490′ E. It covers an area of approximately 6600 ha, with a fenced zone in the western section of approximately 2990 ha, known as the 'Old Zoological Park' (OZP). The Dambwa Local Forest No. 22 lies between 17° 39.962′–17° 49.300′ S and 25° 46.122′–25° 52.798′ E. It covers an area of 13 746 ha and lies to the north of, and shares a 4-km border with the OZP. These protected areas are surrounded by Livingstone town, several villages, small scale and commercial farms, and communal lands.

Livingstone itself lies to the northeast of the MoT NP and has an estimated population of ca. 135 000 residents. The population surrounding the Dambwa Forest was estimated to be over 1680 people in 2005, residing in 11 villages. The principal livelihood system is subsistence agriculture with the main crops being maize, cassava, groundnuts, beans, sorghum, pumpkins and sweet potatoes. Some livestock are also kept, including cattle, goats, pigs and chickens (Ensvol Consult 2007).

The survey was undertaken during August to October 2015, coinciding with maximum seasonal elephant presence within the region (ALERT 2012). Concentric distance bands of 4-km width were defined emanating from the OZP boundary (Figure 1). A grid of 2 km × 2 km blocks (Buij et al. 2007) was overlain on the distance bands. Each block was assigned to a distance band based on within which band most of the block's area fell. Thirty nine blocks to be surveyed were randomly selected based on 20% block sampling intensity within each distance band, giving five sample blocks out of 24 in the 4-km distance band, eight sample blocks out of 40 in the 8-km distance band, 12 blocks out of 60 blocks in the 12-km distance band and 14 blocks out of 72 in the 16-km distance band. A survey start point was randomly selected within each block (Buij et al. 2007) (Figure 1). If the selected survey start point was inaccessible, it was displaced at 0° from the original location as far as necessary, for transects operated from it to be undertaken (Buij et al. 2007).

Thirty eight out of the 39 sample blocks were surveyed (total area covered on 152 transects was 18.85 ha, with four replicates of each transect). One block within the 4-km distance band was not surveyed as it was located on Livingstone airport runway and could not be displaced to an accessible area using the method described. Three further blocks (two in the 4-km distance band and one in the 8 km distance band) were displaced at 0° from the original location as far as necessary for transects operated from them to be undertaken.

At each survey start point, 155-m straight line transects were conducted in each cardinal direction, starting 6 m from the centre of the survey start point to avoid transect overlap. At the end of each transect line, a second parallel transect was undertaken 6 m to the right of the original and back towards the centre (Buij et al. 2007). Presence or absence was recorded as zero or one within 2 m either side of the transect line based on observation of signs of elephant presence, being either dung, tracks or debris from elephants feeding within the transect area. The types of indication observed were also noted.

Detectability creates variation in patch-occupancy surveys as not all signs of elephant presence may be observed (MacKenzie et al. 2002, 2003). To overcome this, each of the four transect lines was independently surveyed by four different trained observers with no communication between them. Surveys were also conducted during dry season, which reduces the negative association between detection and vegetation density (Buij et al. 2007). Inter-observer reliability was assessed using the results from all transects. The calculation was made using the formula A/(A+D), where A is the number of agreements and D is the number of disagreements (Caro et al. 1979). Detection probability was assessed from the findings of all observers from all transects with elephant presence. The calculation was made for all indications combined, and for each indication independently, using the formula $P = n/tr$, where n is the total number of agreements of elephant presence, t is the number of transects with elephant presence and r is the number of independent replications of those transects.

To supplement data collected from transects, additional data sources were utilised to assess habitat occupancy: opportunistic sightings of elephant presence (animals, dung, tracks or feeding) observed between 2011 and 2012 during a previous monitoring programme (ALERT 2012); opportunistic sightings of elephant presence obtained whilst

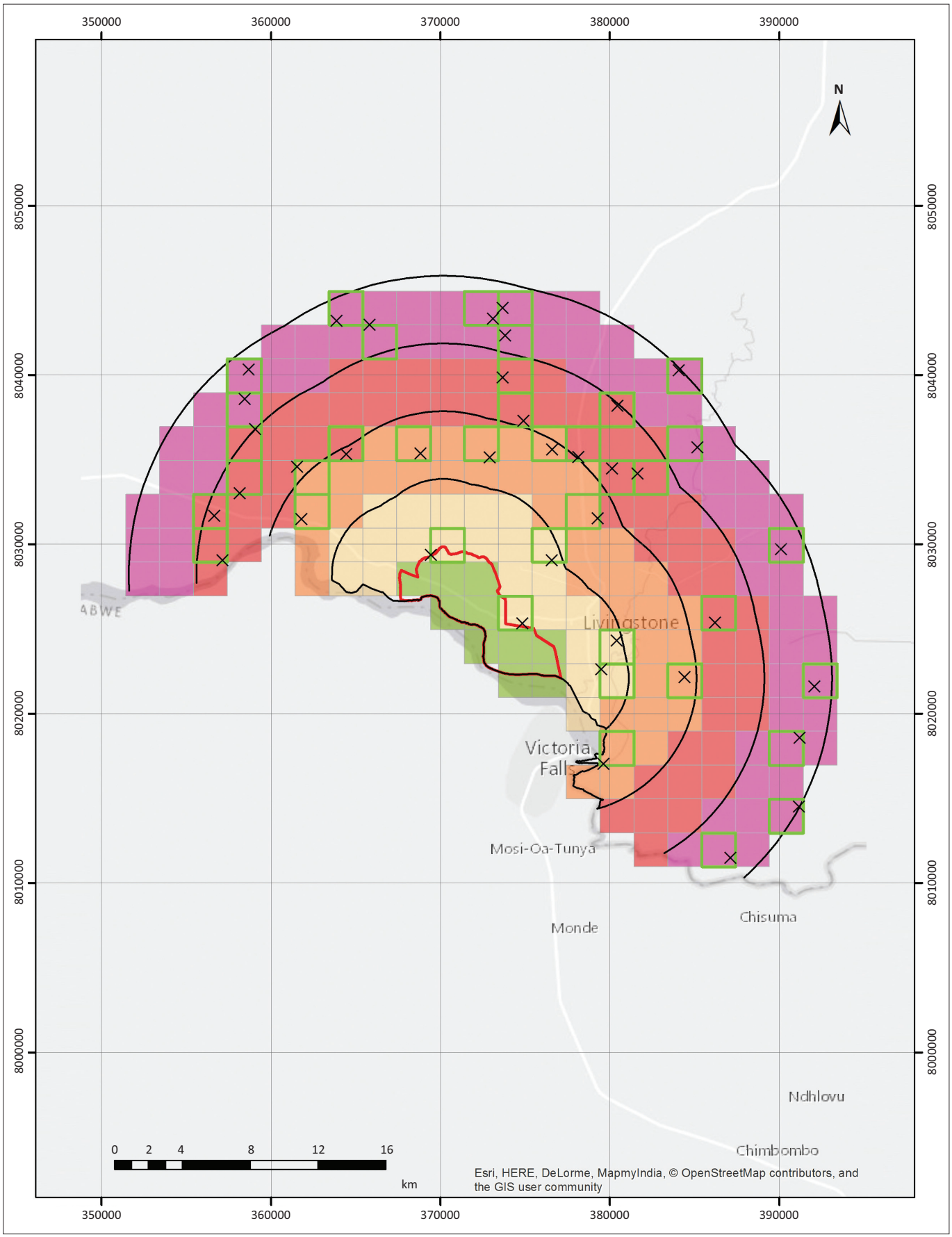
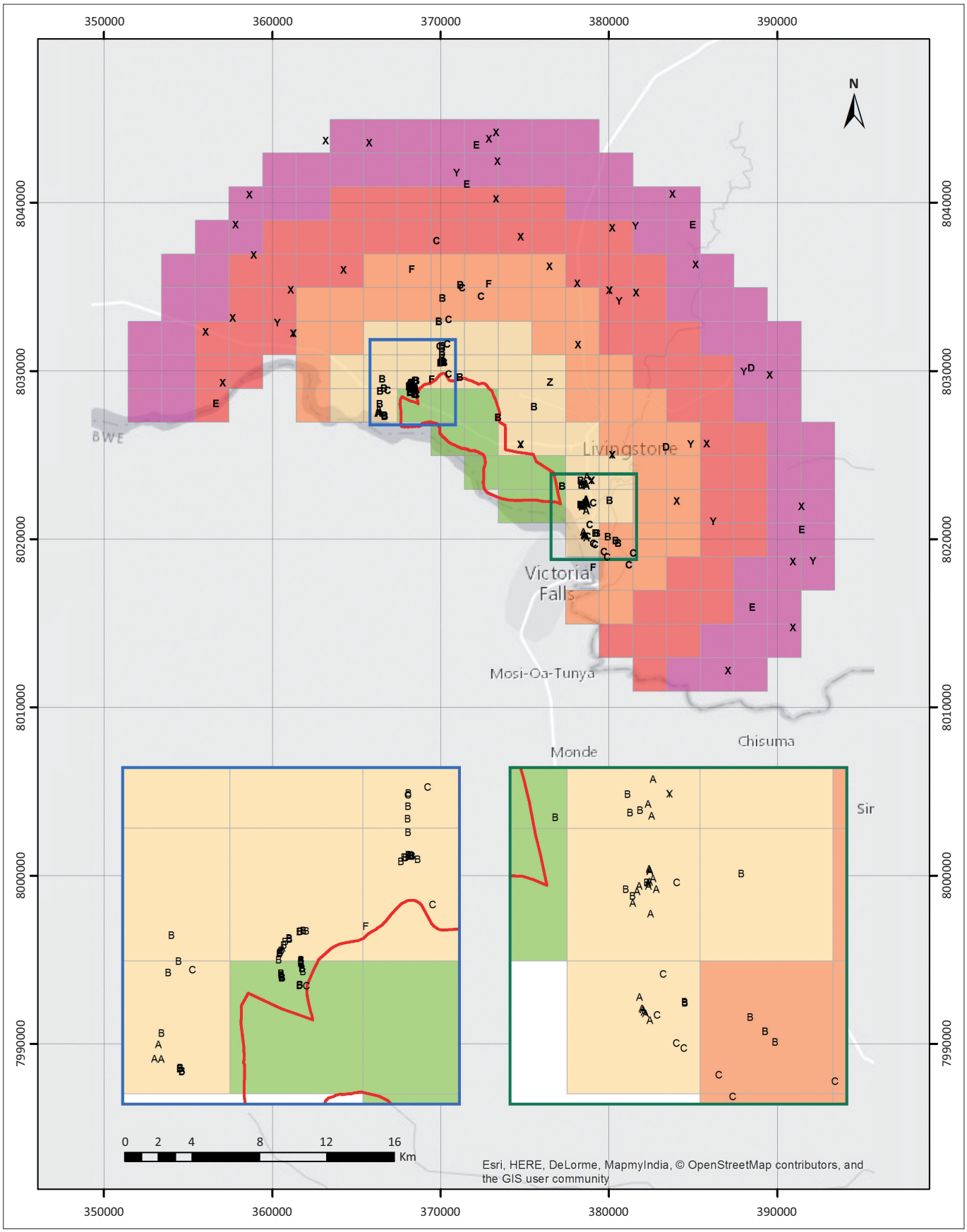


FIGURE 1: Map of the Livingstone area showing the boundary (red line) of the OZP (green shaded area), the distance bands at 4-km intervals from the boundary of the OZP (black lines) and the 2 km × 2 km grid (with block colours indicating into which distance and the block falls). Sampled blocks are highlighted (green outline), with the location of survey start points in sampled blocks shown (black cross).



A, opportunistic sightings of elephants 2010–2012; B, opportunistic sightings of elephant spoor 2011–2012; C, opportunistic sightings of elephant spoor 2015; D, community advised elephant presence 2010–2014; E, community advised elephant presence 2015; F, survey start point with elephant presence; X, survey start point with elephant absence; Y, community advised elephant absence 2010–2015; Z, un-surveyed.

FIGURE 2: Map of the Livingstone area with indications of elephant presence or absence.

travelling to and from survey start points; and opportunistic questioning of community members in the region. Whilst travelling to and from survey start points, community members encountered were asked to confirm if they were currently located at their normal residence. If a positive response was given, they were asked whether they had observed any presence of elephants within 1 km of their homestead during the current year (2015), and the same question over the prior years (2010–2014).

Results

Elephant presence was confirmed at four (10.5%) survey start points on 13 (8.6%) transects (Figure 2). Of these 13 transects, debris from feeding behaviour was observed on all 13, dung on 12 and tracks on 9. Elephant presence as a result of transect surveys was therefore confirmed within the 4- and 8-km distance bands. Elephant absence, or non-detection, was confirmed beyond the 8-km distance band. Opportunistically observed presence of elephants was determined in 2010 ($n = 9$), in 2011 ($n = 13$) and in 2012 ($n = 3$). Opportunistically observed presence of elephant spoor was evident for 2011 ($n = 64$), for 2012 ($n = 14$) and for 2015 ($n = 18$). Community advised presence of elephants was established for the period 2010–2014 ($n = 2$) and for 2015 ($n = 6$), and community advised absence was acquired for the period 2010–2015 ($n = 14$) (see Figure 2 for all determinations).

Inter-observer reliability was assessed to be very high at 0.99, with agreement by all four observers on 150 out of 152 transects. Detection probability for any indication of elephant presence was $p = 0.96$ ($n = 52$). Detection probability varied, however, for each indication of presence: feeding $p = 0.89$ ($n = 52$), dung $p = 0.73$ ($n = 48$) and tracks $p = 0.75$ ($n = 36$).

Discussion

Detection probability for any indication of elephant presence was very high, suggesting that using multiple indicators of elephant presence, along with multiple replicates of each transect, is a robust method for patch-occupancy surveys of elephants. Inter-observer reliability was also high, suggesting that the chosen indicators (feeding behaviour, dung and tracks) can be reliably assessed as present or absent by trained observers. The survey methodology undertaken by Buij et al. (2007) focussed only on dung as an indicator of elephant presence. Detection probability for dung in this survey was assessed as being the lowest of the three indicators. Large tracts of burnt areas due to late dry season fires throughout the region may have negatively impacted the detectability of elephant presence indicators in affected survey areas.

With all sources of elephant presence considered, elephant occupancy is concentrated within 8 km of the boundary of the OZP. Further, presence is focussed around three apparent corridors: (1) around the Sinde River to the west of the OZP, (2) the Dambwa Road, that runs from the OZP along the west of the Dambwa Forest, and (3) around the Maramba River to the east of the OZP. Significant elephant presence was also observed in the unfenced section of the MoT NP to the east of the OZP. Seven community members advised of elephant presence outside of the 8-km distance band, with all but one stating that elephant presence was from one occasion only. One informant, located 11 km due west of the OZP, reported that in 2015 a breeding herd was present in the area for 4 days and that four bulls were resident in the area.

The authors recommend that any planned intensive elephant monitoring in the region should focus on the OZP and the area up to 8-km distance from it, where presence is greatest, to maximise accuracy and cost-efficiency in determining the abundance of elephants. Additional resources should be employed, if possible, beyond this limit, and also along the three identified corridors to assess the level of usage of these areas, and the extent of each corridor, including ascertaining whether they are migration corridors to other protected areas or local movement feeding corridors. The authors also recommend that a patch-occupancy survey is repeated at regular intervals to assess changes in elephant habitat usage in the region over time, and in response to changing land-use patterns and human–elephant conflict mitigation measures that may be introduced.

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Competing interests

The authors declare that they have no financial or personal relationships that may have inappropriately influenced them in writing this article.

Authors' contributions

D.A.Y. was the project leader. D.A.Y., J.A., L.C., A.K., C.K.L. and B.A.S. were responsible for project design. D.A.Y., J.S.B., M.D.C., A.K. and D.S. undertook most of the data collection. C.K.L. undertook G.I.S. mapping. D.A.Y., J.A, L.C., A.K. and B.A.S. wrote the manuscript.

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