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An Estimation of Blackbuck Abundance and Density in and around Jayamangali Blackbuck Conservation Reserve, Karnataka

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Introduction

The blackbuck (*Antilope cervicapra*) is a medium-sized antelope (31–45 kg) endemic to the Indian subcontinent. Blackbucks are primarily grazing herbivores that are representative species of semi-arid grasslands (Ranjitsinh, 1989). They also browse on leaf litter, flowers and fruits (Jhala, 1997; IUCN, 2017). Besides grasslands, they inhabit open scrub, open salt pans, open woodland and agricultural land (Ranjitsinh, 1989; Jhala, 1997). Blackbucks are group living animals; their social group size is variable and depends greatly on habitat openness (Isvaran, 2007). Larger group sizes in open or treeless habitats, such as grasslands, confer anti-predation benefits like early predator detection (Jarman, 1974; Isvaran, 2007). Blackbucks are key prey species for large carnivores in grasslands and other open habitats. Indian wolves (*Canis lupus pallipes*) are the main predators of blackbucks. Golden jackals (*Canis aureus*) and free-ranging dogs predate on blackbuck fawns (Jhala, 1993; Jethva & Jhala, 2004; Aiyadurai & Jhala, 2006; Jyoti & Rai, 2021). Blackbucks account for 12% of all wildlife species reportedly attacked by domestic dogs in India (Home *et al.*, 2017).

Historically, the blackbuck range encompassed most of the Indian subcontinent, south of the Himalayas (Ranjitsinh, 1989; IUCN, 2017). The species is now extinct in Pakistan and Bangladesh. In Nepal, the species went extinct in the 1970s, owing to excessive poaching. However, rediscovery of blackbuck populations in the region prompted several government-mediated interventions that led to the recovery of blackbuck populations in Nepal (Bist *et al.*, 2021). It is estimated that blackbuck population in Nepal is as low as 200 individuals (Bashishtha *et al.*, 2012). In India, the adult blackbuck population is estimated to be about 35,000 (IUCN, 2017). Given their locally abundant populations in India, blackbucks are currently listed as "Least Concern" in the IUCN Red List of Threatened Species. This is in stark comparison with the first IUCN assessment of the species, three decades ago, which suggested that populations were at a high risk of facing extinction in the wild (IUCN, 2017). The Government of India accords the blackbuck with the highest level of protection, under Schedule I of the Wildlife Protection Act of 1972.

In Karnataka, blackbucks occur mainly in the drier parts of the state (IUCN, 2017). Here, two protected areas have been notified chiefly for the conservation of the blackbuck: Ranibennur Blackbuck Sanctuary and Jayamangali Blackbuck Conservation Reserve. State-wide estimates of blackbuck populations in India do not exist. A few studies have estimated populations in protected areas, and even fewer studies, outside protected areas. A study by Sagar and Antoney (2017) provides a population estimate for Basur Amruth Mahal Kaval Conservation Reserve in Chikkamagaluru district using line transect sampling. They estimated 193 (c. 148–238) blackbucks to occur in an area of 7.36 km^2. This is the first study from Karnataka to provide blackbuck population estimates while accounting for imperfect detection.

From other parts of the country, robust population estimates are available from protected areas of Tamil Nadu, notably from Guindy National Park and Point Calimere Wildlife Sanctuary (Baskaran *et al.*, 2016; Arandhara et al., 2020). Total count population surveys

which do not account for detection probability, have been carried out in Velavadar National Park, Gujarat (Jhala & Isvaran, 2016) and in Aligarh, Uttar Pradesh (Ahamad *et al.*, 2021).

Semi-arid grassland ecosystems are typical blackbuck habitats, enabling the species to reach high densities (Jhala & Isvaran, 2016). Grasses make up a major portion of the blackbuck diet (Jhala, 1997) and also provide camouflage to calves during periods when they are most vulnerable to predation (Priyadarshini *et al.*, 2021). Blackbucks avoid wooded habitats and prefer short grass with height less than 50 cm (Jhala, 1991). Consequently, in a habitat mosaic, blackbucks are restricted to open grassland habitats (Baskaran *et al*., 2016; Arandhara *et al.*, 2021). In these habitats, the spread of the invasive shrub *Prosopis juliflora* has emerged as a significant threat to the ecology of grasslands. A recent study from Tamil Nadu demonstrated that the extent of *Prosopis* woodland and shrub cover has a negative impact on blackbuck density (Arandhara *et al.*, 2021).

In addition to the threat of non-native woody plants replacing native grassland, blackbucks are also at risk of coming in direct conflict with humans. Much of India's open grassland ecosystems have undergone conversion into agricultural land (Tian *et al.*, 2014), resulting in grassland-dependent wild herbivores opting for foraging sources available in croplands (Jhala, 1993). Blackbucks feeding on agricultural crops have been reported through several parts of its range in India (Chauhan & Singh, 1990; Jhala, 1993; Bayani *et al.*, 2016; Debata, 2017; Bajwa & Chauhan, 2019; Rai & Jyoti, 2019). In Abohar Wildlife Sanctuary in Punjab, the extent of crop loss due to nilgai and blackbucks was found to be as high as 40% (Bajwa & Chauhan, 2019). In retaliation to extensive crop loss, agriculturalists may employ preventive methods that can prove highly fatal to blackbucks. Chauhan & Singh (1990) have reported mass blackbuck mortality as a result of high voltage electric fencing used by farmers in Haryana.

In landscapes with high human densities, small patches of protected areas can serve as important refuges for blackbuck persistence (Krishna *et al.*, 2016), provided that levels of human activity are low in these areas (Jha & Isvaran, 2021, preprint). Given the context of lack of scientific information on blackbuck populations, shrinking grassland habitats, and rising anthropogenic pressures, we present a baseline population estimate for blackbucks in and around Jayamangali Blackbuck Conservation Reserve (JBCR). We use a systematic line transect sampling approach to provide baseline abundance and density estimates. A robust population baseline enables managers to draw inferences on temporal population trends and evaluate the effectiveness of management strategies, by comparing it against current population estimates (e.g. Rasphone *et al.*, 2021).

Methods

Study area

Jayamangali Blackbuck Conservation Reserve, situated in the Tumkur district of Karnataka (Map 1) was declared a conservation reserve in the year 2007. The conservation reserve consists of thorny shrubland, Eucalyptus (*Eucalyptus spp.*), Acacia (*Acacia auriculiformis*) and *Hardwikia binata* plantations, and remnant grassland (Gubbi *et al.* 2017) (Figure 1). The 3.24 km^2 reserve is surrounded by an agricultural-grassland mosaic (Figure 2). The commercial crops grown in the area include groundnut, horsegram, green pigeon peas, broad beans, chilli, sweet corn, castor, cotton, paddy, ragi, jowar, areca nut, eggplant, okra, tomato, watermelon, and muskmelon. In recent years, vine and banana cultivation has begun in the landscape. In the years 2019 to 2021, 47 farmers around JBCR have received a total of ₹3,06,686 ex-gratia payment by the government on account of crop loss caused by blackbucks. The affected crops were groundnut, green chilli, jowar, pigeon peas, ragi and corn (KFD, 2022).

Mammalian carnivores found in JBCR include leopard (*Panthera pardus fusca*), sloth bear (*Melursus ursinus*), Indian fox (*Vulpes bengalensis*), golden jackal (*Canis aureus*), jungle cat (*Felis chaus*), rusty-spotted cat (*Prionailurus rubiginosus*), small Indian civet (*Viverricula indica*), and grey mongoose (*Herpestes edwardsii*) (Gubbi *et al.* 2017). The Indian grey wolf (*Canis lupus pallipes*) has been documented in the study region previously (Gubbi, pers. obs.); however there seems to be little evidence of its presence in the area in recent times.

Herbivores besides the blackbuck are chital (*Axis axis*), wild pig (*Sus scrofa*), black-naped hare (*Lepus nigricollis*) and Indian porcupine (*Hystrix indica*) (Gubbi *et al.* 2017).

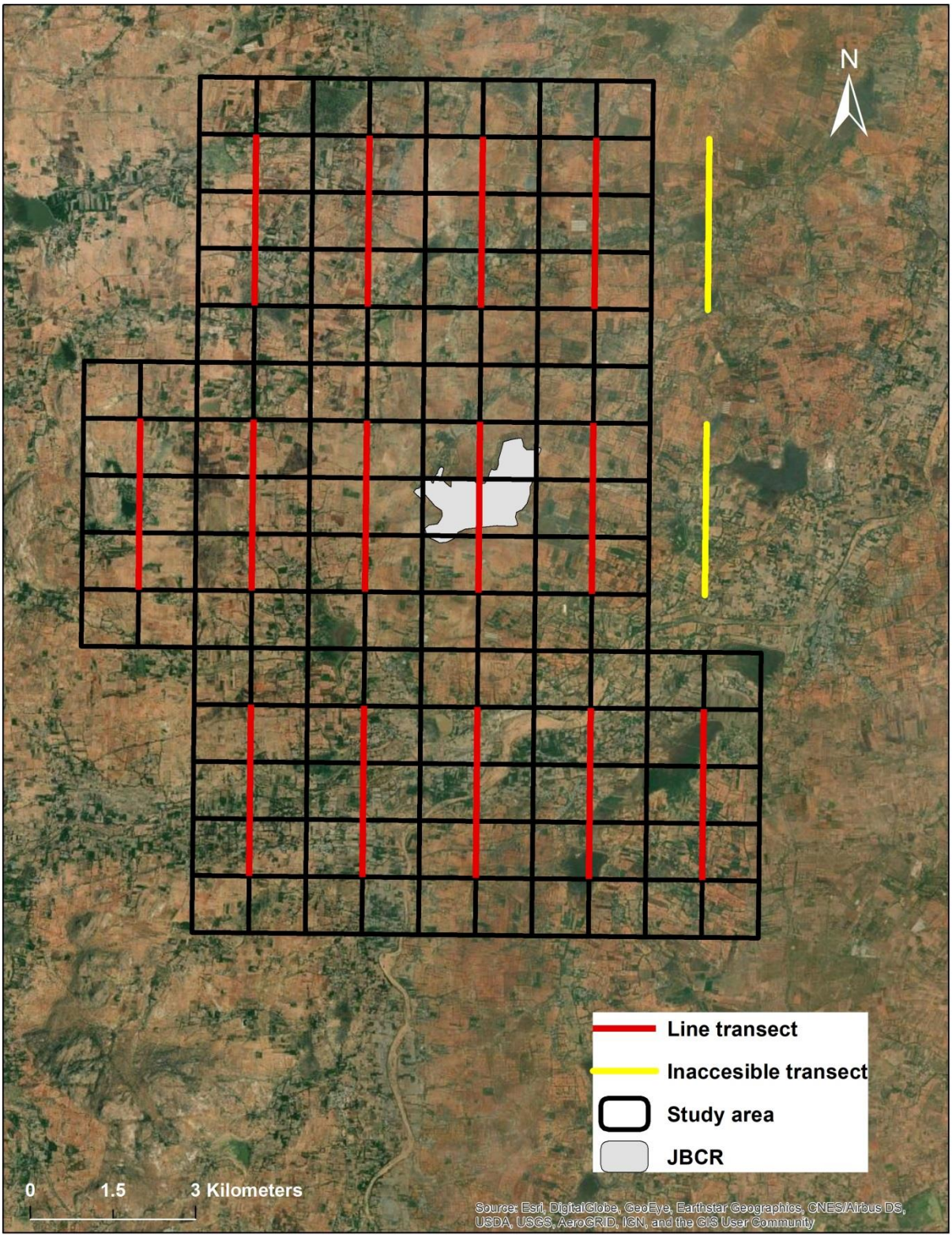
Data collection

A recce was carried out in the month of December 2021 to obtain information on terrain type and accessibility of habitats (Figure 3). A buffer of 5 km radius from the centre of the conservation reserve was drawn to include both, the protected area and surrounding agricultural fields encompassing a diversity of potential blackbuck habitats (Figure 4). To create line transects, the buffer area was divided into grids of 1 x 1 km, using a sampling tool in ArcGIS 10.3 (Esri, 2011). Line transects were systematically placed 2 km apart from each other, at an angle of 0°, facing north (Map 1). The lines were separated by a 2 km distance to ensure that all detections made from the line are independent of each other (Buckland & Turnock, 1992). A total of 16 line transects of 3 km length were created, however, two lines were excluded due to water logging. The resulting study area covered 140 km^2 in area. After this, the start and end points of each line transect were identified using a GPS and compass; and vegetation was cleared along the lines to enable the observer to walk with ease. It was ensured that the width of the lines were such that animals were neither attracted nor distracted from the lines.

Data was collected from 10th January to 31st January 2022 and transect lines were walked during early morning (6.00-8.00 h) and late afternoons (16.00-18.00 h) when blackbucks are most active. Each transect was walked 6 times, to adequately sample the study area and to increase precision. Sampling was carried out by one experienced observer and a Forest Department staff member who walked along the transect line and recorded detected individuals or a group of individuals. At every detection, distance to the animal or to the centre of the animal group was recorded using the Bushnell G Force DX rangefinder; and the angle to the animal and transect line angle was measured with the Sunto MC-2 compass. In order to obtain robust density and abundance estimates, we ensured that all assumptions of the line transect sampling approach were met (Buckland *et al.,* 2001). Given that our team comprised of trained field biologists, errors in measurements were minimized.

Figure 1. Jayamangali Blackbuck Conservation Reserve is dominated by closed habitats comprising of *Hardwikia binata* plantations.

Figure 2. The area surrounding the reserve is an agriculture-grassland mosaic.



Map 1. The line transect sampling design created for this study to estimate blackbuck abundance in and around Jayamangali Blackbuck Conservation Reserve; the study area measures 140 km^2.

Figure 3. In the month of December 2021, a recce was conducted to ascertain the accessibility of transect lines.

Figure 4. Line transect sampling was carried out in natural habitats as well as the agricultural matrix surrounding the Jayamangali Blackbuck Conservation Reserve.

Figure 5. Blackbucks show sexual dimorphism; adult males have a dark pelage with spiralled horns.

Data analysis

The distance sampling analysis was carried out in RStudio (RStudio Team, 2021) using the package 'Distance' (Miller *et al.*, 2019). The main inputs for the analysis are perpendicular distances, sampling effort and cluster or group size. 5% of the data at the largest distances were truncated to exclude outliers, as recommended by Buckland *et al.*, 2010. Six detection function models were fitted to the data; goodness of fit and Akaike Information Criterion (AIC) scores were computed to select the model with the best fit.

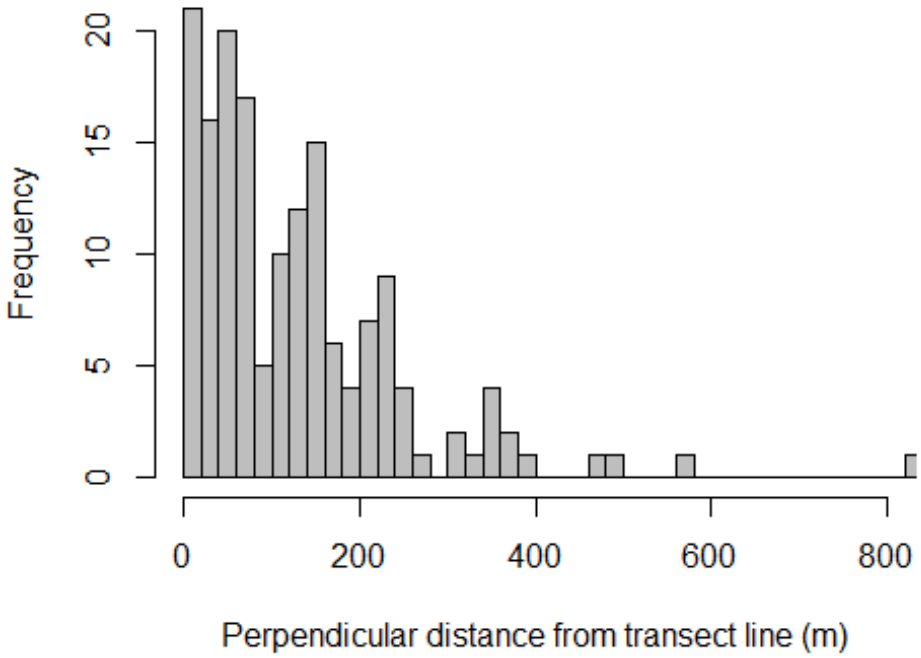


Figure 6. Histogram of blackbuck sighting frequency as a function of perpendicular distance of detections from the transect line. The graph reveals some heaping (rounding) of untruncated data beyond 400 m.

Results

The total sampling effort was 214.8 km. A total of 784 blackbuck individuals were recorded and the mean group size was found to be 4.92. The number of blackbuck detections made at each transect is listed in Table 1 and visualized in Map 2. We selected the half-normal key function model as the model with the best fit, according to AIC scores and the goodness of fit plots. The average detection probability ($\hat{p}$) deduced by the model is 0.53 (±0.03 SE) (Figure 7).

The abundance of blackbucks in the study area (140 km^2) is 2,144.9 (±848.9 SE) individuals. The density of blackbucks is 15.3 (± 6.0 SE) individuals/km^2 (Table 2).

Table 1. Key observations of the line transect sampling carried out to estimate blackbuck density and abundance in and around Jayamangali Blackbuck Conservation Reserve.

Transect No.	Transect length (km)	Sampling effort (km)	No. of detections	No. of individuals	Encounter rate
JM-01	2.1	12.6	4	48	0.32
JM-02	3	18	0	0	0
JM-03	2.5	15	7	40	0.47
JM-04	2.6	15.6	17	46	1.09
JM-06	2.1	12.6	0	0	0
JM-07	3	18	3	7	0.17
JM-08	3	18	81	338	4.5
JM-09	3	18	30	220	1.67
JM-10	3	18	18	84	1
JM-12	2.7	16.2	1	1	0.06
JM-13	2.6	15.6	0	0	0
JM-14	2.4	14.4	0	0	0
JM-15	1.9	11.4	0	0	0
JM-16	1.9	11.4	0	0	0

Table 2. Estimated blackbuck density in and around Jayamangali Blackbuck Conservation Reserve (140 km^2).

Total sampling effort (km)	Number of detections (n)	Mean cluster size	Total encounter rate	Density of individuals đ (per km^2)	Coefficient of Variance (đ) (%)
214.8	161	4.92	0.92	15.32	39.58%

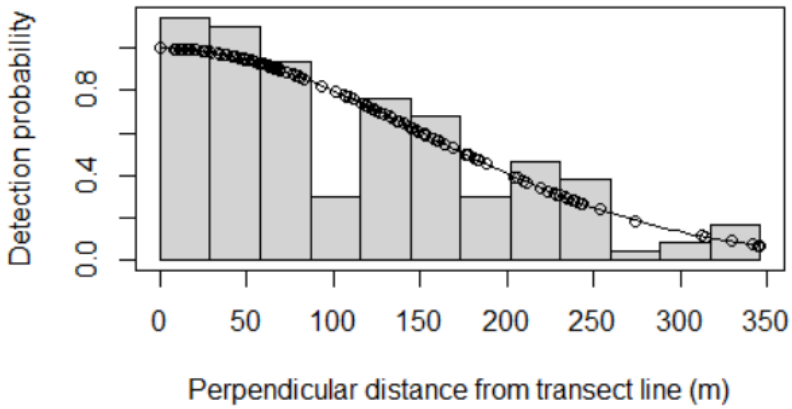
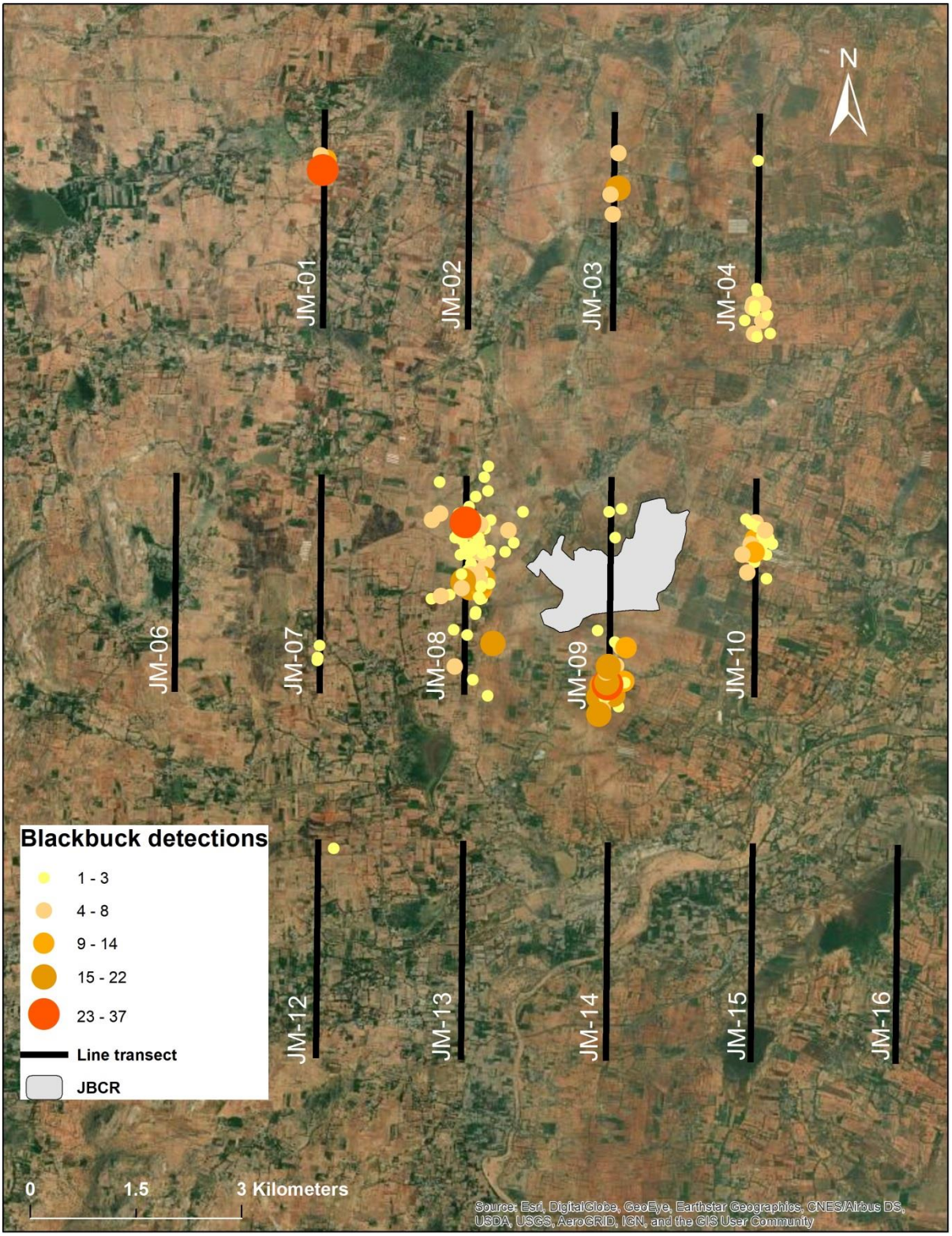


Figure 7. The detection probability curve of the half-normal key function model with 5% truncation of perpendicular distances.



Map 2. Blackbuck detections on different transect lines during the study in and around Jayamangali Blackbuck Conservation Reserve.

Discussion

We used a systematic line transect sampling approach to provide abundance and density estimates for blackbucks in and around JBCR, Karnataka. Our study provides the first scientific estimate of blackbuck populations from this area. In addition, this is the second study that has estimated blackbuck populations in Karnataka, while accounting for imperfect detection.

The density of blackbucks is lower compared to other areas where similar studies have been carried out (Table 3). However, the abundance estimated for the entire study area is high. Our study area extends beyond the conservation reserve into human use areas like agricultural fields. It was important to study the population over a larger area since JBCR itself is very small (3.24 km^2) and blackbucks range beyond the conservation reserve boundaries. Additionally, we found that blackbuck detectability was very low inside the conservation reserve. JBCR is dominated by woody plantations and blackbucks have been reported to avoid wooded habitats (Arandhara *et al.,* 2021).

Table 3. A comparison of blackbuck densities between the current study and previous studies in southern India where similar scientific methods were used.

Study site	Vegetation types	Study area ($km^{2)}$	Blackbuck density per km^2 (SE)
Basur Amruth Mahal Kaaval Conservation Reserve, Karnataka (Sagar & Antoney, 2017)	Open grassland, invasive thorny shrubland	7.6	26.23 (±6)
Point Calimere Wildlife Sanctuary, Tamil Nadu (Baskaran *et al.,* 2016)	Tropical dry evergreen forest, open grassland, coastal scrub, invasive thorny shrubland	30.0	50.2 (±4.79)
Point Calimere Wildlife Sanctuary, Tamil Nadu (Arandhara et al., 2020)	Tropical dry evergreen forest, open grassland, coastal scrub, invasive thorny shrubland	26.5	27.9 (±3.3)
In and around Jayamangali Blackbuck Reserve, Karnataka (current study)	Shrubland, plantations, open grassland, agricultural crop lands	140.0	15.32 (±6.06)

Blackbucks are highly specialized to semi-arid, short-grass ecosystems (Jhala & Isvaran, 2016) and loss of natural grasslands is one of the key threats to blackbuck conservation (IUCN, 2017). Previous studies recommend maintaining open grassland habitats, by preventing the establishment and invasion of exotic woody plants (Jhala, 1993; Arandhara *et al.,* 2021). Afforestation in grassland habitats, particularly with exotic trees like *Eucalyptus*, significantly impacts biodiversity and ecosystem functioning (Cravino & Brazeiro, 2021). It is essential that future management plans for JBCR are rooted in a scientifically sound understanding of blackbuck ecology. We recommend the removal of existing woody plantations from JBCR and that no future plantations are undertaken. Woody plantations have possibly eliminated the Indian wolf and have encouraged the immigration of leopards into the area. Past camera trapping studies have recorded the presence of three leopard individuals in JBCR (Gubbi *et al.,* 2017). The possible local extinction of wolves in Jayamangali may have impacted blackbuck populations, since wolves are the main natural predators of blackbucks (Jhala, 1993). In the absence of a key predator, blackbuck populations could significantly rise. This can in turn aggravate human-blackbuck conflict instances in this agricultural landscape. While natural grassland predators are necessary for regulating blackbuck populations, predators in the form of free-ranging dogs are a threat to blackbucks in JBCR. They have been observed to hunt both fawn and adult blackbucks in the region (Gubbi, pers. obs.).

Robust population estimates are important to scientifically understand the effectiveness of protected areas in species conservation. We believe that the baseline results of this study have important conservation implications for blackbuck conservation in JBCR and across Karnataka. We recommend that annual blackbuck population estimates be conducted using distance sampling in JBCR. This will provide a temporal understanding of trends in blackbuck populations, and accordingly inform conservation and management plans.

Conclusion

It is estimated that the total blackbuck population spread across India and Nepal is 35,000. This makes JBCR a significant stronghold for blackbucks in Karnataka and India. This area is perhaps a key area for the long-term survival of the species in the state. However, the peaceful co-existence of people and blackbucks in JBCR will depend on the restoration of native grasslands and the effective mitigation of potential conflict with farmers in the landscape.

Key management recommendations

1. Removal of woody plantations such as *Eucalyptus* spp., *Acacia auriculiformis, Hardwikia binata,* and *Tamarindus indica* from JBCR.

2. Annual population monitoring using distance sampling by line transect methodology.

3. Dispersal of timely and appropriate ex-gratia payments to farmers during human-blackbuck conflict instances.

4. Providing suitable incentives to farmers to grow blackbuck-friendly crops (horsegram, groundnut).

5. Making additions to the eco-sensitive zone plan to account for changing cropping patterns around JBCR and to suggest suitable crop alternatives.

6. Controlling the free-ranging dog population, given their threat to blackbucks as predators.

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