Eco. Env. & Cons. 29 (January Suppl. Issue) : 2023; pp. (S272-S283)

ISSN 0971–765X

DOI No.: http://doi.org/10.53550/EEC.2023.v29i01s.042

A Promising Habitat Space for Blackbucks *Antilope cervicapra* Delimited by Declining Open Grassland Tracts and Increasing Tall Vegetations

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(Received 20 June, 2021; Accepted 4 August, 2022)

ABSTRACT

This study was carried out in four consecutive years (2017–2020) to evaluate how increased tall vegetation growth changed the promising nature of open grassland habitat for blackbucks in Basur Amruth Mahal Kaval Blackbuck Conservation Reserve with an area of $7.36km^2$. Based on facts that blackbucks avoid tall and thick vegetations and prefer only plain tracts for anti-predator benefits, our investigation gained curiosity on their activities of choosing bed down/resting behaviour locations inside and the outside their natural habitat. The focus of the study was to understand evolving behavioural adaptations of blackbuck herds against increasing habitat edges and predation pressures by utilizing the locally available open areas of agricultural crop fields outside their home ranges. Predation by leopards (0.407 individuals per sq. km) on blackbuck found predominant in this area probably at the habitat edges. The number of locally emigrating individuals made significant rise ($\bar{x}$ = 112<, 132<, 158<, 191) from 2017 to 2020. Despite fluctuations, over all point density of habitat use by blackbucks declined from 22.6 to 10.02 points per Sq. Km inside the Kaval and rise from 5.23 to 9.32 points per Sq. Km outside the Kaval. With apparent uncertainties, Normalized Difference Vegetation Index (NDVI) showed fluctuating in the open grasslands (0.142>, 0.047<, 0.734>, 0.07) and gradual rise in the other elements. Vegetation control measures should be taken for providing healthy and promising open grassland habitat for blackbucks.

Key words: *Blackbuck, Grassland, Habitat preference, Basur Kaval, Conservation Reserve.*

Introduction

Grasslands are main platform for stockbreeding and are also home to numerous minority nationalities. Climate change has become an important research hotspot in modern ecology because of its potential effects on the stability and sustainability of grassland ecosystems (Cadotte *et al*. 2012). Grasslands belong to the most critically endangered ecosystems in the tropics, they are often treated as waste lands and conservation efforts are directed rarely towards these landscapes (Sagar and Anthony, 2017). Blackbuck *Antilope cervicapra* is one of the large wild herbivores in the Bovidae Family, found in most grassland ecosystems of the Indian subcontinent. Basur Amruth Mahal Kaval Blackbuck Conservation Reserve, fragile and dynamic habitat with extreme anthropogenic pressures has now lost its major open grassland areas due to outgrowth of perennial shrubs.

Blackbuck (*Antilope cervicapra* Linnaeus, 1758) is a species of Bovidae family. Blackbucks are largely

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found in groups in many regions of India and Nepal, except for the north-eastern region. The Blackbuck plays an important role in the ecosystem by serving as an important prey-base for carnivores such as wolves and Jackals *Canis aureus*. Like most large mammals, (particularly larger than 15kg), blackbucks are threatened from overhunting, habtitat destruction and feral dogs (Madhusudan and Mishra, 2003; Schipper *et al*., 2008; Davidson *et al*., 2009).

Blackbuck is primarily a grazing animal that avoids forested areas. It survived in semi-desert regions, where it is able to find scattered vegetation. Blackbucks are diurnal feeders, surviving mainly on short grasses, and can live without drinking water (Schaller, 1967). Blackbuck is an animal of the open, flat to terrain with apparent undulation reaching its greatest abundance in areas covered with thorn and dry deciduous forest. It is easily adaptable to wastelands, agricultural lands and cultivated areas at peripheries. It prefers open plains and avoids hilly and forested areas (Walker, 1964). Blackbucks are herbivorous animals that prefer open habitat with low growing grasses rather than tall grasses (Berwick, 1974). Apart from nutritional requirements, absence of tall vegetation that can be used as cover by predators will be a prime factor influencing habitat use by blackbucks. Most studies report that foraging blackbucks spend relatively little time in tall grasslands and shrublands (Ranjitsinh 1989, Jhala 1991).

Remote sensing has long been an effective way of monitoring land cover with its ability to quickly retrieve information at large scale, and has became the effective method to obtain information of forest cover (Jia *et al*., 2012, Townshend *et al*., 2012). Normalized difference vegetation index (NDVI) is the most abundantly used vegetation index for retrieval of vegetation canopy biophysical properties. Several studies have investigated the spatial scale dependencies of NDVI and the relationship between NDVI and fractional vegetation cover, but without any consensus on the two issues (Jiang *et al*. 2006).

Leopards *Panthera pardus* have catholic diet preferences and are generally thought to prey on ungulates of medium-size (Hayward *et al*., 2006). It is the most widespread member of the large felids (Myers, 1986), occurring entire sub-Saharan Africa, India and southern Asia (Nowell and Jackson, 1996). This is widely due to its high adaptability in hunting and feeding behaviour (Bertram, 1999). Leopards are comprehensive in their habitat use, ranging from tropical rainforest to arid savannah, and from alpine mountains to the edges of urban areas, but break their highest densities in riparian zones (Bailey 1993), emphasizing that they can live wherever there is sufficient vegetation cover and prey animals with adequate size (Bertram, 1999). Leopard found frequently preying on blackbuck and domestic cattle in this isolated habitat as an ambush predator.

Certain studies have been conducted on the crop depredation by blackbucks (Manakadan and Rahmani, 1998) so far and accounted that is the reason behind venturing out of their home ranges. But there are no studies considering the consequences of leopard's ambush predation pressures on blackbuck facilitated by habitat edges from increasing outgrowth of tall vegetations and declining open grassland area and the outcome of these threat factors driving the blackbuck herds to go out of their home ranges as a strategy for escaping predation pressures in the dark phase. In the context, ambushing predation by leopards may hold over-influence on blackbuck populations. This study was carried out in a dynamic and fragile grassland system of Basur Amruth Mahal Kaval Blackbuck Conservation Reserve, Karnataka as an attempt to reveal that how such fragmentation forces have drastically changed the livelihood of blackbucks in their home ranges.

Methodology

Study Area

Basur Amruth Mahal Kaval Blackbuck Conservation Reserve (BAMKBCR) situated between 13º-40′-57.28'' to 13º-38′-21.02'' latitude North and between 76º-04′-23.59' ′ to 76º-04′-16.05'' longitude East, located in Kadur Taluk, Chikkamagaluru District of Karnataka State on the Southern Plateau of the Deccan Peninsula. This Conservation Reserve forms a mosaic of different vegetation structures of typical Peninsular Indian open grassland ecosystem. It also serves as range land for the Amruth Mahal Cattle Breeding Centre which works under the aegis of Ajjampura Amruth Mahal Kaval. Hence the name locally known as "Kaval" (in Kannada), it means the grassland, rangeland or pastureland. Despite its small size (7.36 km^2), the reserve harbours a rich grass vegetation, fauna including mammalian herbivores Blackbuck (*Antilope cervicapra*), Wild Boar (*Sus scrofa cristatus*), Indian Hare (*Lepus nigricllois*), top predators such as Indian Leopard (*Panthera parades* *fusca*), Indian Wolf (*Canis lupus pallipes*) and mesopredators such as Golden Jackal (*Canis aureus indicus*) and the Indian Fox (*Vulpes bengalensis*). It was declared a Conservation Reserve in 2011 as a strategic measure for protecting the resident blackbuck population and associated wildlife which were facing numerous threats till then.

The conservation reserve is a contiguous habitat contained with isolated grassland patches with human settlement at one end and the agriculture crop fields around the periphery. This habitat is constantly subjected to fragmentation forces like outgrowth of perennial shrubs, vehicular movements, herdsmen intrusion and overgrazing pressures more recently.

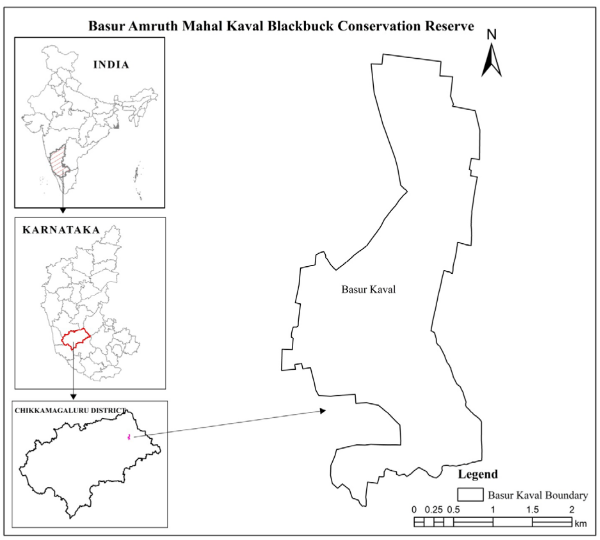


Fig. 1. Location map, Basur Amruth Mahal Kaval Blackbuck Conservation Reserve (BAMKBCR) (Kaval/ Basur Kaval).

Materials and Methods

Migratory displacement and changing habitat use by blackbuck herds

Our observation that blackbuck herds venturing out of the Kaval into the crop fields by crossing the boundary between the areas in order to escape habitat edge based predation pressures. To verify this information basically, we first received opinions from the farmers in the crop fields around the Kaval by random meet and private semi-structured interview method (Jones *et al.*, 2008). Based on their confirmations, we started to investigate and observe transboundary movements of the herds during the early evenings and early mornings.

Initially, the detection and location of fresh and scattered dung piles of blackbuck herds were done in all landscape elements with edges and transitions. The same were carried out in the surrounding crop fields. Fresh and scattered dung piles are recorded immediate morning at the bed down locations of the blackbuck herds where they were stayed resting in groups. These dung middens and their locations varied with every sampling trial unlike the territorial dung piles of lekking males. The dung piles created by blackbucks in group can be clearly differentiated by scattered, irregular patterns, non territorial and are selective specific for the open areas (Fig. 4), where the territorial males produce collective and concentrated dung piles with repeated defecation (Mungall, 1978; Ranjithsinh, 1989; Prasad, 1989). Scattered dung middens are characterized by irregular, unclear, overall circular or randomly spread and created by the blackbucks in herds of any age groups at the bed down sites. These dung midden locations marked using Global Positioning System (GPS) immediately after the blackbuck herds left place. These points were layered in the Arc-Map software for spatiotemporal analysis (Kunwar, 2015) and to generate point density maps.

Normalized Difference Vegetation Index

The normalized difference vegetation index (NDVI) is one of the most abundantly used vegetation indexes and its uses in satellite assessment and monitoring of global vegetation cover has been well explained from the past two decades (Huete & Liu, 1994; Leprieur *et al.*, 2000). It is basically defined;

$$\mathrm{NDVI} = \frac{N-R}{N+R} \qquad (1)$$

Where, R and N represent surface reflectance optimised over visible red (λ = 0.6µm) and near infrared (NIR) (λ = 0.8µm) regions of the spectrum, respectively. The NDVI was correlated with certain biophysical properties of vegetations, such as leaf area index (LAI), fractional vegetation cover and vegetation condition (Jiang *et al.*, 2006). Surface reflectance data for NDVI analysis was acquired from Sentinel-2 (Zhou *et al.*, 2019) which measures 10m × 10m of pixel resolution, collected in four consecutive years from 2017 to 2020.

Detection of carnivores and predation pressures

Survey for the potential predators was conducted by camera trap method (Marnewick *et al.*, 2008). Camera traps were deployed in 6 major locations of suspected leopard movements on a regular basis. Such locations locally named Jadanakatte (13º 39′ 40.33'' N and 76º 04′ 42.78' ′ E) , Seenanakatte (13º 40′ 20.64'' N and 76º 04′ 45.04' ′ E), Naganakatte (13º 39′ 24.95'' N and 76º 04′ 01.47' ′ E), Watch Tower (13º 39′ 22.45'' N and 76º 04′ 39.03' ′ E), Konanakatte (13º 38′ 36.05'' N and 76º 04′ 22.54' ′ E) and backyards of Amruth Mahal Kaval Breeding Centre (13º 38′ 22.39'' N and 76º 04′ 26.61' ′ E).

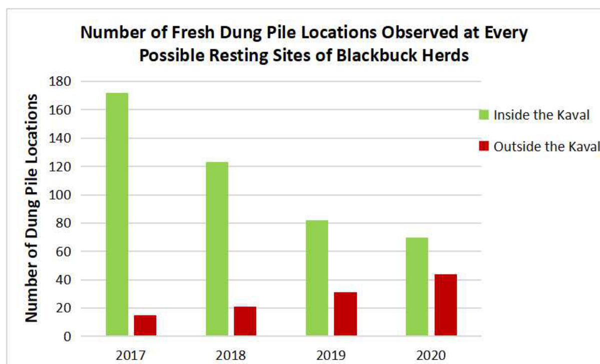
Results

Our observations under twilight conditions of each day that these blackbuck herds take short migration out of the Kaval (home range) into the open crop fields adjacent to the boundary, immigrate back into the Kaval before the dawn appears. They were going out of the kaval only for the resting/ bed down purposes. All other biological activities including sparring, lekking, mating, grouping and variation and allied herd activities with primary foraging practices were found only inside the mean habitat during day time.

Strategic shift in habitat preference by the blackbuck herds

A short decline in the number of fresh dung pile locations of blackbuck herds (Table 1 and Graph 1) in the years 2017, 2018, 2019, 2020 (Σ× =172>, 123>, 82>, 70) respectively were recorded inside their home ranges. Meanwhile in the same period a sharp rise in the number of dung pile locations (Σ×=15<, 21<, 31<, 44) outside their home ranges i.e. in the crop fields were recorded during the survey. With the steady state increasing crude population of blackbucks (N_t = 238<, 262<, 277<, 296) in the Kaval, the mean number of observed individuals venturing out of the Kaval were also increasing ($\bar{x}$ = 112<, 132<, 158<, 191) in the same years respectively.

Point density maps (Fig. 2) revealed fluctuating trends, but a significant decline in the density of dung pile locations from 2017 to 2020 (22.6>, 16.03>, 6.51<, 10.02 points per Sq Km) inside the Kaval. As per the observations these fluctuations in point density indicate that blackbucks reduced their area of habitat use and started to reuse the same locations or at the immediate vicinity in response to reduction in open areas against tall vegetations inside the Kaval. Then the maps (Fig. 3) showed fluctuating, but a significant rise in the density of dung pile locations (5.23>, 4.46<, 5.94<, 9.32 points per Sq Km) in the same years outside the Kaval. But here the fluctuating tendencies are an indication of blackbucks exploring the new locations for bed down activities and of a short term distribution for occupying these locations outside the Kaval. These groups were found resting as the openness of the locations in their priority such as short growing crops (e.g. Groundnut) and young stage of crops (Ragi, Sesame, Green Gram), cultivated, harvested but left uncultivated and at the borders of crop fields. Such



Graph 1. Changing intensity of habitat use by blackbucks both inside and outside the Kaval from 2017 to 2020.

Table 1. Observational details on the change in habitat preferences by blackbucks.

Sampling Period (Year)	**Number of fresh dung pile locations**		**Population trends of blackbucks from 2017 to 2020**	**Observed number of individuals emigrating towards the crop fields each day**	**Point density of habitat use by blackbucksblackbucks**	
	Inside the Kaval (Σ×)	**Outside the Kaval** (Σ×)	(N_t)	Mean ($\bar{x}$)	**Inside the Kaval** (Points per Sq Km)	**Outside the Kaval** (Points per Sq Km)
2017	172	15	238	112	22.6	5.23
2018	123	21	262	132	16.03	4.46
2019	82	31	277	158	6.51	5.94
2020	70	44	296	191	10.02	9.32

behaviour of choosing open crop fields paved way for crop depredation by blackbucks in these areas.

In addition, local farmers noted that these antelopes take such short emigrations every day and nights without fail. These groups rest till morning and leave the fields before dawns, return to their home range.

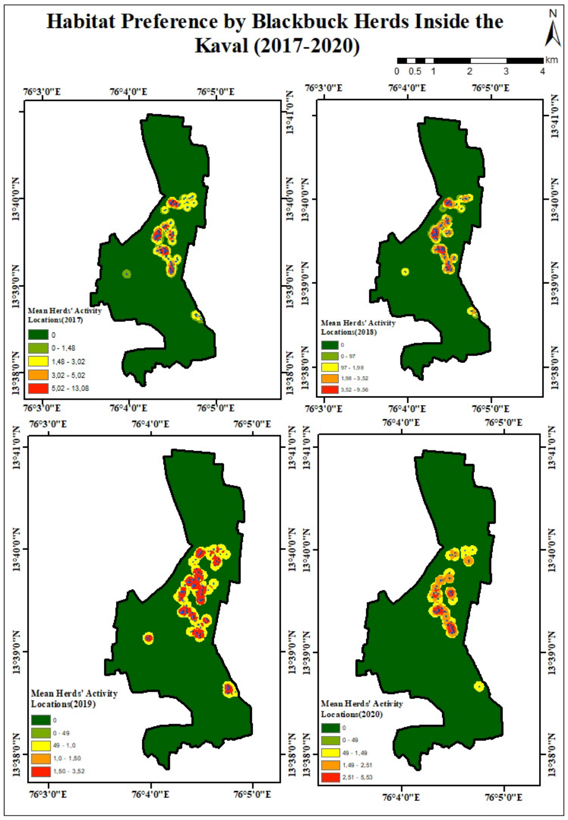


Fig. 2. Point density maps showing intensity of habitat use by blackbucks throughout the year (2017-2020) inside the Kaval:

Change in habitat structure and vegetation gradients

The Normalised Difference Vegetation Index (NDVI) values showed a fluctuating trends in grassland vegetation (0.142>, 0.047<, 0.734>, 0.07), but a gradual increase in grass-shrub complexes (0.167>, 0.164<, 0.209<, 0.224), perennial shrubs (0.199<, 0.205<, 0.259<, 0.279), sparse scrub vegetations (0.248<, 0.276<, 0.341<, 0.367), dense scrub vegetations (0.436<, 0.495<, 0.537<, 0.645) respectively in four consecutive years 2017, 2018, 2019 and 2020 (Table 2). But open grasslands decreased with time

Table 2. NDVI predictions of vegetation changes with respective outgrowth of perennial shrubs from 2017 to 2020.

Landscape Element	2017			2018			2019			2020		
	Pixels/ Cells Count	Area (in Acres)	NDVI	Pixels/ Cells Count	Area (in Acres)	NDVI	Pixels/ Cells Count	Area (in Acres)	NDVI	Pixels/ Cells Count	Area (in Acres)	NDVI
Open Grassland Vegetation	14291	353.1383	0.14294202	13468	332.8015	0.04700508	13287	328.328	0.17347997	14231	351.6556	0.07044853
Grass-Shrub Complex	14916	368.5823	0.16754704	16564	409.3053	0.16412431	16638	411.1339	0.20943936	15530	383.754	0.22411744
Perennial Shrub Outgrowth	15752	389.2403	0.19938883	15555	384.3724	0.20560403	14394	355.6834	0.25978249	15776	389.833	0.27969982
Sparse Scrub Vegetation	14647	361.9352	0.24859887	14565	359.9089	0.27636357	14902	368.2364	0.34129042	14597	360.6997	0.36797771
Dense Scrub Vegetation	13792	340.8077	0.43675490	13246	327.3157	0.49596211	14177	350.3212	0.53786838	13112	324.0045	0.64588958

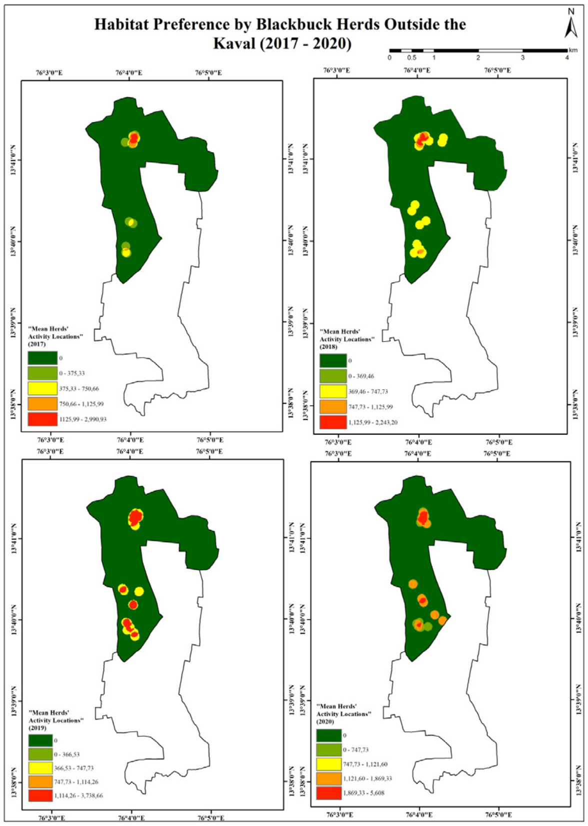
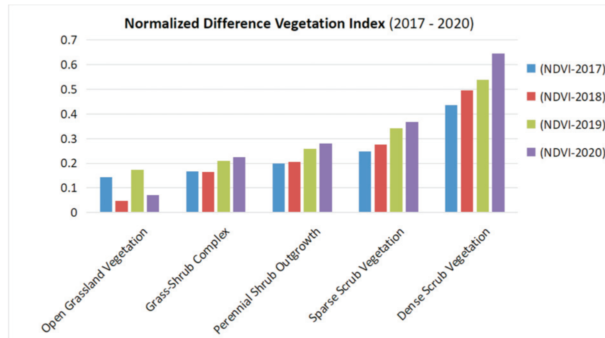


Fig. 3. Point density maps showing intensity of habitat use by blackbucks throughout the year (2017-2020) outside the Kaval.

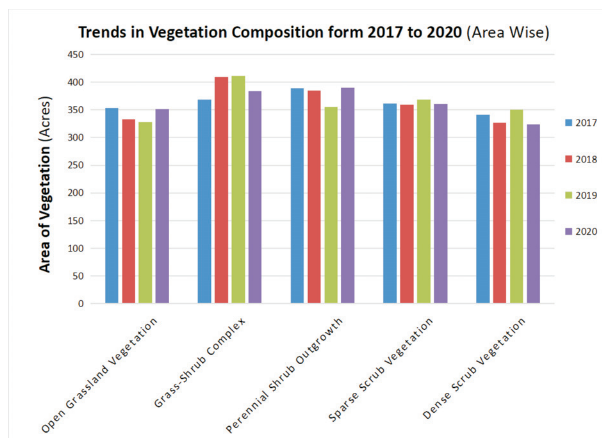
against invasive outgrowth of perennial shrubs *Dodonaea viscosa*, *Prosopis juliflora*, *Lantana camara* and *Barleria mysorensis* in the same period.

Uncertain predictions of NDVI on vegetation changes

The NDVI results indicate apparent uncertainties in the open grassland systems in four consecutive years, but with assured increasing tendencies in the tall vegetations (Graph. 2). To address the issue of uncertain results from the NDVI method (Graph. 2), it is to partially disagree with the calculation of area of occupied vegetation type in acres by multiplying number of pixels with the scale of the pixels used in the NDVI (Graph. 3). This is because huge overlap between red, orange and yellow bands, the indicatorstors of open grassland, grass-shrub com-



Graph 2. NDVI results with differentiation of vegetation changes from 2017 to 2020.



Graph 3. Uncertainty in NDVI results on area wise prediction of vegetation changes from 2017 to 2020.

Fig. 4. Blackbucks venturing out of the Kaval into the crop fields and a sample of their scattered dung piles

plex and perennial shrubs in the reclassified NDVI results (Fig. 5). The grass-shrub complex (showed a remarkable increase from 368.5823 to 383.754 acres against other elements) and the perennial shrub are mainly dominated by *Dodonaea viscosa*, *Lantana camara* and *Barleria mysorensis*, where as both elements has the same reflective colour (Pale Green) as that of the grassland (Lawn Green).

Hence the huge interference and the overlap of these landscape elements with their reflective colour bands have derailed the predictions of the spatiotemporal changes in the vegetation composition by NDVI method (Fig. 6). However in practical, there is a large scale spatial acquisition of tall vegetations against the grass cover in the past recent (2017-2020).The dense scrub vegetation with major shrubs including *Prosopis juliflora*, *Prosopis cineraria*, *Acacia catechu*, *Carissa carandas*, *Limnonia acidissima*, etc. showed very less outgrowth at negligible rate when compared to vigorous outgrowth of *Dodonaea viscosa* and *Lantana camara*.

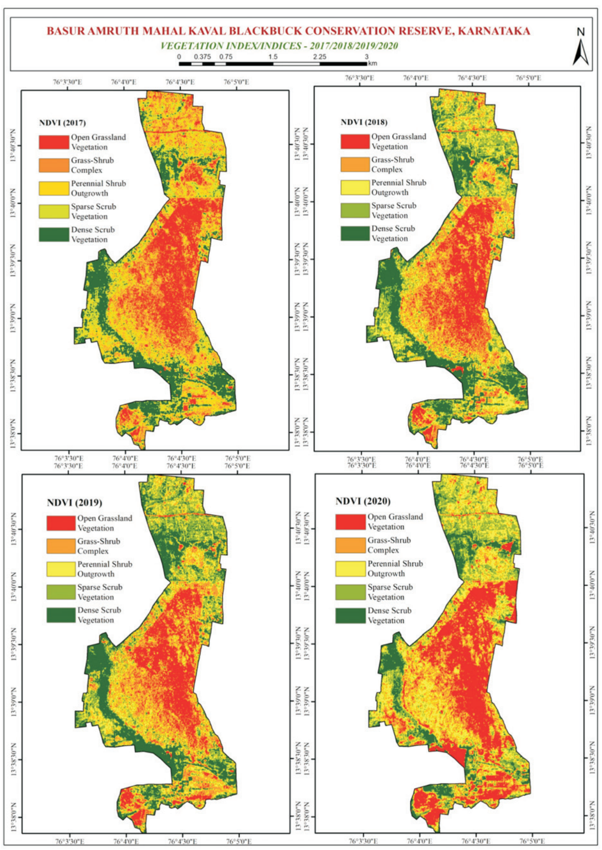


Fig. 5. BAMKBCR maps with Normalised Difference Vegetation Index (NDVI) of four consecutive years 2017, 2018, 2019 and 2020.

Fig. 6. A mosaic of vegetation types where *Dodonaea viscosa* exhibiting near range of colour band (Pale Green) like grassland tracts (Lawn Green) as such can be differentiated with the Lush/Dark Green band of scrub vegetation in the Kaval. These factors lead to uncertainties in NDVI predictions (red to orange band) on the increasing outgrowth of perennial shrubs against the grass cover.

Predation pressures by Leopard

The leopard (*Panthera pardus fusca*) was found top predator of blackbucks in the Kaval. Incidental observations through camera-trap survey revealed that it is regularly preying on blackbuck (Fig. 7) as well as other species including wild boar, black-naped hare, Amruth Mahal cattle, domestic livestock, etc., in the Kaval. It occupies the highest position in the food chain of this ecosystem. Currently the leopard population density occurs at 0.407 individuals per sq. km (an individual occupied 2.45 sq. km area with overlapping ranges). It is thought to be ambushing on the blackbucks at the habitat edges between open grasslands and tall vegetations. One such location near watch tower a male blackbuck killed by a leopard.

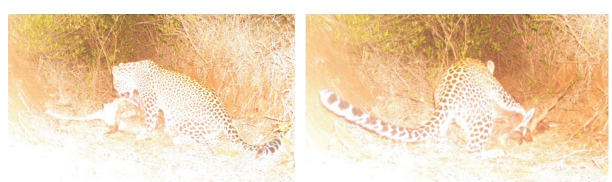


Fig. 7. Leopards consistently hunting on blackbucks at the habitat edges between open grassland and tall vegetations.

Discussion

Outgrowth of tall vegetations causing decline in promising habitat for blackbucks

Out of total area 7.36 km^2 of the Conservation Reserve, only 18% (Fig. 5) (NDVI, 2020) of the vegetation remained as open grassland which only provides lekking area for blackbucks. It is also an open area where social re-organisation of herds (Mungall 1978; Isvaran, 2003), hiding fawns in small bushes (Ranjithsinh, 1989) and rest or bed down of herds (Isvaran, 2007) takes place. The remaining proportion includes outgrowth of perennial shrubs *Dodonaea viscosa* and *Lantana camara*, sparse and dense scrub vegetations *Prosopis juliflora*, *Prosopis cineraria*, *Acacia catechu*, *Carissa carandas*, *Limnonia acidissima* including *Eucalyptus* plantations creating habitat edge (Levin, 2009) with the open grassland vegetation.

The proliferation of invasive non-native plants have altered rangelands and have resulted in broad-scale changes in plant and animal communities and altered the biotic conditions of systems. The most significant of these invasive plants can lead to ecosystem instability, and sometimes irreversible transformational changes (DiTomaso *et al*., 2000). Colonization of *Dodonaea* in grasslands contributed to a further limitation of available forage for ruminants, increased the land-use adaptation changes, spatially spread seasonal livestock migrations, and accelerated further spread dynamics. The heavy rains in 2013 then provided the boost for the growth of now well-established *Dodonaea* shrubs that further outcompeted the grass cover. Discussions with pastoralists and recently sedentarized crop farmers in the area in 2014, highlighted their growing concern and despair with this 'new weed'. The invasive behaviour of *Dodonaea* is limiting the choice of adaptation strategies in some localities (Becker *et al*., 2016). It is also found that of *Dodonaea viscosa* exerts allelopathic effects on grass community in terms of germination, plumule growth, radical growth and fresh and dry biomass (Farrukh and Muhammad, 2010).

Another recent but rapidly growing problem is the invasion of semi-arid grasslands throughout India by the woody plant *Prosopis juliflora*. The conversion of grasslands into woody habitats was resulted in further decrease in blackbuck numbers, since blackbuck densities are highest in open grasslands and scrub, and decrease as woody vegetation cover increases (Mungall, 1978, Ranjitsinh, 1989, Shankar, Raman *et al*., 1995; Isvaran, 2005). One such site was south and east forest of Mudumalai Wildlife Sanctuary, with persistent *Prosopis juliflora*, there was a proliferation of *Opuntia dillenii* which reduces the suitability of blackbuck habitat. Eradication of that weed and control of *Prosopis juliflora* in that landscape was suggested (Johnsingh *et al*., 2010).

Local emigration as strategic escape from predation

Due to the outgrowth of perennial shrubs, habitat edges (Levin, 2009) are constantly increasing interface of open habitat and closed habitat, which facilitates the ambushing hunting strategy of the leopards. Displaying intolerance towards the increased habitat edge of the grass-shrub complex, an interference of the perennial shrub invasion over the open grassland, blackbuck herds showed greater affinity towards the open crop fields outside the Kaval for rest or bed down. Eventually these crop fields have become remedial habitat space for bed down or resting activities of blackbuck herds. This leads to increasing cases of crop depredation by blackbucks around the conservation reserve. Foraging outside the natural habitat definitely involves crop depredation (Manakadan and Rahmani, 1998).

During the day, these animals usually rest in open areas despite the heat. Further they rarely rest or bed down in those areas. They are more vigilant when close to tall vegetation, suggesting that their perception of the threat from predators increases when they are close to tall vegetation (Isvaran, 2007). Like many other antelopes which have evolved in open plains, blackbucks probably rely on early detection and speed to escape from predators (Mungall, 1978; Ranjitsinh, 1989). This indicates why they avoid areas where the tall vegetation structure may hinder detection and flight.

This local emigration of blackbucks involves a set of observed behavioural challenges related to timing of venture, crossing well traversed roads, camouflage of the animal with environment, choosing the bed down locations in the crop fields, electrocuted fences, barbed wire fences, avoiding exposure to humans. Human-blackbuck conflicts pose the significant threat to survival of blackbuck in such areas. So use of naked wires with electrocution of 220V current around the crop area has also forced death of blackbucks (Chauhan and Singh, 1990). Accidents and pollution also have effect on blackbuck population size (Schaller, 1967; Macdonald, 1984; Sheikh and Molur, 2004; Meena and Chourasia, 2018). Habitat degradation, road accidents, illegal poaching, overgrazing by domestic cattle, and wildlife crime has already reduced the blackbuck population to limited site at its endemic area as case study observed at Marwar region. Another important threat factor is habitat fragmentation by road constructions. Road accidents caused highest mortality especially to fawns (Meena *et al.,* 2017; Meena and Jaipal, 2020). Blackbuck herds may be subjected to the above said threat factors during their local migrations.

The hunting method of leopards requires dense vegetation cover to be successful, more importantly edge habitats are also beneficial (Karanth and Sunquist, 1995). Therefore, there is no benefit to group hunting as a leopard must capture its prey before it can flee (Bertram, 1979) and, if once detected, leopards have very little chance to successful capture of prey (Rice, 1986). Hayward *et al.* in 2006, mentioned that the Mean Jacob's Index for leopard preying on blackbucks was -1(±1 SE), recorded the blackbuck as a prey potential ($n_p = 1$) and actual prey item ($n_a = 0$), mean percentage abundance of blackbuck was 0.4% (±1 SE). Through camera-trap study in the Kaval (Fig. 7), it is clearly evident that leopards preying on the blackbucks regularly at the habitat edges.

Followed by the decline of the wolf in most of its geographical range, the jackal has become the main predator of the blackbuck. Consequently, predation pressure on blackbuck populations may now be concentrated at the fawn stage (Krishnan, 1972). Despite predation by leopard and jackal, feral dogs from nearby villages also venture inside the conservation reserve, found hunting the blackbuck, disturbing their lekking arena of the male blackbucks and sometimes causing dispersal of the harem with their fawns by chasing. Predation on blackbuck found to be threat to endangered blackbuck at many places like case reported at Marwar region of India where feral dogs caused decline in blackbuck population during rainy season (Meena and Jaipal, 2020). Predation by leopard, hyena, and stray dog were also observed as main threats to blackbuck inside BCA, Nepal (Gyawali *et al*., 2020).

Uncertainties in NDVI values

With the use of a linear mixture reflectance model, Hanan *et al*. (1991) found the NDVI of a mixed pixel to be dependent not only on the NDVI of pixel components and their proportions, but also on the brightness of the components. There is a large bias in NDVI values at different resolutions in landscapes containing vegetation, open water (Jiang *et al*., 2006) and other elements. Here in a mosaic of *Dodonaea viscosa* outgrowth and grassland vegetation with apparent similarities in the colour reflectance (Pale Green and Lawn Green) respectively, resulted in a huge overlap in the pixel components of NDVI and oriented or misled proportions can be expected in these landscapes.

Conclusion

From the above observed incidents in the conservation reserve, it is understood that these antelopes have found that there won't be any human disturbances in the open crop fields under dark conditions as they visit them only during day time. Hence these blackbucks have adapted to venture out into the crop fields located adjacent to the Kaval boundary and return back into the home ranges before the dawn arrives. But this adaptation was a result of increasing habitat edges coupled with ambushing predation pressures by the leopard inside their home ranges.

Hence these blackbuck herds going out of the Kaval in the dark time for resting in the open crop fields is a precautionary measure of escaping the ambushing hunting tactics of the leopard and also the fear of being hunted at the edges drive them towards finding a remedial open system at the immediate vicinity. These virtues played by blackbucks are in the pursuit of escape from leopard's ambush predation.

Predation in natural conditions can be a balancing act of the food chain in an ecosystem. There would be no long term benefit to a predator in becoming very successful that it killed all the breeding adults in a prey population. Therefore equilibrium is set up between prey and predator (Mathur 2010). But it is suggested that it should not cross the limitations of threshold rates on the grounds of increased habitat edges in this conservation reserve. This may lead to major imbalance in the population structures of the prey animals. Right management of vegetation and long term preservation of openness of the grassland systems can bring about the true balance in the prey-predator relationships in these landscapes. As blackbucks are grazers and prefer open short grasslands, which seem to reflect both dietary preferences and anti-predator strategies, only the openness of vegetation holds its importance in terms of witnessing the livelihood and all biological activities of the blackbuck herds.

Space and time are the fundamental physical dimensions required for the existence of life on earth. In nature, organisms are neither distributed uniformly nor at random, instead forming some sort of spatial pattern. The spatial change in habitat structure or gradients due to various energy inputs, disturbances, and species interactions may also result in spatially evolved adaptations in communities of organisms, as well as change in the observed biological and ecological events. Habitat preference and the livelihood of blackbuck herds can be best assured by preserving the openness of their inhabiting grasslands.

Suggestions

1. In the wake of protecting the blackbucks and their habitat, Karnataka Forest Department is preparing a comprehensive management plan for this Conservation Reserve. Considering the above ecological problems, it is important to suggest that more priorities should be given to the vegetation management; highlighting openness of the grassland should be constantly maintained in the lekking arena of blackbucks.
2. External grazing forces such as sheep, goat, and domestic cattle groups must be strictly banned inside the Kaval in order to maintain the consistency in the recovery of the grassland vegetation and retain sustainability in future.
3. Through this study, it is to infer that only the openness of the grasslands can make the habitat suitable and promising for the resident blackbuck populations. This suitability of habitat for blackbucks was hampered by the invasive growth of the perennial shrubs in the Kaval. Phase by phase removal of these shrubs by uprooting method and maintaining the openness of the blackbuck habitat is strongly recommended.
4. Vegetation is a link between the atmosphere, soil, and water and is sensitive to global climate change (Cramer *et al*., 2001). The long term water retention in the soil has facilitated for the growth of tall vegetations and weeds. This has a negative effect on the seasonal and annual phenology of short grasses. This results in a short decline in the grass cover and the abundance of palatable grasses in the Kaval.
5. Only the natural lakes (Jadanakatte, Seenanakatte and Konanakatte) should be left as water bodies in the Kaval. Other created water retention tanks, rain water collection tanks, nala bunds, check dams should not exist within the open grassland systems (lekking areas) of the blackbucks. These tanks and bunds must be closed and maintained a plane surface in these regions for blackbuck movements.

Acknowledgement

Volunteers, who helped in the vegetation and camera trap surveys and worked passionately during the field work,

Forest Watchers of anti-poaching camp at Basur Amruth Mahal Kaval Blackbuck Conservation Reserve and Staff of Karnataka Forest Department, Kadur Range and Chikkamagaluru Division, Chikkamagaluru.

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