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Ecological impact of *Prosopis juliflora* on the habitat conditions of blackbuck in Sathyamangalam tiger reserve, Tamil Nadu, India

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Abstract
Bhavanisagar Range of Sathyamangalam Tiger Reserve in the foothills of the Nilgiris, Tamil Nadu, known for its landscape beauty varied of forest ecosystems and wildlife diversity. Current investigation carried out to assess the impact of *Prosopis juliflora* on habitat condition of blackbuck. The results revealed that *Prosopis* eradicated area attracted more blackbuck density than the *Prosopis* invaded area. Density of blackbuck, in different sites *viz.*, site I, site II and site III with the value of direct sighting 0.56 ha^{-1}, 0.39 ha^{-1} and 0.15 ha^{-1} respectively and indirect sighting 0.37 ha^{-1}, 0.22 $ha^{-1,}$ 0.29 ha^{-1} respectively. An effort was also made to study the impact of *Prosopis juliflora* eradication and effective management for improvement of a blackbuck habitat and indigenous floral species, which shows positive impacts towards high density population of blackbuck in the Sathyamangalam Tiger reserve.

Keywords: Blackbuck, conservation, habitat, improvement, invasive alien species

Introduction
Blackbuck *Antelope cervicapra* is an alluring gazelle-like antelope regarded as the handsome member of the family 'Bovidae'. It lives in open habitat (Schaller *et al*. 1967) [21]. In open grasslands, dry thorn, bush lands and scrublands. Blackbuck has important ecological roles in grassland ecosystem (Kunwar *et al*. 2015) [10]. Blackbuck was once distributed across the country however currently restricted to tiny fragmented patches. Conservation of blackbucks has perpetually been a tangle since acreage is restricted, and grassland in India is one of the least protected habitats. The disgraceful concept in the country is 'Grasslands are Wastelands', plantations of exotic making most grassland species dwell outside the PA's (Prashanth *et al*. 2016) [17]. Invasive Alien Species (IAS), also called exotics, foreign, non-indigenous or non-native are species introduced intentionally or unintentionally outside their natural habitats (Elton, 1958) [4]. Invasive aliens are regarded as the second greatest threat to global biodiversity (Genovesi *et al*. 2015) [5]. Invasive alien species causing the serious threat to Tiger reserve, where *Prosopis juliflora, Lantana camara* and *Opuntia delinii* were invaded in plains and hilly regions of tiger reserve respectively (Premkumar *et al*. 2018) [18]. In the late 1970s and early 1980s, anxious about deforestation, desertification and fuel wood shortages provoked a wave of projects that introduced *Prosopis juliflora* and other hardy tree species to new environments across the world (Mwangi *et al*. 2008) [15]. In India, species richness is estimated to reduce by 63% under *Prosopis juliflora* compared to open lands (Kaur *et al*. 2012) [9]. *Prosopis juliflora*, that was introduced and now could be wide unfold in semi-arid areas, has been noted to drive substantial losses of native vegetation in savannas and grasslands, thereby leading to the potential shrinking of blackbuck habitat. Confoundingly, blackbucks also are noted to eat mesquite seeds, and unwittingly aid in its dispersion through their dung pile (Rathore, 2017) [20]. Sathyamangalam Tiger Reserve (STR), the largest Tiger reserve of Tamil Nadu. The topography of the reserve is highly variable with plains, slopes, hills, streams and rivers. It comprises a large chunk of rain shadow forest area. On the other hand it is bestowed with perennial sources of water, such as the Moyar River. It is predominantly a tropical dry forest, which includes dry thorn, dry mixed deciduous, semi evergreen, hill and riparian forest types (Mani *et al*. 2017) [13]. *Prosopis juliflora* have severely invaded into the ecosystem in many places of the Sathyamangalam Tiger Reserve especially in Bhavanisagar Range. This has reduced the native floral composition and fodder availability to herbivores during the pinch period.

Herbivores such as blackbuck, elephants and bird communities play a major role in dispersing the seeds of those alien invasive species. Suppression of grass and other native species would result in enormous economic and ecological impacts on biodiversity (Management Plan Sathyamangalam wild life sanctuary, 2011) [12]. This study has been conducted to know the impact of *Prosopis juliflora* on the habitat condition of blackbuck in Sathyamangalam Tiger Reserve.

Materials and Methods

Study area

The study area is situated with Nilgiris in the south, Sathyamangalam in the north, Bhavanisagar in east and Segur plateau in west. Geographically, the study site lies at 11° 50′ N latitude and 77°07′ E longitude to 11° 56' N and 77° 02' and at an altitude ranging from 352 to 412 MSL. It receives a mean annual rainfall of 850 mm and the mean minimum and mean maximum temperatures were 21°C and 28°C, respectively. Bhavani and Moyar are the two perennial rivers that run through the reserve area (Mani *et al*. 2017). The study was conducted at Bhavanisagar Range of Sathyamangalam Tiger Reserve, Tamil Nadu, during October 2018 to April 2019. Sathyamangalam Tiger Reserve is the largest protected area in the state of Tamil Nadu, extending over 1455.76 km^2 and the Bhavanisagar range consists of 241.92 km^2 of forest area. The study area accounts to 35.82 km^2. The Forest types found in the study area are *viz.*, Southern tropical dry thorn forest (6 A /C1), Southern Tropical dry mixed deciduous forest (5A/C3), Southern Sub-Tropical hill forest (8A/C1) Southern tropical semi evergreen forest (2A/C2), and Riparian forest along the Moyar River.

Stratification of the study area

The study area was stratified into three areas *viz*., A) *Prosopis juliflora* eradicated and effectively managed area (Site-I), B) Natural forest area - non-invaded area (Site-II), and C) *Prosopis juliflora* invaded area (Site-III).

Study period

The blackbuck population dynamics and its habitat conditions were monitored in transect and sample plots of study areas with different seasons *viz.,* October 2018, January 2019 and April 2019.

Methods

Line transect Method

Direct survey

The basic line transect method as outlined by (Burnham *et al*. 1980) [1] was followed in the study area, six transect lines with 2 km length of each were laid out in accordance with three different sites. Each transect was walked between 7:00 am to 9:00 am. Observing the blackbuck on the transect line was noted using a range finder along with herd size. The age and sex of each individual were noted. The transect lines were monitored and observation was recorded in three different months *viz.,* October 18, January 19, April 19. Using following formula analysis was done.

$$Denisty\ (ha^{-1}) = \frac{Total\ no.of\ individuals\ of\ a\ species\ in\ all\ transect\ lines}{Total\ area\ of\ the\ transect\ line\ sampled}$$

Indirect survey

The indirect evidence were collected from the both six transect lines and 60 sample plots with in the size of 20 x 20 m base on the species effort curve of different sites of the study area of Sathyamangalam Tiger Reserve. Distinct pellet groups were counted. In the field, these come in myriad shapes, sizes, degree of scattering, age and decomposition. It was impossible to remove all ambiguity in what is to be counted as a separate pellet group or not and, in practice each observer forms his own mental image pellet groups which should be counted. There is generally less variation within the counts by the same observer. Hence it was preferred for obtaining data on trends that the same areas be repeatedly sampled by the same observer (Plumptre, 2002) [16]. The density of the animals was calculated with the data collected on the number of pellet groups and footprints. Following formula used to analysis indirect evidences.

$$Density\ (ha)^{-1} = \frac{Total\ no.of\ evidences\ of\ a\ species\ in\ all\ transect\ lines}{Total\ area\ of\ the\ transect\ lines\ sampled}$$

Habitat analysis

Canopy density

The canopy density was estimated by ocular estimation method. In the sample plots, the tree canopy was counted approximately based on spread of canopy and accordingly the canopy density was prepared in percentage.

Cover density

Density board is a convenient method to measured cover density in the field. The density board consists of a 1.80 m long wooden board, having a width of 5 cm, was divided into 6 equal parts of 30 cm each. The alternate panels can be coloured suitably and marked with numbers 1, 2, 3, 4, 5, and 6 in the ascending order from bottom. The board was kept at random, and the obscurity of vision was noted from the distance of 20 m; visible panel numbers were with a '+' mark recorded and the obscure ones as '0'. The cover density was prepared in percentage (Devos *et al*. 1971) [3].

Grass density

The grass density was estimated by using 1sq.m bamboo frame method. Bamboo frames with size of one meter was randomly placed and within one meter, latter the density of grass species was recorded in percentage.

Results and Discussion

Conservation of blackbucks was closely associated with the conservation of their habitat. Surveyed recorded blackbuck sightings which shows a significant habitat preference in the Moyar valley. From the field observations in Bhavanisagar range, it was noticed that blackbuck prefer areas with open habitat, sufficient water availability and share their habitat with cattle. The land cover used was thorny scrub which dominated the landscape. Blackbuck prefers grasslands which provide visibility to outrun predators. They do not rely on their sense of smell or hearing, but their sight, which is highly, developed *Prosopis juliflora* being a highly invasive species which strongly influences blackbuck occupancy. The positive effect of *Acacia* species on blackbuck occupancy was expected as blackbucks are known to browse these species. It is known to provide browse and mast when grass quality is low in the summers (Rathore, 2017) [20]. They were avoided the sloppy areas there was no detection of blackbuck presence in the a priori analysis on such steep slopes.

With regard to density of blackbuck, the study results of direct observation revealed that the highest density was

observed in site I (0.56 ha^{-1}), it was followed by site II (0.39 ha^{-1}), and the least density was recorded at site III (0.15 ha^{-1}) (Table 1) (Figure 1). Based on the indirect evidence highest density was observed in site I (0.37 ha^{-1}) it was followed by site III (0.29 ha^{-1}), and the least density was recorded at site II (0.22 ha^{-1}) (Table 2) (Figure 2). The basic habitat welfare factors like food, water and space was widely distributed all over the area in site I which has leads to high blackbuck density. The site-I- *Prosopis* eradication paved way for more open habitat area and rejuvenation of some less indigenous fodder species that attracting more blackbuck density than the *Prosopis juliflora* invaded in site-III. Less blackbuck population was observed in site III, this might be due to their habitat has mostly been restricted and also presence of *Prosopis juliflora* causing reduction of herbaceous plants leading the reduction in fodder and suitable habitat availability. Similarly findings were also stated by Senait *et al*. (2007) [22], that invasion of *Prosopis juliflora* rangelands caused the shortage of grazing land for animals and reduction in open area. The thorns of Prosopis penetrating into the skin of animals cause more physical injury than local *Acacia* thorns.

In different seasons, the study result shows that maximum blackbuck density was observed in the October 2018 (0.37 ha^{-1}) it was followed by January 2019 (0.33 ha^{-1}), and the least density was observed in April 2019 (0.30 ha^{-1}). This might be due to availability of many habitat welfare factors, like food spectrum, water and cover during the monsoon season. A similar finding was also stated by the Debata (2017) [2], average herd size was higher during monsoon probably because of the fresh growth of grass. Correspondingly Meena *et al*. (2018) [14], reported that the herd size is generally smaller in summer as compared to monsoon or winter.

The Spotted Deer also major herbivores in the study area, which used to consume the pods of *Prosopis juliflora*, which leads to the spreading of *Prosopis juliflora* through pellets. The invasion of *Prosopis juliflora* leads to the reduction in the regeneration of other herbaceous foliage for herbivore. A similar result was also observed by Hundessa *et al*. (2016) [7], that *Prosopis juliflora* encroached lands have reduced the native herbage yield.

The number of blackbuck individuals in the herd varied significantly. Based on the direct sightings, the female adults (FA) was found to be higher than male individuals in three sites irrespective of seasons. Regarding the sex ratio of blackbuck, average number of females for one male blackbuck was higher in site I (1: 9), whereas in site II (1:3), and it was followed by site III (1:1.66). The male individuals are very less than the female individuals. This might be due to that the lack of open habitat which hindered expression of lekking behaviour of blackbucks during the mating season (Table 1). Isvaran (2003) [8] reported that Operational Sex Ratio (OSR) may also be associated with lekking. Correspondingly Langbein *et al*. (1989) [11], stated that habitat structure may influence mating systems through its effect on social group size.

Habitat analysis

In habitat condition of the study area, regarding canopy density, the mean value of highest canopy density was observed in site-II (68.33 per cent), it was followed by site III (38.33 per cent), and the least density was recorded at site I (28.33 per cent) (Table 3) (Figure 3). In natural forest area (site-II) canopy was covered by predominant indigenous tree species. In site-III *Prosopis juliflora* and coexisted tree species has contributed towards canopy density and in the site-I area which was treated under mechanical clearing of Invasive plant *Prosopis Juliflora*, there was large canopy opening.

In case of cover density, the mean value of highest cover density was recorded in site II (71.66 per cent), followed by site I (38.33 per cent), and the least cover density was recorded at site III (31.66 per cent) (Table 3) (Figure 3). In site II natural forest area, the cover density was high because of indigenous species in Southern sub-tropical hill forest. In the site-III highest invasion of *Prosopis juliflora* caused less cover due to the effect on shrubs, cover and, in site-I, the clearing of *Prosopis juliflora* caused less cover density. Correspondingly Shetty (2014) [23] reported that due to the highest density of alien species like *Prosopis juliflora*, *Lantana camara* and *Eupatorium adenophorum* the cover density of Tiger Reserve was in a decreasing manner. Similarly, it was stated by Humaid *et al*. (1998) [6] that *Prosopis juliflora* plants possess allelochemical that inhibit the germination, growth and survival of other plant species whereas its seedlings growth was greater underneath and reduced the cover and grass density in *Prosopis juliflora* invaded area.

With respect to the grass density of study area, the mean value of highest grass density was observed in site II (60.00 per cent), it was followed by site I (43.33 per cent), and the least recorded by site III (21.66 per cent) (Table 3) (Figure 3). In the natural forest of site-II there was an absence of anthropogenic pressure and invasive plant and has led to the highest grass density. In site-I, the eradication of *Prosopis juliflora* was appearing to give positive impact towards grass density and in site-III; the *Prosopis juliflora* was influencing the low grass density. Ranjith (2018) [19] reported that the *Prosopis juliflora* plants possess allelochemical that inhibit the germination, growth and survival of other plant species whereas its seedlings growth was greater underneath and reduced the cover and grass density.

With respect to the habitat condition of blackbuck, it was observed that the site I – *Prosopis* eradicated area has paved way for more canopy opening leads for more grass growth. The moderate cover and grass density has ensured the good habitat condition for open land species- blackbuck.

Table 1: Season and Site wise variation in Blackbuck individuals in STR through direct observation

Site	Month	MA	MSA	FA	FSA	FW	Total	Density
SITE I	Oct-18	2	1	19	0	2	24	0.6
	Jan-19	1	0	21	0	2	24	0.6
	Apr-19	3	0	15	0	1	19	0.48
	Mean	2	0.33	18.33	0	1.66	*	0.56
SITE II	Oct-18	3	2	9	0	3	17	0.43
	Jan-19	4	0	8	2	1	15	0.38
	Apr-19	3	0	10	0	1	14	0.35

	Mean	3.33	0.66	9	0.66	1.66	*	0.39
SITE III	Oct-18	2	1	3	0	0	6	0.15
	Jan-19	3	0	5	0	0	8	0.20
	Apr-19	1	0	2	0	1	4	0.10
	Mean	2	0.33	3.33	0	0.33	*	0.15

(MA- Male adult, MSA- Male sub-adult, FA-Female adult, FSA- Female sub-adult, FW-Fawn)

Table 2: Season and Site wise variation in Blackbuck individuals in STR through indirect observation

Sites	Month						Mean Density
	October	Density	January	Density	April	Density	
SITE I	17	0.42	16	0.4	12	0.30	0.37
SITE II	10	0.25	8	0.2	9	0.23	0.22
SITE III	14	0.35	8	0.2	13	0.33	0.29

Table 3: Seasonal variation of Habitat condition of Black buck in STR

Sites	Month	Canopy Density (%)		Cover Density (%)		Grass Density (%)	
Site-I	October	30	Mean	40	Mean	45	Mean
	January	30	28.33	45	38.33	45	43.33
	April	25		30		40	
Site-II	October	70	68.33	75	71.66	70	60
	January	70		75		60	
	April	65		65		50	
Site-III	October	40	38.33	35	31.66	25	21.66
	January	40		30		20	
	April	35		30		20	

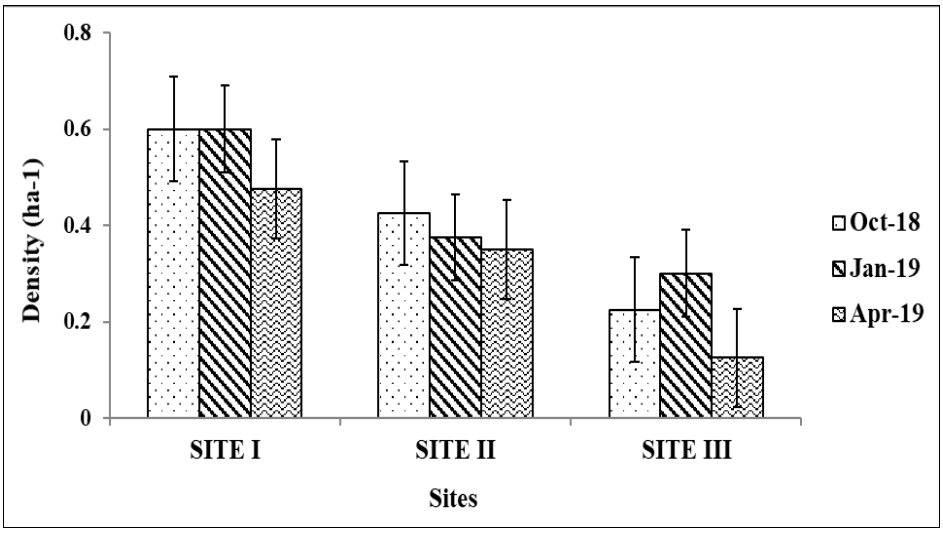

Fig 1: Seasonal and Site wise density variation of Blackbuck in STR through direct observation

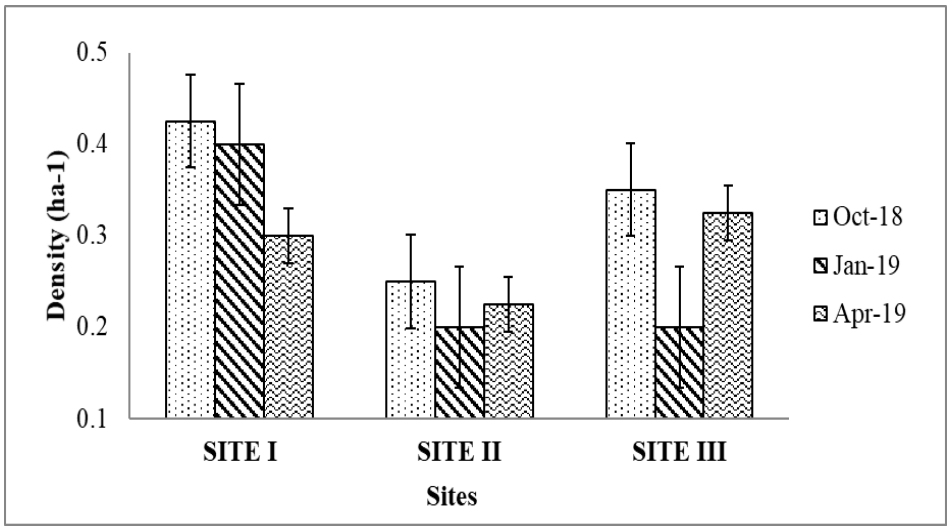

Fig 2: Seasonal and Site wise variation in Blackbuck density through indirect observation.

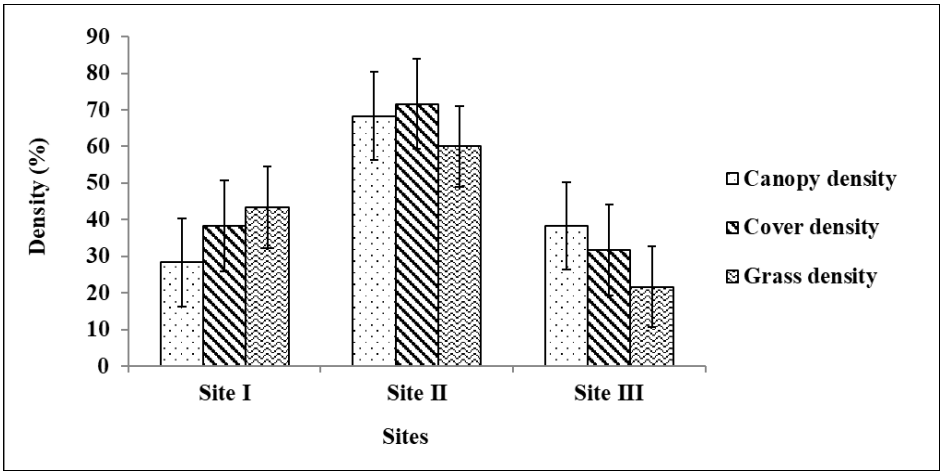

Fig 3: Habitat analysis of Blackbuck in STR

Conclusion

An effort was made to study the impact of *Prosopis juliflora* eradication and effective management for improvement of a blackbuck habitat and indigenous floral species which shows positive impacts towards high density population of blackbuck in the Sathyamangalam Tiger reserve. Hence there was an improvement towards shrub and herbaceous layer composition in the *Prosopis juliflora* eradicated area showing positive trend than *Prosopis juliflora* invaded area. Since the area supports the enormous number of the herbivorous population of blackbuck with spotted deer. Regarding the sex ratio of blackbuck, the male individuals are very less than the female individuals. This might be due to that the lack of open habitat which hindered expression of lekking behaviour of blackbucks during the mating season. The habitat condition of blackbuck, the site I – Prosopis eradicated area has paved way for more canopy opening leads for more grass growth. The moderate cover and grass density has ensured the good habitat condition for open land species blackbuck. Cattle from villages occupying the habitat of blackbuck and they are the main zoophily agents for *Prosopis juliflora* seeds. If this situation continues for few decades, the tiger reserve will be under great threat by invasive alien species. So in future more advanced ecological studies are needed to conclude this complex situation. There was immediate need of standard framework and strong modern controlling strategies (mechanical eradication, prescribed burning and chemical control) to tackle the *Prosopis juliflora* invasion towards biodiversity of Tiger Reserve. The Sathyamangalam Tiger Foundation has initiated the eco-development committees, with involvement community participation. Community-based *Prosopis juliflora* eradication in Tiger reserve will be the sustainable management strategies to ensure the ecological balance and livelihood enhancement of the local tribal community. This study will help to conclude that eradication of *Prosopis Juliflora* has a positive impact towards biodiversity and will serve as baseline data base pertaining to the management of invasive habitats by suitable management plans in Sathyamangalam Tiger Reserve.

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