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Impact of invasive *Prosopis juliflora* on the mammalian diversity of Sathyamangalam tiger reserve, Tamil Nadu, India

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Abstract
The forest in Bhavanisagar range forms a part of the Nilgiris Biosphere Reserve, and is one of the rich biodiversity areas of Western Ghats. Invasive alien species such as *Prosopis juliflora*, *Lantana camara* and *Opuntia delinii* have invaded in plain and hilly regions. Besides these, they created a harmful effect on native environments that include displacement of native species, degradation or elimination of habitat welfare factors, alternation in soil properties, degradation of wildlife forage, adversely altered fire regime and posed a considerable threat to endangered species. The present study was initiated to study the invasion impact of *Prosopis juliflora* on mammalian diversity of Sathyamangalam Tiger Reserve (STR). The results revealed that a total 16 mammal species were documented in this area, through direct and indirect evidences of which 10 species of herbivore 5 species of carnivore and 1 species of omnivore were recorded. In habitat analysis, natural forest significantly was rich in habitat welfare factors for mammal diversity.

Keywords: Mammals, native species, mammal diversity, welfare factors, fire regime

Introduction
Invasive alien plants are non-native organisms and they have the potential to cause, harm to the environment, economics and human health. Invasive alien species are one of the most significant drivers of environmental transformation worldwide. An invasive plant is an alien species which establishes in natural or semi natural ecosystems, an agent of change and threatens native biological diversity. According to the World Conservation Union, invasive plants are generally considered to be the second greatest threat to biodiversity after habitat destruction (Buckley and Roughgarden, 2004) [3]. Exotic plant species have been purposely and/or accidentally introduced throughout the world due to their economic, environmental or aesthetic values. Nonetheless, introduction of new species is not always a success and brings about the possibility of invasiveness of the species which in turn result in negative impacts (economic, environmental and social) (Andersson, 2005) [1]. In the late 1970s and early 1980s, concern about deforestation, desertification and fuelwood shortages prompted a wave of projects that introduced *P. juliflora* and other hardy tree species to new environments across the world (Mwangi and Swallow, 2005) [8] that it did not take *P. juliflora* a long time to be registered as one of the first top 100 invaders. During its introduction from its natives, South America, Central America and the Caribbean, the indigenous knowledge of its management and use were rarely followed resulting to remain under-utilized and unmanaged (Pasiecznik *et al*., 2003) [10]. In Sathyamangalam Tiger reserve *Prosopis juliflora*, *Lantana camara* and *Opuntia dillenii* have severely invaded into the ecosystem at many places. This has reduced the native floral composition and fodder availability to herbivores during the critical dry season. Such a phenomenon has been noticed in Bhavanisagar Range. Large herbivores such as Black buck, Elephants and bird communities play a major role in dispersing the seeds of alien invasive species. It is necessary to investigate the dynamic processes of the seed dispersal by animals and also eliminate plant weeds in a phased to re-establish native species to support of herbivores. (Management Plan for Sathyamangalam Wildlife Sanctuary-2010:2020). The suppression of grass and other native species would result in enormous economic and ecological impacts on biodiversity. As a result of this, we may lose such most important conservation areas with rare, diverse and endemic species and natural heritage.

Material and Methods

Study area

The study area is situated in 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' at an altitude ranging from 352 to 412 MSL. The study was conducted at Bhavanisagar Range of Sathyamangalam Tiger Reserve, Tamil Nadu, during August 2016 to May 2017. Sathyamangalam forest division is the largest forest 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 mixed deciduous forest (5A/C3), Southern Sub-Tropical hill forest (8A/C1) and Riparian forest along the Moyar River.

Stratification of the study area

The study area was stratified as follows:

A. *Prosopis juliflora* eradicated and effectively managed area (Site-I)
B. *Prosopis juliflora* invaded area (Site-II)
C. Natural forest area (Site-III, *Prosopis juliflora* non-invaded area)

Line transect method (Direct survey)

The basic line transect method as outlined by Burnham *et al.* (1980) [4] was followed in the study area as nine transect lines with 2 km length were laid out in accordance with three different sites. Each transect was walked between 7.0 am to 9.0 am. On observing an animal's was noted using a range finder along with group size. The age and sex of each individual were noted. The transect lines were monitored and observation were recorded in three different months *viz.*, September 2016, December 2016 and March 2017.

$$\text{Density of animals (ha}^{-1}) = \frac{\text{Total number of individuals of a species in all transects lines}}{\text{Total area of the transects line sampled}}$$

Indirect survey methods

Observing the ecosystem for evidence, for example, foot prints and pellets, indicating the presence of particular mammals as an indirect method of accounting mammal diversity was carried out in the study area. (Brookhouse *et al*., 1996) [2]. The indirect evidences were collected from all the transect lines as well as from 75 sample plots with of 20 x 20 m laid at different sites of the study area of Sathyamangalam Tiger Reserve.

$$\text{Density of indirect Evidences of animals (ha}^{-1}) = \frac{\text{Total number of evidences of a species in all transects lines}}{\text{Total area of the transects line sampled}}$$

Pug mark census

This method was carried out to enumerate the carnivores in the forest, such as tiger leopard, etc. In this method, the pug marks were recorded and determined, and other extra information like width, length and shape were also be noted (Brookhouse *et al*., 1996) [2].

Dung counts method

Distinct pellet groups were counted. In the field, these come in myriad shapes, sizes, degree of scattering, age and decomposition. It is be 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, 2000) [11].

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

A rough idea of scrub and woodland cover was obtained by counting the number of trees available per unit area, or by the canopy shade as seen on the forest floor. However, this was conveniently measured in the field using a "density board". The density board 1.80 m long wooden board having a width of 5 cm, was divided into 6 equal parts of 30cm each. The alternate panels can be colored 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 recorded with a '+' mark and the obscure ones as 'Zero'. The cover density was prepared in percentage (DeVos and Mosby, 1971) [5].

Grass density

Grasses are equally important in a wild habitat since they provide both fodder as well as cover to the wild animals. The grass density was estimated by using bamboo frames. One meter size of bamboo frames was fixed randomly and within that one meter, the density of grass species was recorded in percentage.

Results and Discussions

That 16 mammal species were recorded in Bhavanisagar range in Sathyamangalam Tiger Reserve, through direct and indirect evidences, consisting of 10 herbivores, 5 species of carnivores and 1 species of omnivore. Shetty (2014) [13] also reported 21 mammal species in Sathyamangalam Tiger Reserve, through direct and indirect evidences.

The mammal density was maximum in site-III, followed by site-I and site-II. The basic habitat factors like food, water and space was widely distributed all over the area in site-III which has to high mammal density. The site-I was rejuvenating with few indigenous fodder species attracting more mammal density than the *Prosopis juliflora* infested site-II causing reduction of herbaceous plants leading the reduction in fodder availability. Regassa *et al*. (2007) [12] reported that invasion of *Prosopis juliflora* in rangelands caused the shortage of grazing land for animals (Fig. 1, Fig. 2).

In case of herbivores, Spotted Deer (*Axis axis*) showed maximum density in all sites during different season *viz.*, September, December and March with the value of 2.96 ha^{-1}, 2.57 ha^{-1} and 2.53 ha^{-1} respectively. This might be due to the presence of food spectrum of Spotted deer in all the sites and the presence of three different forest types in this area has created wider edge and ecotone effect resulting in high animal population and density. The wild dog (*Cuon alpinus*) with the highest mean density was scored among carnivores in the study area *viz.*, 0.53 ha^{-1}, 0.47 ha^{-1}, and 0.26 ha^{-1} in September, December and March respectively in all there sites. This might be due to the availability of more prey population in this area. Based on Shetty (2014) [13] studies, the result deviates from the earlier reports of carnivore density (0.65 ha^{-1}) as recorded by Wild dogs in Sathyamangalam Tiger Reserve.

The wild dog is a small carnivore predator, so its population was not having significant effects towards the spotted deer population. The Black buck and Spotted Deer are the major herbivores in the study area, which consume the pods of *Prosopis juliflora*, spreading it through pellets. The invasion of *Prosopis juliflora* has lead to the reduction in the regeneration of other herbaceous foliage for herbivores. A similar result was also observed by Niguse and Amare (2016) [9] where *Prosopis juliflora* encroached lands have reduced the native herbage yield.

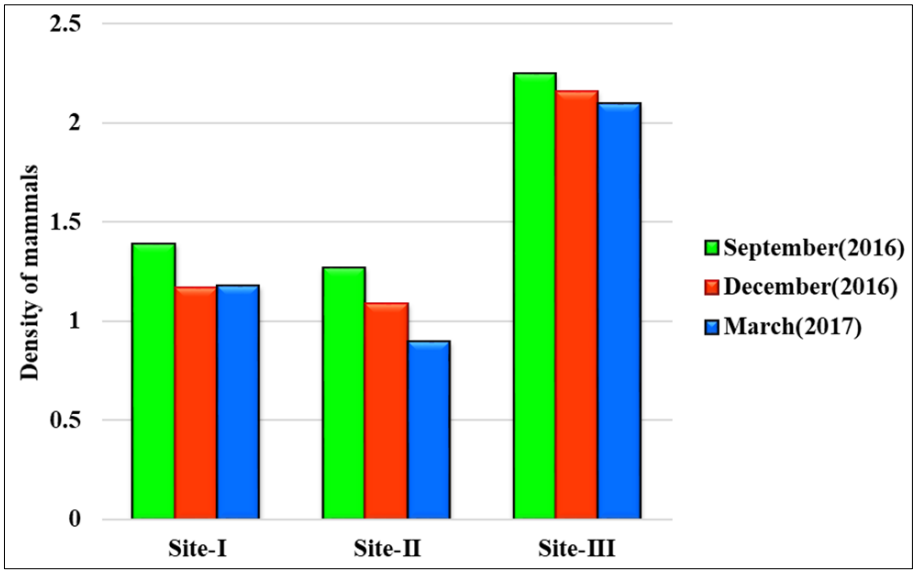

Fig 1: Season wise mammals density through direct observation in the study area

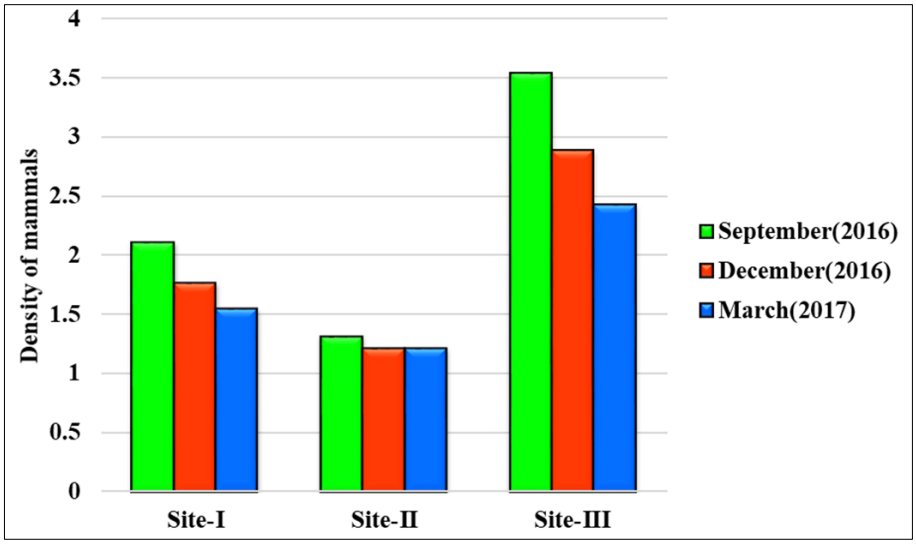

Fig 2: Season wise mammals density through indirect evidences in the study are

Table 1: Season wise mammal diversity in the study area through direct observation

Interval		September 2016							December 2016							March 2017						
Sites		Site-I		Site-II		Site-III		Total	Site-I		Site-II		Site-III		Total	Site-I		Site-II		Site-III		Total
S. No	Common Name	N	D	N	D	N	D		N	D	N	0.03	N	D		N	D	N	D	N	D	
1	Tiger	0	0.00	0	0.00	0	0.00	0.00	0	0.00	0	0.03	0	0.00	0.00	0	0.00	0	0.00	1	0.03	0.03
2	Leopard	0	0.00	0	0.00	0	0.00	0.00	0	0.00	0	0.03	1	0.03	0.03	1	0.03	0	0.00	0	0.00	0.03
3	Wild dog	1	0.03	0	0.00	2	0.07	0.10	0	0.00	0	0.07	0	0.00	0.00	0	0.00	0	0.00	1	0.03	0.03
4	Asiatic Elephant	1	0.03	1	0.03	2	0.07	0.13	0	0.00	1	0.03	1	0.03	0.07	1	0.03	0	0.00	1	0.03	0.07
5	Indian Gaur	1	0.03	0	0.00	2	0.07	0.10	0	0.00	1	1.43	1	0.03	0.07	0	0.00	0	0.00	1	0.03	0.03
6	Spotted Deer	12	0.40	15	0.50	22	0.73	1.63	14	0.47	11	0.40	25	0.83	1.67	10	0.33	9	0.30	24	0.80	1.43
7	Sambar Deer	3	0.10	2	0.07	5	0.17	0.33	2	0.07	1	1.13	6	0.20	0.30	4	0.13	2	0.07	6	0.20	0.40
8	Black buck	8	0.27	10	0.33	18	0.60	1.20	11	0.37	5	0.03	17	0.57	1.10	10	0.33	8	0.27	16	0.53	1.13
9	Wild Boar	0	0.00	0	0.00	1	0.03	0.03	1	0.03	0	0.07	0	0.00	0.03	0	0.00	1	0.03	0	0.00	0.03
10	Common mongoose	2	0.07	2	0.07	3	0.10	0.23	1	0.03	1	0.13	2	0.07	0.13	0	0.00	1	0.03	1	0.03	0.07
11	Indian hare	2	0.07	2	0.07	2	0.07	0.20	1	0.03	2	0.03	3	0.10	0.20	1	0.03	1	0.03	2	0.07	0.13
12	Malabar squirrel	1	0.03	0	0.00	2	0.07	0.10	0	0.00	0	0.30	1	0.03	0.03	0	0.00	0	0.00	1	0.03	0.03
13	Striped squirrel	3	0.10	2	0.07	5	0.17	0.33	2	0.07	3	0.37	5	0.17	0.33	3	0.10	2	0.07	4	0.13	0.30
14	Bonnet Macaque	6	0.20	4	0.13	3	0.10	0.43	3	0.10	6	4.08	3	0.10	0.40	4	0.13	3	0.10	4	0.13	0.37
Total		40	1.33	38	1.27	67	2.25	4.81	35	1.17	31	1.03	65	2.16	4.36	34	1.11	27	0.9	62	2.04	4.08

N= Number of individuals D= Density of animal

Table 2: Season wise mammal diversity in the study area through indirect observation

Interval		September 2016							December 2016							March 2017						
Sites		Site-I		Site-II		Site-III		Total	Site-I		Site-II		Site-III		Total	Site-I		Site-II		Site-III		Total
S. No	Common Name	N	D	N	D	N	D		N	D	N	D	N	D		N	D	N	D	N	D	
1	Tiger	2	0.07	1	0.03	3	0.10	0.20	1	0.03	0	0.00	3	0.10	0.13	2	0.07	1	0.03	3	0.10	0.20
2	Leopard	1	0.03	0	0.00	2	0.07	0.10	1	0.03	0	0.00	1	0.03	0.07	1	0.03	0	0.00	2	0.07	0.10
3	Striped hyena	1	0.03	0	0.00	1	0.03	0.07	2	0.07	1	0.03	1	0.03	0.13	0	0.00	1	0.03	1	0.03	0.07
4	Wild Dog	4	0.13	3	0.10	6	0.20	0.43	5	0.17	3	0.10	6	0.20	0.47	3	0.10	1	0.03	3	0.10	0.23
5	Asiatic Elephant	10	0.33	7	0.23	15	0.50	1.07	8	0.27	4	0.13	12	0.40	0.80	4	0.13	2	0.07	6	0.20	0.40
6	Indian Gaur	4	0.13	3	0.10	12	0.40	0.63	4	0.13	6	0.20	14	0.47	0.80	4	0.13	3	0.10	8	0.27	0.50
7	Spotted Deer	10	0.33	10	0.33	20	0.67	1.33	8	0.27	7	0.23	12	0.40	0.90	9	0.30	10	0.33	14	0.47	1.10
8	Sambar Deer	12	0.40	6	0.20	20	0.67	1.27	6	0.20	3	0.10	10	0.33	0.63	7	0.23	8	0.27	15	0.50	1.00
9	Black buck	18	0.60	10	0.33	24	0.80	1.73	17	0.57	13	0.43	26	0.87	1.87	14	0.47	10	0.33	19	0.63	1.43
10	Wild Boar	2	0.03	0	0.00	1	0.03	0.06	1	0.03	0	0.00	1	0.03	0.06	2	0.06	1	0.03	1	0.03	0.12
11	Sloth Bear	1	0.03	0	0.00	2	0.07	0.10	0	0.00	0	0.00	1	0.03	0.03	1	0.03	0	0.00	1	0.03	0.07
Total		65	2.11	40	1.32	106	3.54	6.99	53	1.77	37	1.22	87	2.89	5.89	47	1.55	37	1.22	73	2.43	5.22

N= Number of individuals D= Density of animal

Habitat analysis

In habitat condition of the study area, regarding canopy density, the mean value of 68.33 per cent, 38.33 per cent and 28.33 per cent was exhibited by site-III, site-II and site-I respectively. In natural forest area (site-III) canopy was covered by predominant indigenous tree species. In site-II *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. Similarly, Praful Shetty (2014) [13] reported that, the average canopy density recorded was 42.8 per cent for the open canopy, 29.5 per cent for the moderate canopy and 27.8 per cent for the closed canopy in Bhavanisagar range of Sathyamangalam Tiger Reserve (Fig. 3).

The mean value was71.66 per cent, 31.66 per cent and 28.33 per cent in site-III, site-II and site-I respectively. In natural forest area, the cover density was high because of indigenous species in Southern sub-tropical hill forest. In the site-II highest invasion of *Prosopis juliflora* caused less cover due to the effect on shrub, cover and in site-I, the clearing of *Prosopis juliflora* caused less cover density. Correspondingly, Praful Shetty (2014) [13] reported that due to the highest density of alien species like *Prosopis juliflora, Lantana camara* and *Euphotorium adenophorum* the cover density of Tiger Reserve was in a decreasing manner. Similarly, it was stated by Warrage and Al-Humaid (1998) [14] 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 (Fig. 3).

With respect to the grass density of study area, the mean value of 60.00 per cent, 43.33 per cent and 21.66 per cent was exhibited by site-III, site-I and site-II respectively. In the natural forest of site-III there was an absence of anthropogenic pressure and invasive plant and has lead 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-II, the *Prosopis juliflora* was influencing the low grass density. Correspondingly, Kahi *et al*., (2009) [6] also found that cover of understory herbaceous plant species in plots invaded by *Prosopis juliflora* was 27 per cent less than under *Acacis tortilis* canopy (Fig. 3).

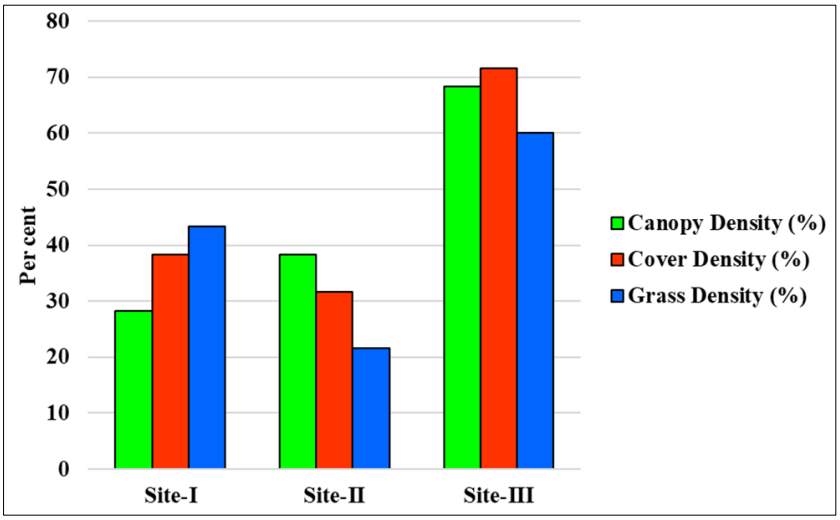

Fig 3: Habitat analysis of the study area

Conclusion

An effort was made to study the impact of *Prosopis juliflora* eradication and effective management for improvement of indigenous floral species which shows positive impacts towards rich faunal base and soil conditions of 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. The assessed natural forest area (site-III) was higher in floral and faunal diversity than *Prosopis juliflora* invaded and eradicated sites. Since the area supports the enormous number of the herbivorous population like Black buck, spotted deer and the Cattle from villages 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 Sathyamangalm Tiger Reserve.

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