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Original investigation

Spatial and dietary overlap between blackbuck (*Antilope cervicapra*) and feral horse (*Equus caballus*) at Point Calimere Wildlife Sanctuary, Southern India: Competition between native versus introduced species

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ABSTRACT

Overgrazing by livestock is a serious threat to the biodiversity in the tropical forests of Asia. Feral horse, an introduced species at Point Calimere Wildlife Sanctuary, is a grazer and overlaps extensively in space and food resources with blackbuck, a native species, and thus could be a potential competitor. We have assessed, between December 2012 and June 2013, if the ecological conditions in the study site favour competition between these two species by assessing their spatial distribution pattern, population density, and dietary overlap. Spatial distribution pattern on direct sighting of both the species across habitats revealed that feral horses ranged mostly in the southern and southeastern parts of the sanctuary, in areas mostly with open grasslands, overlapping extensively in space with blackbuck, a grassland habitat specialist of the sanctuary. Population density estimated using line-transect distance sampling method showed 50 (95% CI 41.6–60.6) blackbucks and 21 (15.2–30.0) feral horses per km^2 of the sanctuary. Dietary overlap assessed through site examination of feeding trails revealed that out of 14 plant species identified from blackbuck diet during the study period, 12 (86%) were also consumed by feral horses. Similarly, food plants such as *Cloris parpata,* a grass species, and herb *Desmodiam dryflorae*, the principal food of blackbuck, were also the major food plants of feral horses. Further, estimation of food consumption rate showed that feral horse consumed significantly more food per unit time (2.8 ± 0.08 g/min) than blackbuck (1.7 ± 0.07 g/min). Dietary overlap estimated using Schoener's Index showed a significant overlap between the two species (overall 89% and habitat-wise 85–90%). An analysis of food preference using Jacob's Preference Index revealed that all the preferred food plants of the blackbuck were equally preferred by feral horses indicating significant overlap in the diet species composition. Although the density estimate revealed a lesser number of feral horses per capita than blackbuck, the higher food consumption rate of the former coupled with larger body mass, could outweigh the higher density of blackbuck and the same is discussed as an effective ecological competitor. Based on the findings appropriate recommendations are made for the management of blackbuck in the sanctuary.

Introduction

Among the various taxa, mammalian species are increasingly subjected to anthropogenic pressure across the globe, with almost one in four threatened with extinction (Schipper et al., 2008) and the scenario is more severe particularly in Asia and Africa. Given the conservation threats facing the mammalian fauna, it is crucial to understand the distribution, abundance, diversity and resource-use patterns of large mammals (Gordon et al., 2004). Overgrazing by livestock is a serious threat to the biodiversity of the tropical forests of Asia and Africa (Baskaran et al., 2012; Niamir-Fuller et al., 2012). Indian blackbuck Antilope cervicapra, an endemic species to Indian sub-continent, the only species in its genus, belongs to the subfamily Antilopinae (true antelopes) and family Bovidae. The species was a widespread common ungulate in Indian subcontinent during the 19th century (Long, 2003) and is now locally extinct in many parts of India owing to extensive hunting, and habitat loss in the form of reforestation, irrigated agriculture and urbanization (Daniel and Arivazhagan, 2008). In India, an estimated 35,000 individuals are patchily distributed in the wild, while its populations in Nepal and Pakistan are regionally extinct and the species

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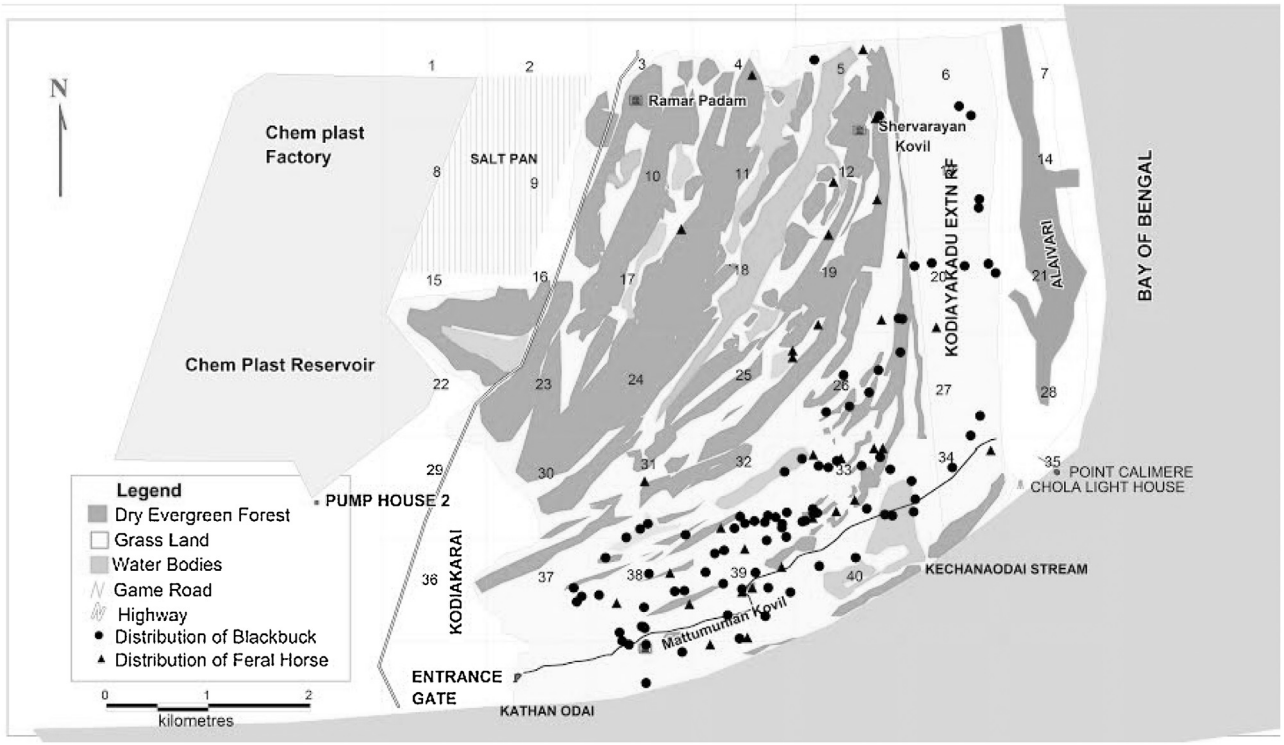

Fig. 1. Map showing the distribution of blackbuck and feral horse at Point Calimere Wildlife Sanctuary, southern India recorded between December 2012 and June 2013. The numbered grids represent the line transect sampling areas.

is categorized as 'near threatened' on the IUCN Red List (IUCN Red List 2015) and placed under Schedule I in Wildlife Protection Act (1972). The species occupies wide range of habitats from tropical, and subtropical woodlands to dry deciduous forests, open plain grassland, riverbanks, semi-desert habitats, crop lands and pasture lands (Long, 2003; Maldron, 2008) of central and southern India. Tamil Nadu, a southern state in India, harbours the largest population for the region with Point Calimere Wildlife Sanctuary holding the highest number. The reserve was established in 1967 especially for the conservation of blackbuck and supports more than 1500 of them (March 2010 census). Apart from blackbuck, the reserve also supports low density of chital *Axis axis* (1.81individuals/km^2), the only other large wild herbivore. In addition, feral horse *Equus caballus* is a unique large herbivore but an introduced species to the reserve. These are free-roaming horses with domesticated ancestry and thus are not wild. The origin of these horses at Point Calimere is unknown precisely and there exist two differing views: according to one, about thousand years ago the Chola kingdom used them for trade with Sri Lanka as well as with Arabia and abandoned them after the decline of the dynasty. The other view is that these horses are the descendants of those brought by the Portuguese, who landed at the nearby Velankanni beach and were used for building the famous church there. These horses were used to transport building materials; while returning home the Portuguese had abandoned them, and they strayed into the forests and adapted to life in the wild (Ramasubramaniyan, 2012).

The blackbuck population showed a declining trend; from over 2300 individuals until 1995, it fell to around 1500 individuals by 2010 (Jagdish, 2011). The conservationists hold contradictory views, with one group saying that the presence of a large number of feral horses occupying grasslands affects the blackbuck population, while the other views them (approximately 150 individuals) not as a potential threat, as blackbuck population (approximately 1500 individuals) outnumbers them. Studies on interspecific competition postulate that the species that use the same resources cannot exist together for long without one competitively excluding the other (Gause, 1934; Schoener, 1968). Spatial or temporal resource partitioning must occur for multiple species to coexist (Caughley and Sinclair, 1994; Morrison et al., 1998). Temporal avoidance as a behavioural mechanism for coexistence was reported among sympatric species (Krausman and Ables, 1981; Valeix et al., 2007; Darmon et al., 2014). Among herbivores competition is severe between species with similar feeding style and similar body weights; when body weights differ, species may partition resources by size and quality, such that each species has exclusive use of resources (Belovsky, 1986; Prins and Olff, 1998; Ritchie and Olff, 1999). Although larger than the blackbuck, does the feral horse partition its resources by size and quality? If not, being a grazer (Duncan, 1992) with overlapping feeding niche with blackbuck, and without a potential predator to regulate its population, could it effectively be a competitor to the blackbuck in the long run? Biological invasions caused by alien species are one of the main threats to native biological diversity (IUCN, 2000), and with significant negative effects on ecosystem services to mankind (Vilà et al., 2010) could the feral horse, being an alien species to Point Calimere, be a threat to the native blackbuck population and for the biodiversity of the reserve? Unfortunately, no comprehensive data exists on this vital but highly ignored aspect. In this paper, we present the first quantitative ecological data on (i) the population and distribution pattern of the blackbuck and the feral horse, and (ii) their diet composition from Point Calimere Wildlife Sanctuary, southern India, to understand the spatial and dietary overlap of the introduced species with the native blackbuck to assess if the ecological context favours competition between the two species.

Materials and methods

Study area

The study was carried out between December 2012 and June 2013 at Point Calimere Wildlife Sanctuary, located between 10°18′

N: 79°51′ E and 10°21′ N: 79°25′ E and lies at the confluence of Bay of Bengal and the Palk Strait, near Nagapattinam, Tamil Nadu. The sanctuary derives its name 'Point Calimere' from the spot inside the sanctuary, where the coast takes a 90° turn from the Bay of Bengal towards the Palk Strait (Fig. 1). The reserve encompasses an area of 30 km^2 of sandy coast fringed by saline swamps and thorny scrub around the backwaters. The coastal area consisting of shore, shallow water, inter-tidal flats, saline lagoons as well as manmade salt pan sites supports >250 species of birds, with about 120 being water birds that include vulnerable species like Spoonbill Sandpiper (*Euryhoryhynchus pygnaeus*), Grey Pelicans (*Pelecanus philippensis*) and Greater and Lesser Flamingoes and is among the 26 wetlands of India designated as of International Importance (pointcalimere.org/overview.htm).

The sanctuary consists of unique vegetation types, viz. tropical dry evergreen, open grassland with patches of open scrub (Ali, 2005). Its tropical dry evergreen forest is considered the richest tract in the entire country. The grasslands located on the southern part of the sanctuary are the natural habitat of the blackbuck. It is also known for other mammals like chital *A. axis*, jackal *Canis aureus*, wild pig *Sus scrofa*, and bonnet macaque *Maecaca radiata* (Ramasubramaniyan, 2012). Although there are no large carnivores to predate the blackbucks, jackals often prey on their fawns in the sanctuary (K. Ramkumar, personal observations). In addition to pressure from the feral horse, its natural habitats also experience anthropogenic pressure from cattle and also from invasion of *Prosopis juliflora* (Nedumaran, 1987; Ali 2005). With an average density of 14 cattle/km^2, the sanctuary experiences grazing pressure from 300 to 600 cattle/day (Ali, 2005). The Prosopis, an alien species, is also considered a serious threat to the natural habitats, as its invasion into open space results in the reduction of native flora (Ali, 2005), which in turn reduces food availability to herbivores like blackbuck and chital.

Study species

The blackbuck is a medium-sized antelope (weighing 23–45 kg), a native to the Indian subcontinent (Mungall et al., 1981; Ranjitsinh, 1989). The species is sexually dimorphic with males larger and conspicuously coloured than females. It is a social species and lives in groups of two to several hundred individuals (Ranjitsinh, 1989), and is also well known to live in different social groups, viz. the female herds consist of adult females and juveniles of both sexes; mixed-sex herds composed of adults and juveniles of both sexes and purely all male herds (Isvaran, 2004). The blackbuck population in the study area remained over 2300 individuals until 1995 but declined to around 1800 by 2006 and further to around 1500 individuals by 2010 (Jagdish, 2011); a recent short-term assessment estimates the population at 1460 (95% CI varies from 1143 to 1865—Ali, 2005).

Distribution pattern and spatial overlap

To identify and map the distribution of blackbuck and the feral horse, a systematic field survey was carried out on foot covering each administrative unit (beat) and forest types of the sanctuary. During the survey, boundaries of administrative units of the forest division were marked on a map in consultation with forest officials and official documents available to record the presence/absence of both the blackbuck and the feral horse. Later, through intensive field surveys of all the habitats, the distribution of blackbuck and feral horse was identified following direct sightings and indirect evidences (droppings). On every sighting of the target species, geo-coordinate data was collected using Global Positioning System (GPS) besides recording their number. The division boundary marked on the Survey of India topographic map and the other land-use observed in and around the studyareawere digitized using Geographical Information System (GIS) software (Arc View 3.3, ESRI Inc.) to create the study area map with various land-use patterns. Later, the geo-coordinate data collected for the direct sightings of blackbuck were superimposed as an additional layer to create the distribution map of the blackbuck; a similar effort was made for the feral horse. In addition, using the presence/absence data on blackbuck and feral horse from the grid used for population estimates, we have developed a matrix in which the row represents a species and the column a grid; their spatial overlap or co-occurrence was quantified using the C-score index (Stone and Roberts, 1990), calculated as $C_{ij} = (r_i - S)(r_j - S)$, where r_i is the number of grid with species i and r_j the number of grid with species j, S being the number of the shared grid. This index quantifies the 'checkerboard units' (Diamond 1975) for the species pair, and larger the index the lesser is the co-occurrence of the species.

Population density estimate

The density of blackbuck and feral horse population was estimated using the line transect method (Burnham et al., 1980). The sanctuary maps were overlaid with 1 × 1 km grid and all the grids were numbered with running serial number resulting in 40 grids. Of these, 37 were selected for sampling. In each grid, a line transect was randomly laid, but aligned to run across drainage patterns and water bodies. From this map, geo-coordinate details were extracted for each line transect start and end points and using them transect lines were established in natural habitats of the sanctuary with the help GPS and field compass. These lines were marked with red colour paint or tags. All these transects were sampled at weekly intervals between January and March 2013 during morning (06:00–10:00 h) or evening (16:00–18:00 h). At every sighting of the blackbuck or feral horse, besides the group size, sighting angle and sighting distance were recorded.

Data analysis

Using the transect data, density was estimated following distance-sampling techniques employing the software DISTANCE (version 6.0, Buckland et al., 2004; Thomas et al., 2005). Group and individual density of blackbuck and feral horse, and their Standard Error (SE) were estimated, evaluating each model of detection probability, viz. uniform, half-normal and hazard-rate with three different series adjustment terms such as cosine, simple polynomial and hermite polynomials (i.e. detection probability uniform with cosine series adjustment, uniform with simple polynomial and uniform with hermite polynomial and similar combination for half-normal and hazard-rate). The best model was selected for estimating density of each species from nine different combinations of analyses, using the minimum *Akaike Information Criteria* (AIC) as the standard model selection procedure,

Assessment of diet composition and biomass consumption

The diet composition or food habits of ungulates are often studied following direct observation method while feeding or noting down the locations, where the animals grazed/browsed and subsequently the site was inspected to record the species consumed (Wallamo et al., 1973). The first of these methods is called grazing minutes or seconds (Hahn, 1945; Buecher, 1950), and the second is feeding site examination method (Lorvaas, 1958). In addition, microhistological identification of plant species collected from fecal material has also been widely used to determine the diet of herbivores. Since both the study animals are primarily grazers we adapted feeding site examination method, as experimental studies showed that this and faecal analysis methods would give similar

or comparable results for grazing animals (Sanders et al., 1976; Shrestha and Wegge, 2006). A minimum of 10 feeding site examinations were planned per target species per month and the feeding sites were chosen from areas used by the study species during their peak feeding, i.e. 6–10 h and 15–18 h. A feeding site examination refers to enumeration of plant species eaten in an area, where a target species was observed to feed for an hour. At each feeding site, a total of 25–30 one-m^2 quadrat was placed at uniform interval along the feeding routes and the frequency of various plant species eaten was recorded based on fresh feeding signs such as exudation of sap, crushed tissue and fresh clippings (Shrestha and Wegge, 2006). After completing an event of feeding site examination, the same group was re-sampled following similar procedure. The feeding site evaluation was done for the two target species on alternate days more or less in the same area. In total, between December 2012 and April 2013, 2780 one-m^2 quadrats consisting of 121,854 fresh feeding signs were recorded with blackbuck accounting for 51,895 fresh feeding signs from 1330 quadrats (mean of 39 feeding signs/quadrat) and the feral horse for 69,959 records from 1450 one-m^2 quadrats (mean of 48 feeding signs/quadrat). Although the duration of observation on the blackbuck (51.5 h) and the feral horse (53 h) was almost equal, feral horses (22 feeding signs/min) accounted for more bite signs than the blackbuck (17 feeding signs/min) given their larger intake per bite owing to larger size of mouth compared to the blackbuck. In addition, to assess the fodder consumption rate, the quantum of fodder consumed per unit time was arrived at by measuring the weight difference in green fodder biomass (wet weight) of grazed areas with nearby un-grazed areas. The grazed and un-grazed areas were differentiated through direct observation on blackbucks and feral horses consisting of various age-sex classes for a minimum of 16 h of observations on each species.

Evaluation of dietary overlap and food preference

We have used Schoener's Index (Schoener, 1968) to estimate the degree of dietary overlap as a measure to decipher the potential for dietary competition between the blackbuck and the feral horse: $D = 1 - 0.5\sum|px\text{-}py|$, where, p$x$ is the proportion of food item i in the diet of species x, and py, the proportion of food item i in the diet of species y. To assess the food preference, data on the availability of various food plants of the blackbuck and feral horses was quantified in areas where feeding data were collected by laying 1 m^2 quadrat and recording the list of food species and their counts (number of individuals) within each quadrat at fortnight intervals. In total, 75 quadrats, representing adequate spatial replicates in each habitat of the sanctuary, were laid to assess the abundance of food plants. Using the proportion of various food plants in the diet recorded in feeding site examination, and the proportion of those available in the environment we have calculated the preference shown to various food plants by the blackbuck and the feral horse following Jacob's Preference Index (Jacobs, 1974). Jacob's Preference Index = $(u - a)/(u + a) - (2 \times u \times a)$, where u is the proportion of a particular category in the diet, and a, the proportion of that category in the population.

Statistical analyses

The data on the frequency occurrence of various food plants recorded in the diet of blackbuck and feral horse was compared using Paired Sample 't' test. Data on food consumption rate arrived based on direct observations on each species was tested using Mann–Whitney U test.

Table 1
Density estimate of blackbuck and feral horse at Point Calimere Wildlife Sanctuary, southern India using line transect direct sighting method and distance sampling analysis (Values with± are mean and standard error).

Parameter	Blackbuck	Feral horse
No. of transects	37	37
Effort (l, km)	350.4	350.4
Number of group detection (n)	413	140
Key function model	Half normal	Hazard rate
Key adjustment	Hermite polynomial	Simple polynomial
Detection probability	0.39 ± 0.014	0.18 ± 0.027
Effective strip width (m)	38.5 ± 1.4	18.6 ± 2.73
Encounter rate of group/km (n/l)	1.18	0.39
Encounter rate % CV	7.32	8.3
Mean group size	3.3 ± 0.16	2.0 ± 0.089
Group density/km^2	15.2 ± 1.24	10.7 ± 1.80
Group density % CV	8.1	16.8
Group density 95% CI	13.0 – 17.9	7.7 – 14.9
Individual density/km^2	50.2 ± 4.79	21.4 ± 3.72
Individual density % CV	9.5	17.43
Individual density 95% CI	41.6 – 60.59	15.2 – 30.0

Results

Distribution pattern and spatial overlap

The distribution pattern of blackbuck and feral horse showed that both the species were largely restricted to southern or south-eastern parts of the sanctuary (Fig. 1), which are predominantly open grasslands with a scatted patch of scrub or tropical dry evergreen forests. Both blackbuck and feral horses are distributed mostly in areas with open habitats, while the tropical dry evergreen forests that dominate the northern and north-eastern part of the sanctuary appeared to be used less by both the species (Fig. 1). Further, within the park, 37 grids were sampled for presence/absence of both blackbucks and feral horses. They were present in 35 grids each and were found together in 33 grids indicating the highest overlap. Furthermore, co-occurrence analysis using presence/absence data from 37 grids showed that the blackbuck and the feral horse are distributed together and their distribution is not independent at the park level going by the smaller C-score Index (C-score = 4).

Population density

In total, 350.4 km of line transect walk yielded more detections of blackbuck (1.2 group/km—% CV 7.32%) than feral horse (0.39 group/km—with slightly higher % CV 8.3). Density estimate using distance sampling method showed that the sampled area harboured an average of 50 (±4.79: SE) blackbucks/km^2. The 95% confidence interval varied from 42 to 61 individuals/km^2 (Table 1). The area had lesser density of feral horse (mean 21 ± 3.72 SE), with a wider 95% CI (15–30 individuals/km^2) (Table 1) than the blackbuck. Higher variation in the number of group detections of feral horses observed among the transects, as reflected in higher % coefficient of variation of group density (16.8%) than for blackbuck (8.1%), has shot up the individual density confidence interval and coefficient of variation (17.43%) indicating the need for more sampling for higher precision. Therefore, the density estimate of feral horse is likely to be higher marginally.

Diet composition and consumption

In total, out of 121,854 fresh feeding signs, we have recorded 15 species of plants in the diet profile of both blackbuck and feral horse. These food plants include three types, viz. grass, herb and climber with *Graminae* and *Cyperanceae* accounting for four species each

Table 2
Diet Composition of blackbuck and feral horse recorded at Point Calimere Wildlife Sanctuary, southern India between December 2012 and June 2013.

Family	Name of the food Plant	Mean ± SE (%)	
		Blackbuck(n = 51891)	Feral horse(n = 69959)
Grass			
Graminae	*Cloris parpata*	63.46 ± 5.23	69.52 ± 5.81
	Egritia mycrophyla	0.84 ± 0.45	0.38 ± 0.19
	Egritia purposes	2.92 ± 1.02	3.16 ± 1.48
	Obtimus compositus	0	2.24 ± 2.50
Cyperanceae	*Cyperus arenarus*	1.46 ± 1.63	3.38 ± 3.78
	Cyperus rotundus	0.18 ± 0.12	2.24 ± 1.17
	Cyperus sanguinolentus	4.08 ± 2.78	2.48 ± 1.10
	Fimbristylis ovate	0.1 ± 0.11	0
Herb			
Fabaceae	*Desmodiam dryflorea*	17.02 ± 2.61	11.7 ± 4.84
Euphorbiaceae	*Euphorbia heyeneana*	0.72 ± 0.43	0.9 ± 0.45
Amaranthasceae	*Suaeda monoica*	2.08 ± 1.52	0.66 ± 0.34
Scrophulariceae	*Marcelinea kartifolea*	0.72 ± 0.38	0.96 ± 0.52
Climber			
Plantaginaceae	*Limnophila haterophyla*	1.38 ± 0.72	0.36 ± 0.40
Rubiaceae	*Oldenlandia umbellata*	0.82 ± 0.92	0
Acantheceae	*Hybondus enneaspertum*	4.22 ± 1.73	2.02 ± 0.28

Table 3
Diet composition of blackbuck and feral horse recorded in different habitat at Point Calimere Wildlife Sanctuary, southern India between December 2012 and June 2013.

Family	Name of the food plant	Mean ± SE (%)			
		Dry Evergreen		Open Grassland	
		Blackbuck (n = 24304)	Feral horse (n = 31389)	Blackbuck (n = 27587)	Feral horse (n = 38570)
Grass					
Graminae	*Cloris parpata*	67.8 ± 3.84	65.5 ± 12.86	67.5 ± 4.65	74.6 ± 5.16
	Egritia mycrophyla	0.7 ± 0.27	1.0 ± 0.25	1.1 ± 0.60	0.3 ± 0.16
	Egritia purposes	1.6 ± 0.32	3.1 ± 1.95	2.4 ± 0.95	1.8 ± 1.22
	Obtimus compositus	0	8.1 ± 8.13	0	0
Cyperanceae	*Cyperus arenarus*	0	0	1.5 ± 1.45	3.4 ± 3.37
	Cyperus rotundus	0.1 ± 0.13	1.6 ± 0.88	0.3 ± 0.13	1.2 ± 0.75
	Cyperus sanguinolentus	6.6 ± 3.18	2.9 ± 0.82	4.0 ± 2.59	2.9 ± 0.82
	Fimbristylis ovate	0.2 ± 0.22	0	0	0
Herb					
Fabaceae	*Desmodiam dryflorea*	15.8 ± 2.37	11.8 ± 5.82	15.6 ± 3.37	13.3 ± 5.24
Euphorbiaceae	*Eukaliptus service*	0.7 ± 0.51	0.8 ± 0.42	1.1 ± 0.39	1.2 ± 0.44
Amaranthasceae	*Suaeda monoica*	2.2 ± 2.21	1.3 ± 0.90	2.0 ± 1.26	0.9 ± 0.48
Scrophulariceae	*Marcelinea kartifolea*	0.5 ± 0.55	1 ± 0.52	1.2 ± 0.39	1.4 ± 0.75
Climber					
Plantaginaceae	*Limnophila haterophyla*	1.4 ± 0.91	1.3 ± 1.30	1.5 ± 0.53	0.2 ± 0.23
Rubiaceae	*Oldenlandia umbellata*	0	0	1.5 ± 0.81	0
Acantheceae	*Hybondus enneaspertum*	2.3 ± 0.72	1.5 ± 0.55	3.3 ± 0.70	2.1 ± 0.78

and one species each of *Fabaceae*, *Euphorbiaceae*, *Amaranthasceae*, *Scrophulariceae*, *Plantaginaceae*, *Rubiaceae* and *Acantheceae*. The feeding site examinations made on the blackbuck revealed that it fed on 14 food plants (Table 2), of which 12 (86%) were also eaten by feral horses revealing a higher overlap in diet species composition. Further, the percent occurrence of various food plants in the diet of blackbuck showed that over 80% of its diet comes from two species, viz. grass *Cloris parpata* (64%) and herb *Desmodiam dryflorea* (17%) indicating their importance in its diet (Table 2). Similarly, data showed that the two food plants that contributed >80% of the diet of blackbuck also contributed over 80% diet of the feral horses during the study period in the same area. Paired sample 't' test revealed insignificant variation ($t = -1.103$, $df = 14$, $p = 0.289$) in the frequency occurrence of various food plants recorded in their diet indicating similarity in diet species composition between the two species. Habitat-wise analyses (Table 3) also showed that the contribution of various food plants to their diet did not vary statistically (tropical dry evergreen: $t = -1.447$, $df = 12$, $p = 0.173$, grassland: $t = -0.942$, $df = 12$, $p = 0.363$) indicating similarity in their diet composition. The higher dependence of feral horse on the food sources of blackbuck both in terms of number of food plants and their percentage contribution is likely to reduce the resource availability to the native population of blackbuck in the sanctuary and thus could be a potential competitor. A comparison of the biomass of fodder consumption rate showed that the feral horse consumed significantly larger quantity of food (2.8 ± 0.08 g/min) per capita than the blackbuck (1.7 ± 0.07 g/min) (Mann–Whitney U 0.00158, $p < 0.001$).

Dietary overlap and diet preference

Results on dietary overlap using Schoener's Index revealed that the overall diet composition of the two species overlapped extensively to the tune of 89% in the study area and almost to the same level habitat-wise too (tropical dry evergreen: 90.7% and open grasslands: 85.7%). These results further support the earlier statement that both the species use the same plant resources as their food. Jacob's Food Preference Index showed that of the 15 species of food plants recorded in their diet, 11 had similar pattern of pref-

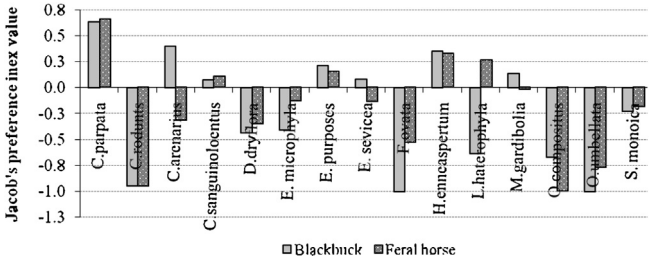

Fig. 2. Food preference shown by blackbuck and feral horse to various food items at Point Calimere Wildlife Sanctuary, southern India between December 2012 and June 2013.

erence indicating a higher potential for competition with similar food niche (Fig. 2).

Discussion

The study showed that the population density of feral horse is only half that of the blackbuck but occupies mostly the same habitats as of the blackbuck, as shown by the distribution map. Further, co-occurrence analysis also showed that both the species overlapped extensively in space, as C-score value was small. Although this study was restricted to a seven-month period from December 2012 to June 2013, both the species overlap spatially throughout the year. The spatial overlap between the species is likely to be lesser during this period, as peak dry spell in the study area starts in June and goes on till August. Among sympatric ungulates, higher overlap may suggest either competition in a situation with limiting resources or a lack of competition in that assemblage of species may co-exist with an alternative partitioning of nich-space (Nichols, 2012). We do not have data to show temporal resource partitioning or alternative partitioning of nich-space between the feral horse and the blackbuck in the study area. However, our observations on both species with similar kind of time activity patterns during daylight hours and sometime even together with similar activities (K. Ramkumaran and G. Karthikeyan, personal communication) suggest no temporal resource partitioning or alternative partitioning of nich-space. Even if temporal partitioning exists between the two species, feral horse could still be a potential threat to the blackbuck and needs to be controlled or eliminated, as it is an introduced species to the ecosystem. Modern horses are mainly grazers (Duncan, 1992) unlike their ancestors of Miocene period that were predominantly browsers with low-crowned teeth (Mihlbacher et al., 2011). Similarly, the blackbucks are also mainly grazers (Mungall et al., 1981). Given the grazing nature of both the species and occupying the same open grasslands niche for feeding, a significant spatial overlap is inevitable as shown by smaller C-score value.

Knowledge on the food habits of wild, feral and domestic herbivores is a fundamental need for effective management of rangeland resources and conservation of wildlife, because potential competition between native and domestic herbivores is a major consideration influencing the management and conservation of native herbivores in rangeland ecosystems (Augustine and Springer, 2014). Data on diet composition including the principal diet species reveals a higher overlap in their composition between the blackbuck and the feral horse. The higher overlap in the diet with no temporal partitioning of resources by the species in the use of areas indicates significant spatiotemporal overlap. Although sympatric species are expected to partition their resources during the season, when resources are limited (Mysterud, 2000; Kleynhans et al., 2011), lack of temporal partitioning in these two species suggests that being an introduced species the feral horse might lack evolutionary history with the native blackbuck making competition apparent.

Similar to the present study, Nedumaran (1987) reported that graminoids as the dominant food of blackbuck at Point Calimere Sanctuary; most of these serve as principal foods for cattle in the same study area. The insignificant differences observed in the composition of diet items between the blackbuck and the feral horse, and the highest dietary overlap (89%) recorded between the two species supports that introduced feral horses compete significantly for food resources with native blackbuck population. Although the density estimate showed that in the sanctuary the feral horses are fewer in number than the blackbucks, the higher consumption rate of feral horses coupled with their larger body mass could outweigh the higher density of blackbuck and thus be a potential ecological competitor. Both the blackbuck and the feral horse being grazers, as the contribution of grass species to their overall diet exceeded 70%, the overlap in diet composition is very likely, as is common among herbivores with grazing and browsing feeding habitats (Prins and Fritz, 2008). In much of the semi-arid ecosystems of Asia, where pastoralism is the main subsistence occupation, grazing competition from livestock displaces the wild ungulates including large mammals (Shrestha and Wegge, 2008; Agoramoorthy, 2010; Baskaran et al., 2011). Studies on dietary overlap between the blackbuck and cattle at Point Calimere (Nedumaran, 1987; Muralidharan, 1985) hold a similar view, that is, grazing by local cattle in the sanctuary is a potential threat to the blackbuck population. The scenario of cattle grazing pressure has also been observed during the present study period. Thus, this study further shows that apart from cattle, the invasive feral horses emerge as another potential competitor to native blackbuck population. Besides the pressure from feral horse and domestic cattle, the natural habitat has been adversely affected by *P. juliflora*, an alien species, which is also considered a serious threat, as its invasion into open space results in the reduction of native flora and extent of grasslands (Ali, 2005), which in turn reduces the food availability to herbivores like blackbuck and chital. Multiple pressure from the invasion of *Prosopis*, to overgrazing by cattle and feral horse on the grassland habitat, would result in tremendous decline in grass biomass needed to support the blackbuck population in the study area.

Feral horse exclosure study in North America provided evidence that grazing pressure of feral horse significantly reduced the plant species growth, and richness, percent cover, and abundance of grasses and shrubs, as well as small mammal burrows (Beever and Brussard, 2000). Several studies were conducted on dietary overlap between white-tailed deer and cattle (Thill and Martin, 1985) in Louisiana Pine-Bluestem Range, U.S.A., between *Cervus elaphus* and cattle in semi-arid temperate grassland (Pordomingo and Rucci, 2000), between black-tailed deer *Odocoileus hemionus* and elk *C. elaphus* (Gogan and Barrett, 1995), between mule deer *O. hemionus* and elk, between elk and cattle, and between mule deer and cattle (Hansen and Reid, 1975). Their general conclusion is that if different herbivore species, whether browsers or grazers, utilize a given area with considerable overlap in diet, there is some segregation too. Many conclusions on competition or the lack thereof have been drawn from these studies in diet overlap (Prins and Fritz, 2008). Theoretically, among herbivores, competition is predicted to be severe between species with similar feeding style and similar body weights; when body weights differ, species may partition resources by size and quality, such that each species has exclusive resources (Belovsky, 1986; Prins and Olff, 1998; Ritchie and Olff, 1999). Although both the blackbuck and feral horse are different in their body size, there was no resource partitioning among them and both species showed an extensive spatial and dietary overlap, as evidenced by data on spatial distribution and dietary overlap (Schoener's Index). Further, temporal partitioning of daily activities between species within animal communities, may promote coex-

istence by reducing behavioural interference, particularly when species highly overlap in the use of space and resources (Valeix et al., 2007; Darmon et al., 2014). However, no temporal partitioning in daily activities could be observed between the species. Since feral horse, an alien or introduced species to Point Calimere with no previous opportunity for co-evolution with indigenous taxa, unlike the species in natural communities, shows greater overlap in terms of diet and habitat use to the native blackbuck and thus could be a greater potential for competitive interactions, as shown by other taxa elsewhere (Putman and Sharma, 1987; Ferretti et al., 2011). Thus, this study clearly established the spatial and dietary similarity or overlap between the two species, a first step towards assessing competitive interactions. However, comparative phenotypic data showing diminished health or individual fitness, i.e. reproduction are needed to confirm the evidence of competition between these species (Thill and Martin, 1985). Thus, detailed studies on health assessment and reproduction of blackbuck population at Point Calimere Wildlife Sanctuary should be the next step to address this vital, but highly ignored issue and compare them with other populations facing less biotic pressure.

Conclusions and recommendations

The study showed that the feral horses introduced to the Point Calimere Wildlife Sanctuary numbering about half of the population size of the blackbuck overlaps extensively on space and diet with the native species of blackbuck. The feral horse with higher consumption rate and larger body mass than the blackbuck, without natural predator, could be an ecologically potential competitor to the blackbuck population in the sanctuary. Nevertheless, detailed studies on health and reproduction of blackbuck at Point Calimere Wildlife Sanctuary comparing with other populations with lesser biotic pressure could provide clues to more vital but highly ignored issue of long-term conservation of the largest population of true antelopes. Since introduced species show ecological requirements similar to the natives, a great potential for competition exists leading to ecological replacement (Ferretti and Lovari, 2014), and hence an appropriate measure like translocation of introduced feral horses or controlling their population through immunocontraception or castration of males is needed to conserve the native ungulates and other biodiversity the reserve harbours.

Disclosure of potential conflicts of interest

This study was carried out without any external financial support.

Research involving human participants and/or animals

The study did not use any human participant and the study animals were observed in natural habitat without any capture or experiment.

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