

**Resource selection by large herbivores with special
reference to blackbuck (*Antilope cervicapra*) in Point
Calimere Wildlife Sanctuary, Tamil Nadu**

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CERTIFICATE

This is to certify that **Mr. Frank Sadrack Jabaraj. D** has carried out an original piece of research in partial fulfillment of Master's Degree in Wildlife Science of Saurashtra University, Rajkot. The topic of his dissertation is "**Resource selection by large herbivores with special reference to blackbuck (*Antilope cervicapra*) in Point Calimere Wildlife Sanctuary, Tamil Nadu**". The study was carried out under our supervision from December 2012 to June 2013. We hereby certify that this work has not been submitted for any degree to any University.

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Summary

Most of the wildlife habitats in India are shared by a number of ungulate species. This encompasses both wild and domestic ungulates. In areas, where both domestic and wild ungulates co-occur, it is essential to understand the ecological interactions among them so as to better manage the habitat and wild species. Competition between livestock and wild herbivores has remained contentious and it has remained as major a conservation issue for native ungulates. This work aimed to investigate the resource selection by wild (Blackbuck and Chital) and domestic ungulates (Feral horse and Cattle) with special emphasis on Black Buck in Point Calimere Wildlife Sanctuary in Tamil Nadu. The Black buck *Antelope cervicapra* Linnaeus (1758) is a grazer that is listed as near threatened species (IUCN Red list, 2012) and has been accorded the Schedule I status by the Indian Wildlife Protection Act, 1972. Black buck numbers in India have come down intensely in the last century and this antelope is currently restricted to small and scattered populations. Hunting and loss of suitable habitat are considered to be principal factors for the reduction in numbers.

The present study deals with estimating the abundance and density of the wild and domestic ungulates using distance sampling and to determine the food habits and habitat use of these ungulates in the coastal landscape of Point Calimere wildlife Sanctuary, Tamil Nadu. The study was conducted from December 2012 to April 2013. Population densities of four sympatric ungulates in Point Calimere Wildlife Sanctuary, Tamil Nadu, was estimated using Distance sampling under line transect technique between January and April 2013. A total of eight line transects were laid with the total length 14.8 km, covering three habitats- Grassland, Mudflat and Tropical Dry Evergreen Forest (TDEF). Each transect varied in length from 1.5 to 2 km and was walked thrice in each month. A total of 628 sightings of the target species were recorded in the line transects (n= 458 black buck, n=58 chital, n=50 feral horses and n=62 cattle). The total effort was 177.6 km (grassland- 57.6 km, Mudflat-26 km and TDEF -96 km). The estimated density (number of individuals per km² ± SE) of blackbuck was 37.1 ± 5.2 with group density of 9.6 ± 3.1, chital was 4.5 ± 0.9 with group density of 2.7 ± 0.5, feral horse was 7.6 ± 1.2 with

group density of 3.3 ± 0.3 and cattle was 21.9 ± 3.3 with group density of 2.5 ± 0.4 . Adult sex ratio (Male: Female) of blackbuck was 12.5 Male/100 Female, and for chital it was 25 Male/ 100 Female. The Female: Fawn ratio of blackbuck was 24.2 Fawn/100 Female and for chital it was 21 Fawn/100 Female.

Most ungulates show a temporal diet variation between monocot and dicot dominated diets. This study investigated the habitat use and diet overlap between wild ungulates (blackbuck, chital), domestic livestock (Brahmini cattle) and feral horse at Point Calimere Wildlife Sanctuary, Tamil Nadu during January 2013 to April 2013. The assumption of the study was that black buck has high degree of food and habitat overlap with other sympatric ungulates in the study area. The food habits and diet overlap of ungulates were estimated using feeding site method (Lovaas, 1958). The line transects that are laid for estimating the densities of the herbivores were used for studying the ungulate- habitat interactions. Two types of analysis were used for the assessment of habitat use, one- way analysis of variance (ANOVA) and multiple regression analysis. Levin's measure of Niche breadth showed highest for feral horse (0.89), followed by cattle (0.72), blackbuck (0.48) and lowest for chital (0.26). Pianka's index (Pianka 1973) showed high diet overlap between blackbuck and cattle (95 %) followed by blackbuck and feral horse (81 %), blackbuck and chital (38.1%) and cattle and feral horse (91.3%). Forty three forage species were identified to be eaten by all target species out of which blackbuck utilized 23 food plants, chital 33, cattle 29 and feral horse 35 food plants. The nutrient analysis of the food plants eaten by the sympatric ungulates was done and with respect to blackbuck, multiple regression analysis was done for the 23 plant species it has fed. The result showed that blackbuck did not show any significant difference towards nutrient contents of the utilized food plants. Dung/pellet analysis revealed that all the four species utilized monocots (graminoids) in high proportion where blackbuck utilized 82.12%, chital 74.63%, cattle 85.7% and feral horse 84.9%. The observed high competition for the available food resources especially for graminoids by the domestic livestock and feral horses is a matter of concern. Creation of livestock- free areas is necessary for the conservation of blackbuck in the Sanctuary.

The present study provided empirical information on competition between the wild ungulates and the livestock. The availability of forage species depleted during summer. The livestock grazing inside the Sanctuary should be banned completely in order to avoid this severe competition. Since the villagers do not have any other avenues apart from sending the livestock into the forest for fodder, the Forest Department should provide alternatives to the villager's livestock by growing fodder grasses outside the Sanctuary. Nature education and awareness programme should be initiated around the Sanctuary areas for the villagers and children to create awareness about the importance of the Sanctuary. The Feral horses in the sanctuary are not wild and they act as competitor to the blackbuck. Removal of the feral horses from the Sanctuary should be a priority option, since their competing nature with blackbuck acts as major threat to blackbuck's long term survival. Competition can have a major role to play in determining the final fate of the blackbuck. Hence controlling cattle grazing through fencing, public awareness as well as legal measures will play crucial role for conserving the blackbuck which forms the eastern most coastal population in the country.

This study was conducted for just one season *i.e* during January to April 2013. Future monitoring of blackbucks should involve generating empirical information pertaining to resource selection among ungulates across different seasons, impact of high stocking density of domestic ungulates on blackbuck, effect of invasive species *viz. P. juliflora* and *L. camara* on blackbuck and its habitats and effect of anthropogenic pressures *viz.* tourism, poaching etc. on blackbucks. The above information will help in making informed management decisions that will aid in conserving the blackbucks and its habitat on a long run.

Competition between livestock and wild herbivores has remained contentious (Mishra et al. 2004) and it has remained as major a conservation issue for native ungulates. Livestock grazing impacts on native wildlife is an important conservation concern globally (Rawat 2007, Prins 1992, Voeten 1999). Generally, high diet similarity between ungulate pair indicates competitive interaction at high density and limited food resources (Wegge et al. 2006). Knowledge on the food habits of wild and domestic ungulates is a basic requirement for the management of grassland resources (Bhattacharya et al. 2012). One of the basic reasons for conflict has been the assumed competition for resources between wild and domestic animals (Mishra et al. 2004). Competition is considered to be the major selective force causing differential use of resources, although processes like predation or different responses of species to environmental gradients may also lead to resource partitioning (Schoener 1974). Among native herbivores overlap in resource use is not expected based on evolutionary segregation. In a native assemblage to which an exotic species has been introduced, an overlap in resource use can occur under food limited conditions and it implies competition (Voeten and Prins 1999). The effects of introducing a new species should be apparent if the new species is ecologically similar to the species already occurring (Voeten and Prins 1999).

Large mammalian herbivore species coexist by partitioning the key niche dimensions of diet and habitat (Chase and Leibold 2003, Schoener 1974). Habitat is the most common dimension followed by food resources (Schoener 1974). In areas where resources vary seasonally the diet and habitat selection by large herbivores varies both temporally and spatially (Kleynhans et al. 2011). In tropical areas with wet-dry cyclic weather patterns, plant quality varies seasonally (Hopkins 2000, Prins and Loth 1988, Styles and Skinner 1997). The wet season, when plants have low fibre and high nutrient concentrations, is the season with the highest quality forage for herbivores, the dry season when plants invest more in structural carbohydrates (fibre) and have their highest carbon: nitrogen ratios, is the season with lowest quality forage for

herbivores. Therefore, in tropical areas where the year is divided into dry and wet seasons, large herbivores are challenged to satisfy their nutritional needs more in the dry season rather than in the wet. Efficient range management for ungulate population requires extensive knowledge of their food habits and diet quality (Holecheck et al. 1982, Mofareh et al. 1997). Thus food habits give an insight on the primary forage types, diet quality and competition among herbivores. Competition is a scale dependent phenomenon. Apart from diet overlap, abundance and distribution availability of food also determine the level of competition among domestic and wild ungulates.

Most of the wildlife habitats in India harbour a diverse assemblage of mammalian herbivores from mouse deer (*Tragulus memmina*) to elephant (*Elephas maximus*). Plant material generally consumed by large herbivores is mainly composed of soluble cell contents and the cell wall (Van Soest 1982). Nutrients available to an herbivore from a particular plant are determined by the ability of the herbivore to break down its chemical structure into digestible products. Plant tissue is mainly composed of carbohydrates and very low amounts of protein (Mattson 1980). Thus ungulates have to invest a large amount of energy and time harvesting enough forage to sequester the necessary amount of nitrogen (N) from plants (Mattson 1980, Iason and Van Wieren 1999). Plants also have lignin and secondary compounds that reduce digestibility (Robbins et al. 1987 and Cordon 2007). The quantity and suitability of available forage have been recognised as important factors limiting ungulate populations (Iason and Van Wieren 1999). Plants can be broadly classified as graminoids (monocotyledonous) and non-graminoids (dicotyledonous) (Short 1971). Hofmann (1989) classified herbivores into grazers, browsers and intermediate feeders based on the adaptations required for specialised feeding on graminoids or browse. Many herbivores show considerable temporal variation in the contribution of graminoids and browse to their diets (Bodmer 1990, Brown and Doucet 1991). Temporal variation in diet implies that herbivores shift their diet along the grazer browser continuum in response to environmental factors. Such diet shifts can either be in response to seasonal changes in forage quality (Iason and Van Wieren 1999, Hulbert et al. 2001) or due to competition from another sympatric herbivore (Hulbert and Andersen 2001).

Availability of grass and browse led to diversification of ungulates that were adapted in their digestive morphology and physiology to different forage types (Janis 2008). The difference in the tissue lignification and secondary chemical compounds led to the requirement of special adaptations in the physiology of ungulates exploiting specific forage types (graze and browse) (Janis 2008). Grazers and browsers thus evolved to deal with their forage in different and specialised ways.

Point Calimere forms one of the isolated populations of blackbuck in Indian Sub-continent. The Sanctuary holds population of both wild and domestic ungulates. The present study mainly focussed on the population estimation of these sympatric ungulates since it is important in conservation point of view. Moreover the area is shared by both wild and domestic ungulates and hence there seems to be a high overlap for food resources as well as for habitat. The foraging species was taken into account since it determines the very survival of the species and its nutrient content was analysed. So the present study assessed the population status of blackbuck, chital, feral horses and cattle along with investigating their habitat use, food habits and diet overlap.

1.1 Study species

The blackbuck *Antelope cervicapra* Linnaeus (1758) is a grazer that is listed as near threatened species (IUCN Red list, 2012) and has been accorded the Schedule I status by the Indian Wildlife Protection Act, 1972. Blackbuck belongs to the tribe Antilopini and gazelles are their closest extant relatives (Effron 1976, Rebholz and Harley 1979). Two subspecies of blackbuck are recognised: one in the north western region *A. c. rajputanae* and the eastern and southern *A. c. cervicapra* (Groves 1980, Ranjitsinh 1989). Body size, horn length and the darkness of male coats typically decrease from north to south and from west to east (Krishnan 1972, Ranjitsinh 1989).

Blackbuck is native to the Indian sub-continent. They are found in variety of habitats from semi-arid grasslands and scrub to open forest (Schaller 1967, Isvaran 2005). They historically ranged from Peshawar (Pakistan) in the northwest, through the Indo-gangetic plains up to the plains of Western Assam in the east, centrally in the Deccan, in open plain areas along the Western coast of the peninsula, and along the eastern coastal plains to southern Tamil Nadu (Blanford 1988, Lydekker 1907). Within their range they were one of the most abundant ungulates of the plains. But the current distribution is reduced much. Within India they are found in majority of the part of their former range. But the population which was large and contiguous previously has been scattered and isolated into small patches. Blackbuck population today is confined to areas in Maharashtra, Orissa, Punjab, Rajasthan, Haryana, Andhra Pradesh, Tamil Nadu and Karnataka with a few small pockets in Central India. Velavadar in Gujarat, Tal Chappar in Rajasthan, Nannaj in Maharashtra, Rollapadu in Andhra Pradesh, Ranebennur in Karnataka and Point Calimere in Tamil Nadu hold some good concentrations of Blackbuck within protected areas (Ranjitsinh 1989, Rahmani 1991, Isvaran 2003). Outside India blackbuck is regionally extinct in Pakistan, Bangladesh and Nepal. Although native to the Indian subcontinent a good number of blackbuck are found in U.S.A and Argentina where they have been introduced (Ungulates of India, 2004).

Blackbuck numbers in India have come down intensely in the last century and this antelope is currently restricted to small and scattered populations. Hunting and loss of suitable habitat are considered to be principal factors for the reduction in numbers. As a result of hunting, blackbuck numbers had already diminished rapidly by the time they were given complete legal protection and the healthy populations were only found in areas with some form of protection (Gee 1989, Krishnan 1972). Because of the conversion of the semi-arid open habitats into agricultural or pastoral land resulted in the decline of the population (Mungall 1978). Group living in open plains is thought to primarily be an adaptation to reduce the risk of predation (Jarman 1974). Group living also has its cost, competition for forage and other resources and the risk of acquiring diseases may increase with group size and such costs may limit group. Blackbucks are typically found in groups which are variable in size. The main types of groups are

female groups (adult females and immature of both sexes), all male groups (adult and immature males) and mixed sex groups (adults and immature of both sexes). The major exceptions to such group living are territorial males and females who leave their group to give birth and solitary for a large part of the time while their fawns are very young (Mungall 1978, Ranjitsinh 1982, Isvaran 2003).

Point Calimere Wildlife Sanctuary was created in 1967 for the conservation of blackbuck *Antelope cervicapra*, locally known as "Velimann". The blackbuck of Point Calimere represents one of the isolated populations existing in Tamilnadu, with other populations in the Guindy National Park (Chennai), Vallanadu Wildlife Sanctuary in Tuticorin, Mudumalai Tiger Reserve and Sathyamangalam Wildlife Sanctuary (Erode district). Blackbuck show variation in group size both between populations and within populations. Group sizes excluding single individuals vary from 2 to 36 animals in Mudmal (Prasad 1983) to 2 to 129 at Point Calimere (Nair 1976) and 100 to 400 at Velavadar (Isvaran 2003). Such variation among populations probably arises from differences between them in ecological conditions, such as habitat structure and resource abundance (Isvaran 2003).

In Point a recent census (April 2011) showed that there has been a decline in the population of blackbuck. One of the reasons attributed to the decline in black buck populations was the increase in numbers of feral horses in the Sanctuary which accounts for about 150 in numbers. Though the population is small when compared with blackbuck it remains as a threat in competition for available resources. The feral horses being larger in size tend to force the antelope in search of new territories. Further blackbuck faces competition for food from the domestic cattle. Most of these cattle are from the two villages located in the Sanctuary. *Prosopis juliflora* also been considered as a major threat to blackbuck (Ali 2005). The plant is consumed by the feral horses, domestic cattle and they act as seed dispersers which in turn increase the area under *P. juliflora* which results in reduction in the grassland area for the blackbuck which are mainly grazers. Next to blackbuck, the chital (*Axis axis*) is a major herbivore in the Sanctuary.

The chital is believed to be an introduced species in the Sanctuary. Due to absence of reliable records, the origin of chital in the Sanctuary is inconclusive. According to the local people, these animals were found in the Sanctuary from a very long time. Since it is known that chital have been translocated to the Sanctuary from other parts of the state from time to time, it is possible that they might have been introduced in the past. The chital usually stay in herds and mostly inhabit the forest habitat of the Sanctuary. The chital are usually restricted only to the Ramar patham area in the northern part of the Sanctuary. However nowadays they are seen in the southern parts of the Sanctuary and the grasslands areas as well. Usually they restrict themselves to the forested areas till march but start to move into the grasslands once the food resources start depleting in the summer. The feral horses in the Sanctuary are an unique feature. They are domestic horses that have become wild in the course of time and are not wild horses as sometimes thought to be. However there are no true wild horse in the country. Most of these horses which were used earlier by britishers in the past have been left as the time passed due to arrival of roads and vehicles.

Some of the other major threats to the biodiversity of the Sanctuary include loss of habitat for water birds, soil and water salinization by adjacent salt pans, spread of invasive *Prosopis juliflora*, cattle grazing and scarcity of freshwater. The major objective of this study has been to assess the demographic status of wild and domestic large herbivores with reference to blackbuck, chital, feral horses and livestock. Since there is an expected competition for the available resources among the wild ungulates and domestic cattle the present study was aimed to focus on the resource use by these wild herbivores, food habits of these ungulates and to find out if there is any dietary overlap between the wild ungulates and domestic livestock (with special reference to blackbuck).

1.2 Study Area

Point Calimere Wildlife Sanctuary is located in the Nagapattinam district of Tamilnadu and encompasses 22.50 sq. km of sandy coast fringed by saline swamps and thorny scrub around the backwaters. It is located between 10°17' – 10°22'N Latitude and 79°25' – 79°52'E Longitude.

Point Calimere Sanctuary has a unique mix of grasslands, mudflats, backwaters, sand dunes and tropical evergreen forest. The Tropical Dry Evergreen Forest (TDEF) of the Sanctuary is considered to be one of the richest tracts in the country. The grasslands on the southern part of the Sanctuary are the natural habitat of the blackbuck. The Sanctuary is an island surrounded by sea on its east and south and by swampy backwaters in the remaining two sides

1.2.1 Topography and Soil properties

The general topography of the Sanctuary consists of low sand dunes located along the coast and in the Western periphery with coastal plains and mudflats in between. Shifting of sand dunes near the coast takes place in the summer due to strong wind from the sea. Most of the sand dunes have stabilised due to the growth of *P. juliflora*, *Spinyfix littoralis* and *Ipomea biloba*. The sand dunes located in the western part of the Sanctuary are bigger than the one near the coast. Most of these sand dunes have stabilised under the growth of the Tropical Dry Evergreen Forests. The tallest dune located at the Ramar patham is around 22 m above MSL. This is the highest point in Nagapattinam district and shrine of Lord Rama is located on this dune. The Coastal plains consist mostly of grasslands which are interspersed with low shrubs. A number of streams and depressions are present in the coastal plains that gently slope from a northeast to a south west direction. During rainy season from October to January these areas get inundated with rainwater and remain flooded for three to four months a year. The mudflats are located near Alavari on the eastern part of the Sanctuary north of the British lighthouse.

The soil of the Sanctuary does not belong to any particular soil-type. The top layer of the soil is in clayey sandy structure and occurs to a depth of 1.5 metre. Deeper down the soil becomes

increasingly rich in clay. Due to the coastal location and annual inundation by brackish water the soil in the Sanctuary is slightly saline. In the grasslands, the soil is more saline compared to the other parts of the Sanctuary as it gets inundated with brackish water during the rains. This has favoured the growth of halophytes such as *Suaeda monica* and *Salicornia brachiata* in the grasslands. The soil in the sand dunes consists of fine grained sand which is yellowish white in colour and poor in humus. The tidal mudflats in the eastern part of the Sanctuary carry alluvial soil which is poor in organic matter.

Salinity of the soil in the Sanctuary has been rising gradually due to the overflow of saline effluents from the nearby salt pans. Seepage of saline residue from the salt pans has resulted in salinization of the ground water near the Sanctuary and the human habitation as well.

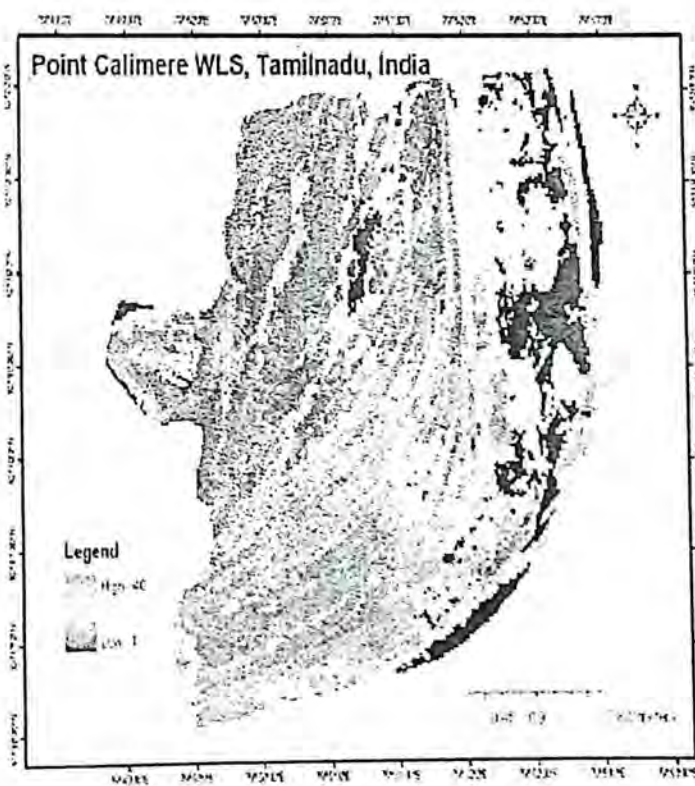


Fig 1 Map of the Study area Point Calimere Wildlife Sanctuary, Tamil Nadu

1.2.2 Climate

The climate of the Sanctuary is a hot humid and a rainy winter. Rainfall mainly occurs during the Northeast monsoon from October to December. The average rainfall received in the Sanctuary is about 1280mm. At times the Sanctuary also receives rainfall in the pre-monsoon and southwest monsoon showers between April and August. The period between April and September is the driest period in the Sanctuary. Being located in a cyclone prone area, rainfall due to cyclonic depressions also occurs.

Temperature in the Sanctuary usually varies from season to season. The forest areas are generally cool even on hot days. In contrast, temperature in the open grasslands is usually high even during winter. December and January are usually the coolest among the months. Average temperature during hottest months usually is 32° C. Maximum temperature can raise upto 43° C in May and June is also windy months when strong wind blow in the Sanctuary that carries fine sand particles. The sand laden winds scorch the vegetation and dry the grasses and leaves.

1.2.3 Vegetation

The vegetation of the Sanctuary fall under two categories of forest: Tropical Dry Evergreen Forest (7/C1) and the Mangrove Scrub (4B/TS1) (Champion and Seth 1968). Three hundred sixty four species of flowering plants have been identified in the Sanctuary of which 50 % are herbs and the rest are climbers, shrubs and trees. One third of the Sanctuary falls under Tropical Dry Evergreen Forest (TDEF). The thickest forests are located on the western part of the Sanctuary. Towards the east these forests gradually thin out to a scrubland interspersed with open grasslands. *Manilkara hexandra*, locally called as *Palai*, is the dominant Dry evergreen species in the sanctuary. It grows to a height of 40 feet or more and forms as an important source for fruit eating birds. Other important top canopy trees include species such as *Syzygium cumini*, *Pongamia pinnata*, *Ficus benghalensis* and *Ficus microcarpa*. The top canopy trees are located mostly in the western part of the sanctuary. *Vanda tessellate* an orchid is also found in the thick area of the Sanctuary.

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The middle canopy is dominated by invasive *P. juliflora*. Some of the other important middle canopy trees include *Salvadora persica*, *Cassia fistula*, *Dichrostachys cinerea*, *Metinus emerginatus* and *Hemicyclia sepiaria*. *Cassia fistula* is also present but usually less than *P. juliflora*. *Memecylon umbellatum* is the most abundant shrub species followed by *Randia dumatorum*, *Maba buxifolia*, *Glycosmis emarginata*, *Zizyphus innophyllum*, *Carissa spinarum*, *Gmelina asiatica* and *Hemidesmus indicus*. *Memecylon umbellatum*, *Maba buxifolia* and *Manilkara hexandra* are referred to as the M³ species as they are generally found in the Tropical Dry Evergreen Forest. The shrub species such as *Carissa spinarum*, *Hugonia mystax*, *Scutia myritina*, *Olax scandens*, *Phoenix pusilla*, *Memecylon umbellatum* and *Zizyphus innophyllum* are important sources of food for the frugivorous birds.

Climbers of both perennial and annual are found in the Sanctuary. Some of the important climbers in the Sanctuary include species such as *Tinospora cordifolia*, *Solanum trilobatum*, *Asparagus racemosus*, *Mucuna pruriens*, *Abrus precatorius*, *Clitoria ternatea* and *Hemidesmus indicus*. Some of the climbers are used for preparing traditional medicines by the local people. During the month of December and January *Droscera indica* and *Drosera burmani* come up after the receding of the flood waters. Along the sand dunes of the coast species such as *Calotropis gigantean*, *Ipomea pescapre*, *Prosopis juliflora* and *Spinifex littoreus* occur. Most of the *P. juliflora* along the coast have been uprooted in the recent times and grass species have been sown by the forest department in the recent years. In the Sanctuary there are no deciduous trees except *Lannea coromandelica* which is an introduced one.

1.2.4 Mangroves of the Sanctuary

Avicennia marina and *Excoecaria agallocha* are the two major mangrove species found in the Sanctuary. They are usually found near Muniappan Lake and also in the interior of the forest. The mangroves in the Southern and eastern part thrive well but in the northern bank it is mainly degraded due to the contamination of the ground water by effluents from adjoining saltpans and chemical factory. It is interesting to find *Salvadora persica* along the areas of fresh water such as Pudukulam which is near the western periphery of the sanctuary along with *Avicennia marina* and *Excoecaria agallocha*. Some of the new growths of *Salavadora persica* is

also observed in the open grassland. Mangrove associates such as *Suaeda monoica* and *Salicornia brachiata* occur in the shallow areas of the grasslands near the Old british lighthouse and also along the coasts that receive brackish water during the rainy seasons.

1.2.5 Medicinal plants of the Sanctuary

Out of 364 plant species found in the Sanctuary, 198 have been identified as having medicinal properties (<http://www.pointcalimere.com/animals.htm>). Majority of the medicinal plants are herbs, followed by trees, shrubs and climbers. The predominant medicinal plant families in the Sanctuary include Fabaceae, Euphorbiaceae and Rubiaceae. A number of such plants are used for the preparation of local cures and health tonics. As most of the medicinal plants in the Sanctuary are endangered, a program for the conservation of medicinal plants was launched during 1994-95 with funding from FRLHT Bangalore. This program concluded in 2002.

1.2.6 Fruiting Phenology of plants in the Sanctuary

Fruiting starts from the month of October with the onset of the northeast monsoon and peaks during February and March. Peak fruiting season is marked by the arrival of the frugivorous landbirds in the Sanctuary. In summer, June is the lowest fruiting season. Of the total 364 plant species in the Sanctuary, 88 bear fleshy fruits which have different fruiting patterns in the Sanctuary. Species such as *Salvadora persica*, *Ficus benghalensis*, *Carissa spinarum*, *Olax scandens* and *Salacia chinensis* produce fruits more than once a year. Plants such as *Walsura trifolia* and *Lannea coromandelica* only fruit during summer and pre-monsoon as the fruiting trees are less in the Sanctuary during that period.

1.2.7 Fauna of the sanctuary

The Sanctuary is home to 14 mammalian, 18 reptilian and nine amphibian species (<http://www.pointcalimere.com/animals.htm>). Besides black buck, the other animals of the Sanctuary include the chital (*Axis axis*), Jackal (*Canis aureus*), bonnet Monkey (*Macaqa radiata*), wild pig (*Sus scrofa*), small Indian civet (*Viverricula indica*), common mongoose (*Herpestes edwardsi*), blacknaped hare (*Lepus nigricollis nigricollis*), feral horse, bengal monitor lizard (*Varanus bengalensis*) and star tortoise (*Geochelone elegans*). The Sanctuary is well known for

the large variety of migratory water birds that visit every year for winter feeding. Of the 103 species of migratory water birds recorded in the Sanctuary (<http://www.pointcalimere.com/animals.htm>), the most prominent is the greater flamingo. During the months of north east monsoon bottlenose dolphin *Tursiops truncatus* can be sighted along the shore.

1.3 Literature Review

Blackbuck is endemic to the Indian subcontinent (Ungulates of India, 2004). Though earlier formed PAN India presence, it has been now restricted to few pockets in the Indian subcontinent. The reasons may be attributed to poaching, conversion of grasslands, competition for space and food from other domestic ungulates and spread of invasive species like *P. juliflora*. Studies on the general ecology and behaviour of blackbuck have been carried out in American and European enclosures (Backhaus 1958, Walther 1958, Benz 1973, Mungall 1978) and in the native habitat (Blanford 1991, Lydekker 1924, Prater 1965, Schaller 1967, Krishnan 1972, Nair 1976). The results of these observations have proved that black buck has similar behaviour patterns, social organization and ecology to that of African species such as gazelles and impala.

With respect to Indian subcontinent a number of studies on blackbuck have been carried out on various aspects. Predation on blackbuck by wolves in Velavadar National park was studied by Jhala (1992), Prasad (1983) depicted the seasonal changes in the herd structure of blackbuck, Isvaran and Jhala (2000) assessed the variation in lekking costs in blackbuck at the Velavadar National Park, Gujarat, the evolution of lekking was also studied by Isvaran (2003), importance of water in the ecophysiology of blackbuck (Jhala et al. 1992) and seasonal effects on the nutritional ecology of blackbuck (Jhala 1997) were also studied in Velavadar National Park. Interspecific variation in group size in blackbuck was described by Isvaran (2007), female grouping as the best predictor of lekking in blackbuck was also reported by Isvaran K (2005), ecology and management of chital and blackbuck in Guindy National Park was also studied by Raman et al (1996).

With regard to Point Calimere, studies on population survey and observations on behaviour of blackbuck was done by Nair (1975), the population dynamics and behaviour of blackbuck was studied by Bharathidasan (1983), Nedumaran (1987) studied the influence of cattle grazing on food and feeding habits of blackbuck, a comparative study of water requirement for blackbuck and chital was carried out by Kalaiarasan (1986), Saranraj (2009) looked into the conflicts in food and feeding habits between blackbuck and cattle, Krishnan (1972) carried out an ecological survey of the larger mammals of peninsular India, and field studies for the conservation and Management of Point Calimere Complex was conducted and prepared by Ali (2005).

1.4 Justification of the study

Point Calimere Wildlife Sanctuary is a globally significant landscape and has been designated as a Ramsar site. It harbours a small isolated population of blackbuck and forms the eastern most distribution of the species in the Indian Subcontinent. This small area is also shared by other herbivores like chital, feral horses and domestic livestock. Previous studies have documented conservation threats for this landscape in terms of invasive species, coastal development viz. salt pans, aquaculture and over abundant livestock. However, empirical information on ecological interactions among wild and domestic herbivores still non-existent in a wider scale at Point Calimere. Moreover blackbuck populations are at decreasing trend due to the conversion of grasslands into dense thorny shrublands due to the spread of *P. juliflora*. This will eventually result in the decrease of the blackbuck densities which highly prefer grasslands and scrub (Mungall 1978, Ranjitsinh 1989). Apart from conversion of grasslands many other threats including poaching, competition for resources, sharing of the habitat of blackbuck along with domestic cattle and feral horse and other management issues play an important role in the declining of the blackbuck numbers. So the present study assessed the population status of blackbuck, chital, feral horses and cattle along with investigating their habitat use, food habits and diet overlap. Moreover due to the spread of *P. juliflora* it is quite essential to check the resource use of the forage species of the blackbuck and also to characterize the diet of these herbivores.

1.5 Objectives

1. To estimate the population status of the wild and domestic ungulates with respect to blackbuck, chital, feral horse and livestock.
2. To investigate the food habits and diet overlap of these herbivores.

1.6 Hypothesis tested

1. Co-occurring wild and domestic herbivores have a high degree of resource overlap.
2. Food selection of blackbuck is mainly influenced by nutritional value of the plant species.

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Chapter 2: Estimation of wild and domestic ungulate densities in Point Calimere Wildlife Sanctuary, Tamil Nadu

Abstract

Population densities of four sympatric ungulates in Point Calimere Wildlife Sanctuary, Tamil Nadu, were estimated using Distance sampling under line transect technique between January and April 2013. A total of eight line transects were laid with the total length 14.8 km, covering three habitats- Grassland, Mudflat and Tropical Dry Evergreen Forest (TDEF). Each transect varied in length from 1.5 to 2 km and was walked thrice in each month. A total of 628 sightings of the target species were recorded in the line transects (n= 458 black buck, n=58 chital, n=50 feral horses and n=62 cattle). The total effort was 177.6 km (grassland- 57.6 km, Mudflat-26 km and TDEF -96 km). The estimated density (number of individuals per km²± SE) of blackbuck was 37.1 ± 5.2 with group density of 9.6 ± 3.1, chital was 4.5 ± 0.9 with group density of 2.7 ± 0.5, feral horse was 7.6 ± 1.2 with group density of 3.3 ± 0.3 and cattle was 21.9 ± 3.3 with group density of 2.5 ± 0.4. Adult sex ratio (Male: Female) of blackbuck was 12.5 Male/100 Female, and for chital it was 25 Male/ 100 Female. The Female: Fawn ratio of blackbuck was 24.2 Fawn/100 Female and for chital it was 21 Fawn/100 Female.

Keywords: Density, Line transects, Ungulates, Sex ratio, Female: fawn ratio

2.1 Introduction

The abundance and distribution of organisms in time and space is one of the fundamental focuses of ecological research (Buckland et al. 1993). The estimation of large herbivore abundance, biomass and population structure is a process that is central to wildlife conservation and management, essentially with respect to long term wildlife monitoring and prey-predator relationships (Buckland et al. 1993). The study of the biotic and abiotic factors that govern the distribution and abundance of animals has become all the more vital not only for their conservation and management, but also for those species dependent on them. Ecologists have stressed the important role that large herbivores play in tropical ecosystems through their influence on forest structure, composition, productivity, soil structure and succession (McNaughton 1979, Crawley 1983). One of the major challenges in preserving large herbivores is monitoring their populations, which is very critical to measure the success of management interventions. Monitoring herbivore population dynamics helps to understand various ecological processes at landscape and ecosystems levels. Large herbivores, particularly are very difficult to conserve due to several factors; inherently low population densities, unique habitat requirements, tendency to raid crops and in several cases their consumption by local people (Karanth and Sunquist 1992).

Line transect based census method is considered to be very effective and reliable in estimating abundance of ungulates in the Indian sub-continent (Karanth et al. 2004). Since estimating animal densities using Distance sampling method corrects the bias of non-detection this method is preferred over others (Karanth and Nichols 1998). Distance sampling is a widely used group of closely related methods for estimating the density or abundance of biological populations. The basic idea is that the observer performs a standardized survey along a series of lines or points searching for objects of interest (usually animals or cluster of animals). For each object detected they record the distance from line or point to the object. Not all the objects that the observers pass will be detected, but a fundamental assumption of the basic method is that all objects that are actually on the line or point are detected. The key to distance sampling analyses is to fit a detection function to the observed distances and use this fitted

function to estimate the proportion of objects missed by the survey. This method allows for the fact that some of the animals will go undetected and that there is a tendency for detectability to decrease with increasing distance from the transect line.

In Point Calimere Wildlife Sanctuary the flagship species blackbuck along with the other sympatric ungulates i.e. chital, feral horse and domestic cattle forms the major ungulate assemblage. In recent years it has been found (Anon 2011) that the population of black buck is on a decline and there were many reasons attributed to it. The reasons for the decline have been suggested to be competition with livestock, habitat degradation and poaching or a combination of these threats. Through this work, I aimed to understand the population status of the sympatric ungulates, which can in turn aid in understanding the ecological interactions among wild and domestic ungulates. This study mainly focused on the population status of these sympatric ungulates in different habitats with special reference to blackbuck. The major objective of this study is to estimate the blackbuck density along with other sympatric species in the study area.

2.2 Study area

The field study was carried out in Point Calimere wildlife Sanctuary (10°17' – 10°22'N Latitude and 79°25' – 79°52'E Longitude) in the Nagapattinam district of Tamilnadu. Comprising of an area of 22.50 sq. km of sandy coast it is fringed by saline swamps and thorny scrub around the backwaters. The Sanctuary has a distinctive mix of grasslands, mudflats, backwaters, sand dunes and tropical evergreen forest Fig.1. The topography of the Sanctuary usually consists of low sand dunes located along the coast and in the Western periphery with coastal plains and mudflats in between. During rainy season from October to January these areas get inundated with rainwater and remain flooded for three to four months a year. The mudflats are located near Alavari on the eastern part of the Sanctuary. The climate of the Sanctuary is a hot humid and a rainy winter. Rainfall mainly occurs during the Northeast monsoon from October to December. The average rainfall received in the Sanctuary is about 1280mm. The vegetation of the Sanctuary fall under two categories: Tropical Dry Evergreen forest (7/C1) and the Mangrove

Scrub (4B/TS1) (Champion and Seth 1968). Three and sixty four species of flowering plants have been identified in the Sanctuary of which 50 % are herbs and the rest are climbers, shrubs and trees. *Manilkara hexandra*, locally called as *Palai*, is the dominant dry evergreen species in the Sanctuary. The Sanctuary is home to 14 mammalian, 18 reptilian and nine amphibian species. Besides blackbuck, the other animals of the Sanctuary include the chital (*Axis axis*), Jackal (*Canis aureus*), bonnet Monkey (*Macaqa radiata*), wild pig (*Sus scrofa*), small Indian civet (*Viverricula indica*), common mongoose (*Herpestes edwardsi*), blacknaped hare (*Lepus nigricollis nigricollis*), feral horse, Bengal monitor lizard (*Varanus bengalensis*) and star tortoise (*Geochelone elegans*) (<http://www.pointcalimere.com/animals.html>).

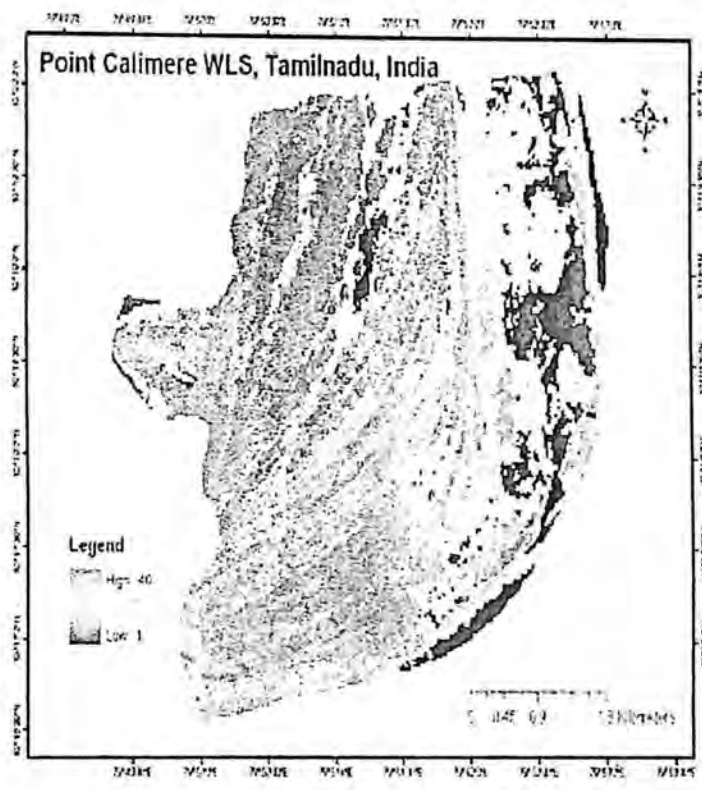


Fig 1 Map of the Study area, Point Calimere Wildlife Sanctuary, Tamil Nadu

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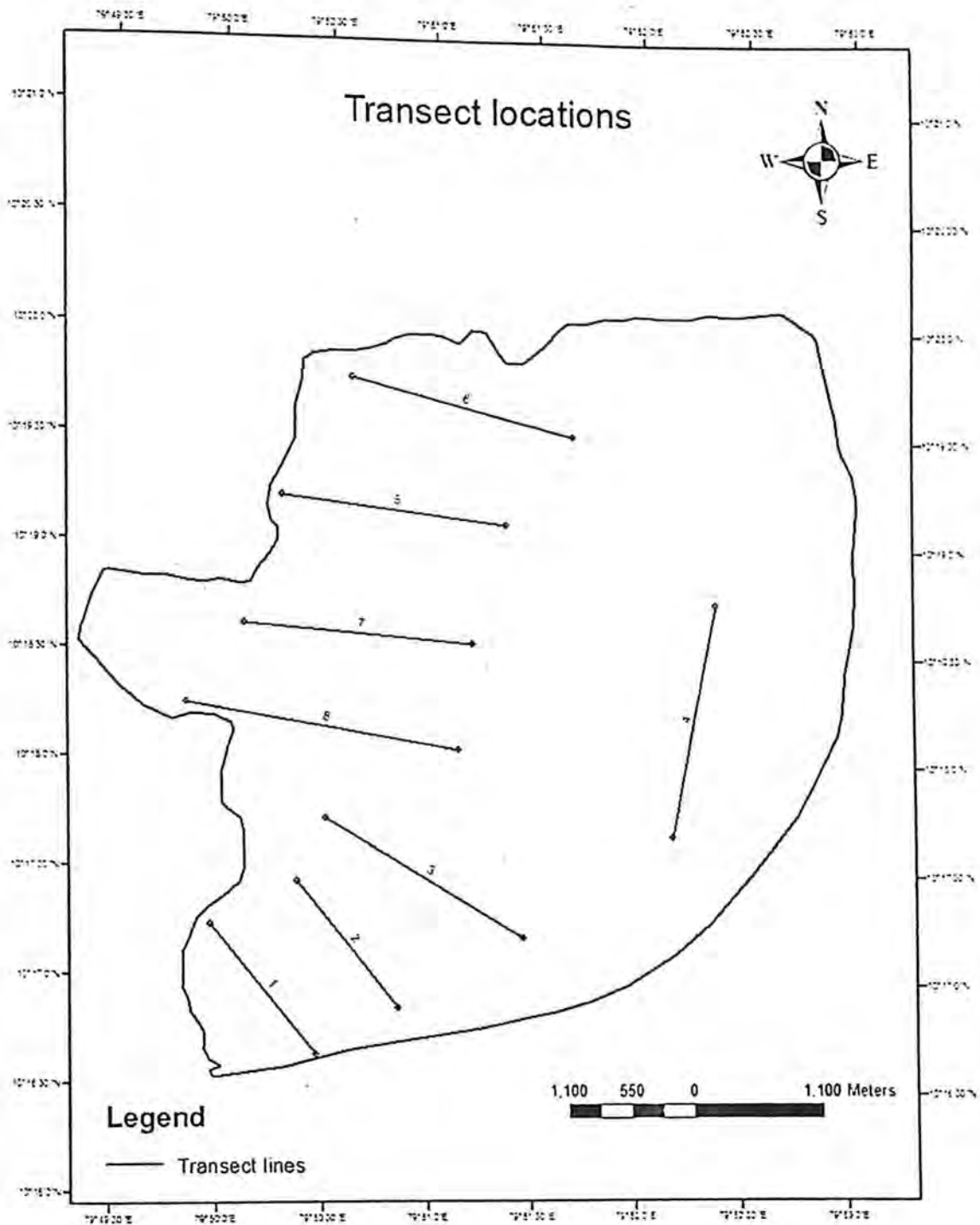


Fig 2. Map showing distribution of line transects in Point Calimere Wildlife Sanctuary, Tamil Nadu.

2.3 Methodology

To estimate the abundance and density of large herbivores, the standard line transect method (Buckland et al. 2001; Karanth et al. 2002) was used. This method has been widely applied to estimate the densities of prey species in different forest in Indian subcontinent (Khan et al. 1996; Lancia et al. 1994; Karanth and Sunquist 1995; Biswas and Sankar 2002; Sankar and Johnsingh 2002; Bagchi et al. 2003, Sankar et al. 2010). The following assumptions were made for the line- transect sampling in the present study

1. The animals are randomly and independently distributed in the study area.
2. The sighting of one animal is independent of the sighting of another.
3. No animal is counted more than once.
4. Animals are fixed at the initial sighting position and do not move before being counted.
5. The response behaviour of the population as a whole does not substantially change in the course of running a transect.
6. The individuals are homogeneous with regard to their responsive behaviour, regardless of sex and age.
7. The probability of an animal being seen, given that it is a right angle distance y from the line transect path (irrespective of which side of path it is on), is a simple function $g(y)$, say of y , such that $g(0)= 1$ (i.e. probability 1 of seeing an animal on the path).
8. Animals directly on the line will never be missed.
9. Distances and angles are measured accurately. (Seber 1982; Burnham et al. 1980; Buckland et al. 2001).

A total of eight transects which varied in length from 1.5 to 2.0 km were laid in the study area covering all major habitats. The total length was 14.8 km Fig.2. The primary considerations in establishing the transects is to have an adequate coverage of the study area and representation of the habitat types in which herbivore densities could be expected to differ. The Sanctuary has three habitats: Grassland, Mudflat and Tropical Dry Evergreen Forest (TDEF). The assumption of the study is that blackbuck density varies with the livestock population and also across the

habitats. Field survey data were collected between 06:00 and 08:00 hrs. Since the study species occur in clusters the distance and angles were recorded to the centre of each cluster. At each detection of an animal or from centre of the group, the species, sex of the individual, cluster size, the observer to animal sighting distance and sighting angle were recorded. Sighting distance was measured using laser rangefinder, and the bearing was recorded using a magnetic compass. Each transect was walked thrice in each month from January 2013 to April 2013 for a period of four months. The data was analysed using DISTANCE software 6.2 (Thomas et al. 2009) to estimate density of study species.

Data was checked for errors before using program distance (Jathanna et al. 2003; Wang 2008) and exploratory analysis was carried out to check for the evidence of evasive movements before detections (Buckland et al. 2001; Wang 2008). To get the best model fit data was truncated and the best model was selected on the basis of lowest AIC (Akaike Information Criteria) value (Buckland et al. 1996, Burnham et al. 1980).

2.4 Results

2.4.1 Population density

The estimated group size and densities of study species are given in Table 1. A total of 628 sightings were recorded on the line transects of which 458 sightings belonged to black buck, 58 chital, 50 feral horses and 62 brahmini cattle. The total effort was 177.6 km (grassland- 57.6 Km, mudflat-26 Km, TDEF-96 Km). The estimated overall density (number of individuals per km² ± SE) of blackbuck was 37.1±5.2, CV 14.5% with group density of 9.6±3.1, chital was 4.5±0.9 with group density of 2.7±0.5 CV 19%, feral horse was 7.6±1.2, CV 20.3% with group density of 3.3±0.3 and cattle was 21.9±3.3, CV 18% with group density of 2.5±0.4. The estimated blackbuck density was high in grassland i.e 23.6 ± 1.1 km⁻², followed by feral horse 14.6 ± 0.5 km⁻², and cattle 4.6± 0.2 km⁻². The estimated blackbuck density in mudflat was 10.8 ± 0.2 km⁻², and in TDEF it was 3.2 ± 0.1 km⁻², whereasthe feral horse (4.5 ± 0.2 and 2.2± 0.1) and cattle (1.8± 0.01 and 1.1± 0.1) densities were lower than blackbuck (Fig 3). In these habitats, the half normal/cosine model was best fitted for the blackbuck and chital. In case of feral horse and

cattle, negative exponential was fitted as the best model. The results of the analysis variance indicates that the mean density of black buck was significantly different among the habitats ($P < 0.05$). Individual and group density of wild and domestic ungulates is given in the Fig.4 and age and sex structure of blackbuck is given in Fig.5. Adult sex ratio (Male: Female) of blackbuck was 12.5 Male/100 Female, and for chital it was 25 Male/ 100 Female. The Female: Fawn ratio of blackbuck was 24.2 Fawn/100 Female and for chital it was 21 Fawn/100 Female (Table.2). The group size for blackbuck (with SE) was 4.3 ± 0.2 , chital 2.1 ± 0.1 , feral horse 3.2 ± 0.2 and cattle 8.03 ± 1.2 Fig.6. Detection probability i.e. of blackbuck, chital, feral horse and cattle along the line transects is shown in Fig 7,8,9 and 10 respectively.

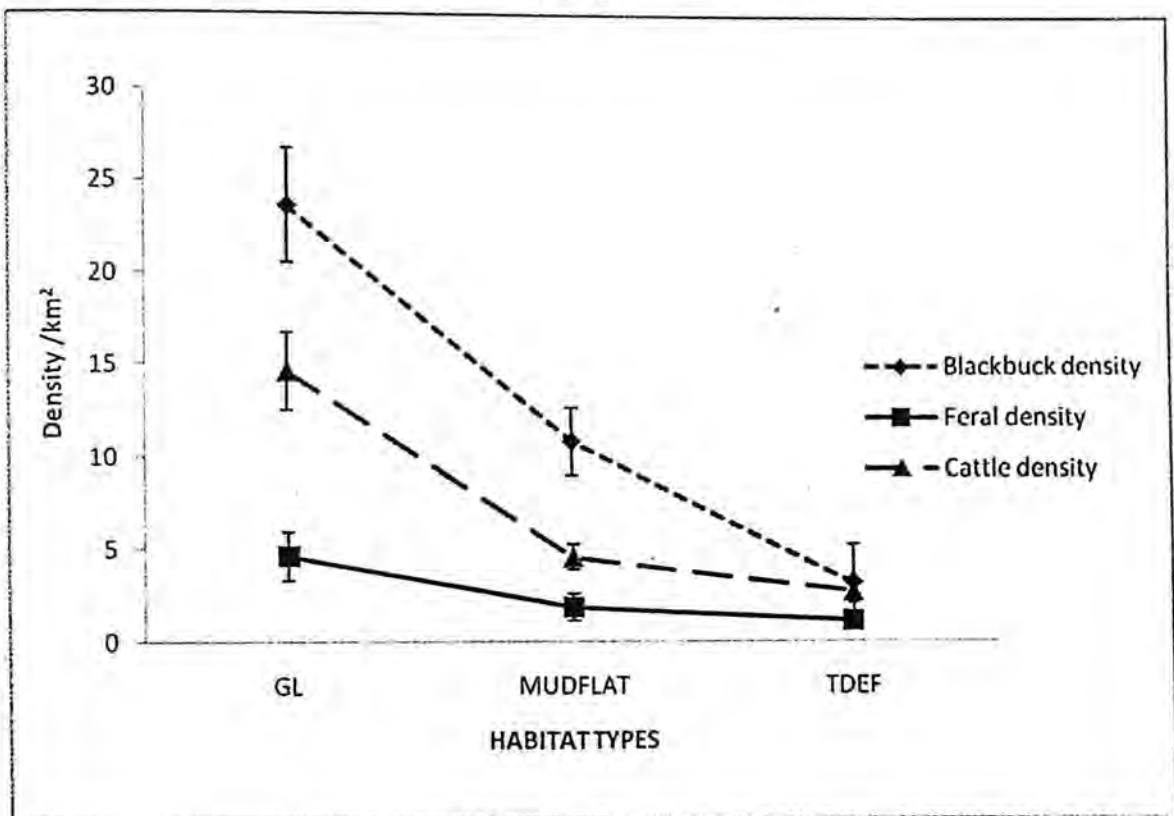


Fig 3. Density of ungulates in different habitat types in Point Calimere Wildlife Sanctuary Tamil Nadu (January 2013 to April 2013).

Table 1. Estimated densities and group size of ungulates in Point Calimere Wildlife Sanctuary, Tamil Nadu (January 2013 to April 2013)

| Species | No.of detections | ESW | AIC | Detection Probability | Group Size | Group density±SE | Individual density± SE |
|-------------|------------------|------------|--------|-----------------------|------------|------------------|------------------------|
| Black buck | 458 | 132.95±4.2 | 827.4 | 0.9 | 4.3±0.2 | 9.6±3.1 | 37.1±5.2 |
| Chital | 58 | 58.9±5.8 | 100.72 | 0.8 | 2.1±0.1 | 2.7±0.5 | 4.5±0.9 |
| Feral horse | 50 | 74.1±10.2 | 115.7 | 0.5 | 3.2±0.2 | 3.3±0.3 | 7.6±1.2 |
| Cattle | 62 | 76.91±8.2 | 167.2 | 0.9 | 8.03±1.2 | 2.5±0.4 | 21.9±3.3 |

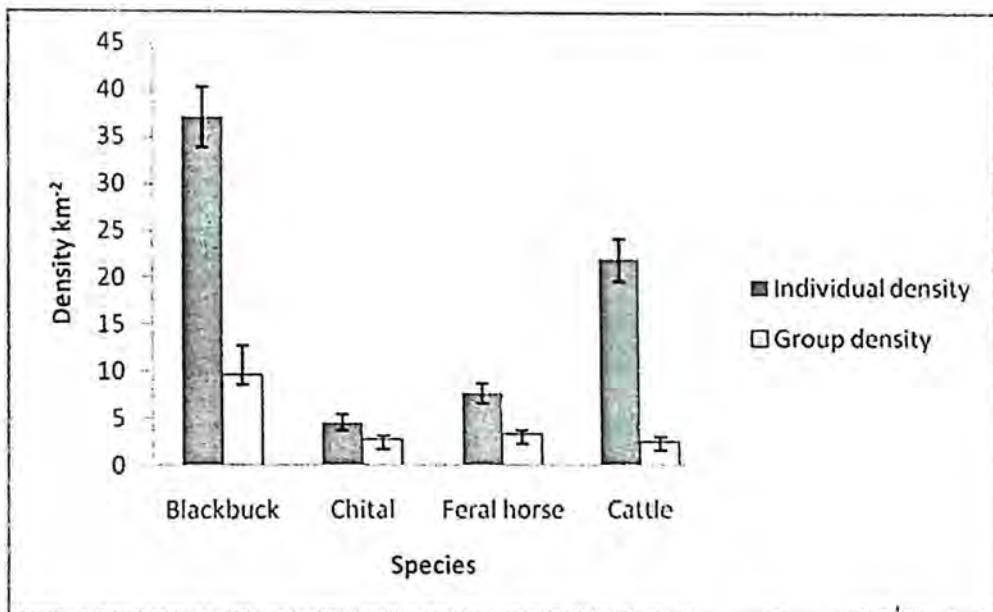


Fig 4 Individual and group density of wild and domestic ungulates in Point Calimere Wildlife Sanctuary, Tamil Nadu (January to April 2013)

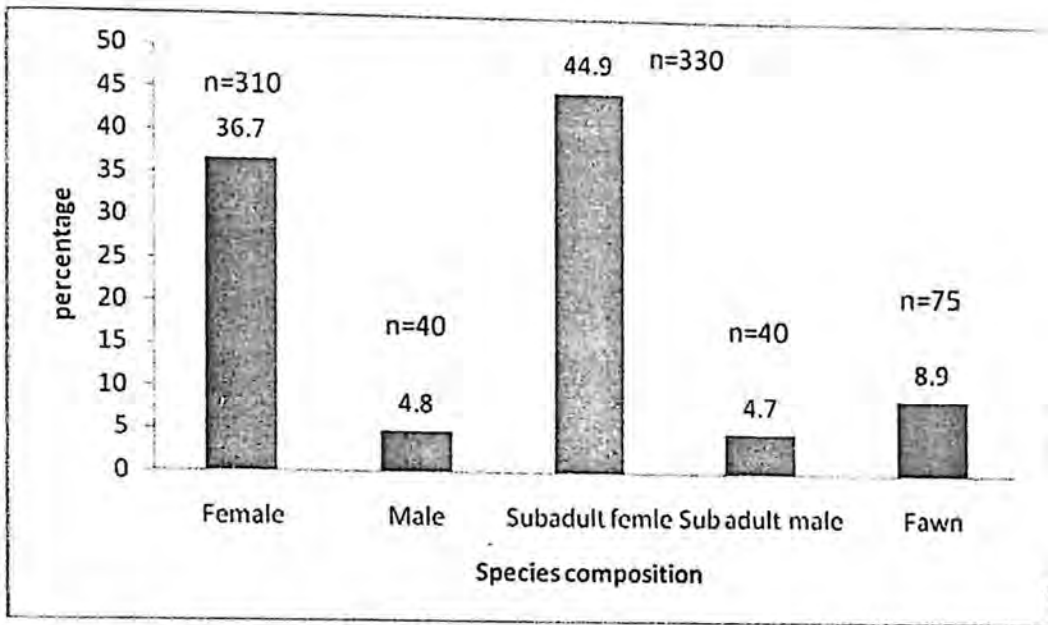


Fig 5. Age and Sex structure of blackbuck in Point Calimere Wildlife Sanctuary, Tamil Nadu.

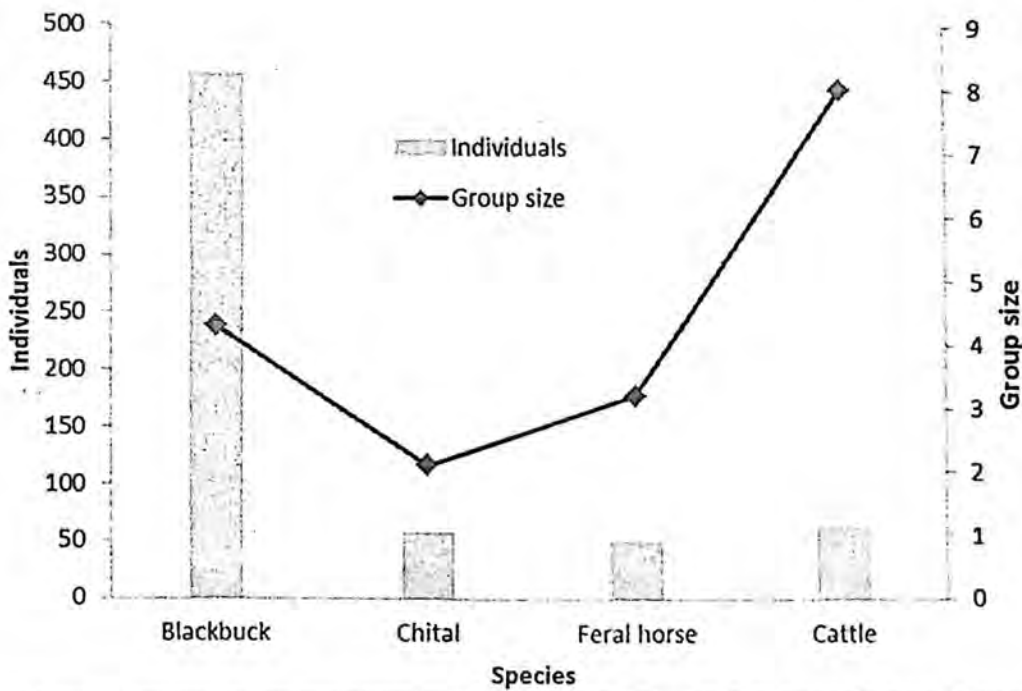


Fig 6 Estimated group size and total number of individuals of wild and domestic ungulates in Point Calimere Wildlife Sanctuary, Tamil Nadu.

Table 2 Sex ratio (Male: Female) and Female: Fawn ratio of blackbuck and chital in Point Calimere Wildlife Sanctuary, Tamil Nadu (January –April 2013)

| Species | Number of individuals | Male:Female ratio | Number of individuals | Female:Fawn Ratio |
|-----------|-----------------------------------|----------------------|----------------------------|----------------------|
| Blackbuck | M=80, female 640 (Adult+Subadult) | 12.5 male/100 female | Adult female 310, fawn=75) | 24.2 fawn/100 female |
| Chital | M=20, female 80 (Adult+Subadult) | 25male/100 female | Adult female 38, fawn=8) | 21 fawn/100 female |

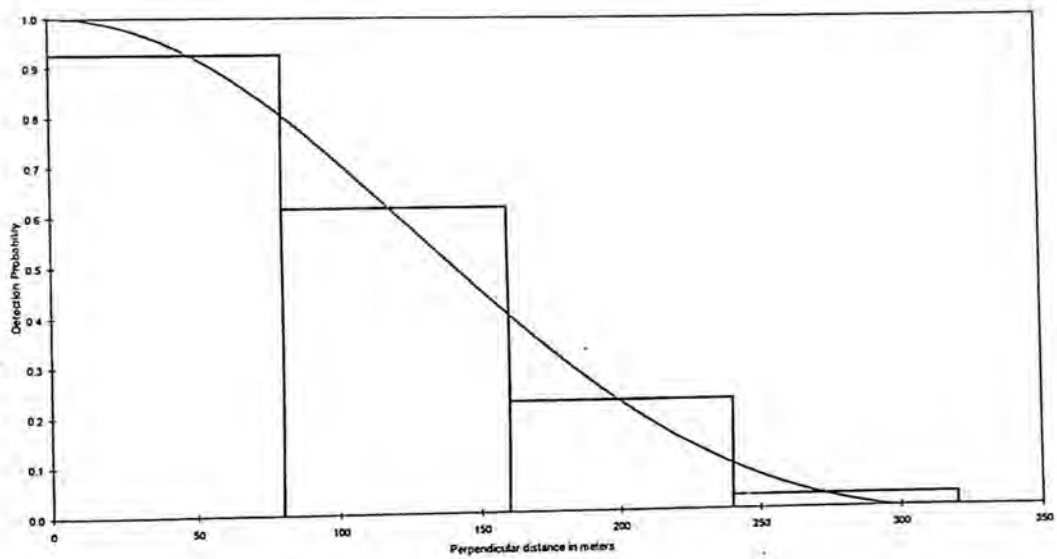


Fig 7. Detection probability of blackbuck in Point Calimere Wildlife Sanctuary (January 2013 to April 2013)

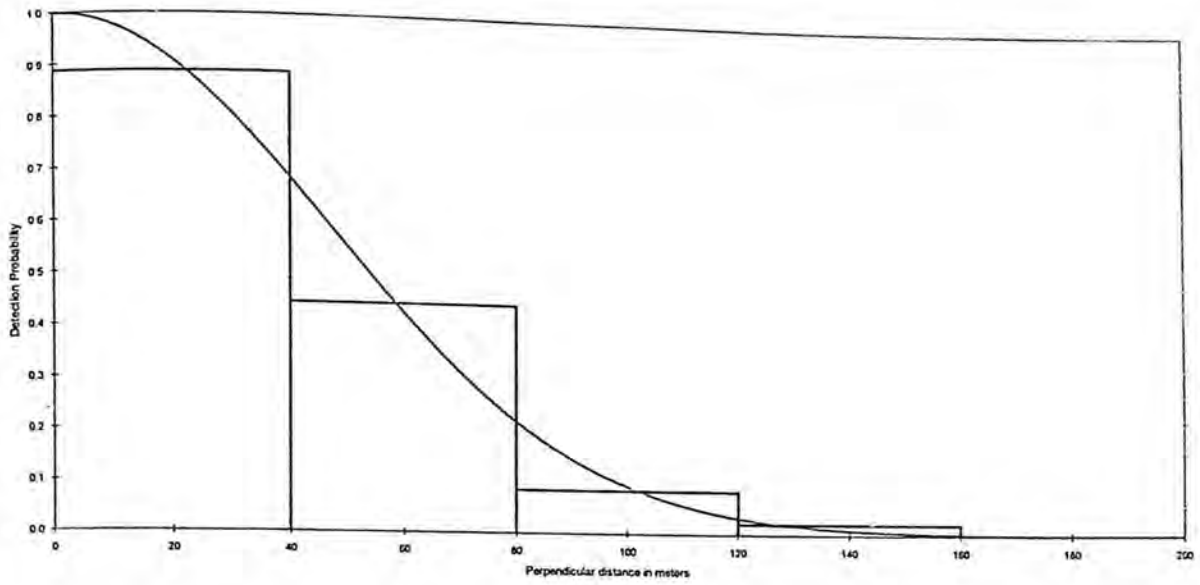


Fig 8. Detection probability of chital in Point Calimere Wildlife Sanctuary, Tamil Nadu (January 2013 to April 2013)

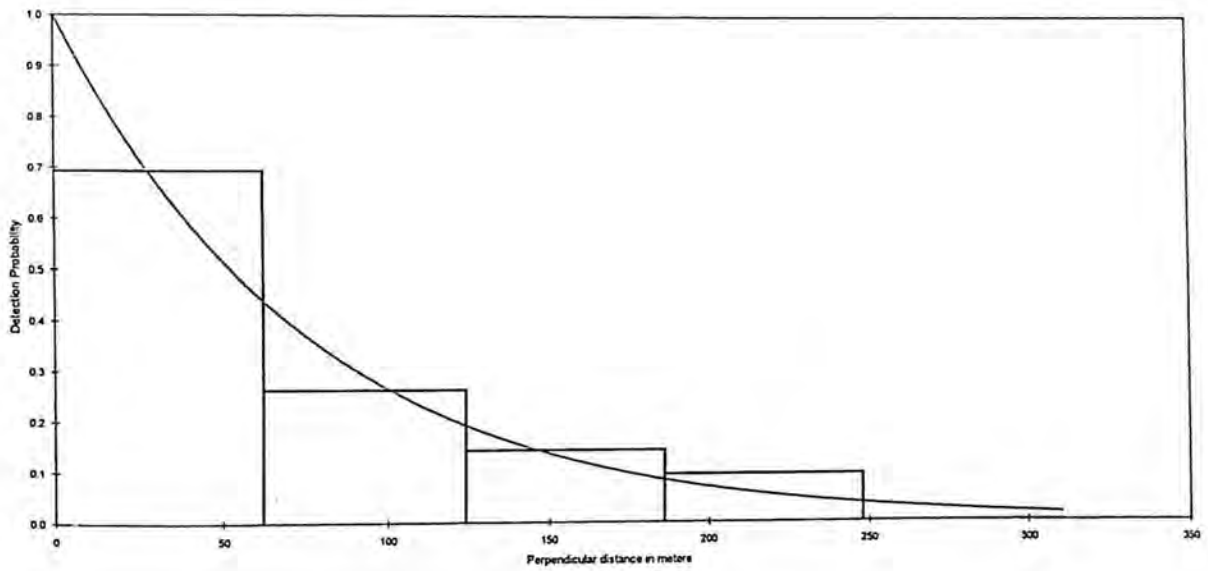


Fig 9. Detection probability of feral horse in Point Calimere Wildlife Sanctuary, Tamil Nadu (January 2013 to April 2013)

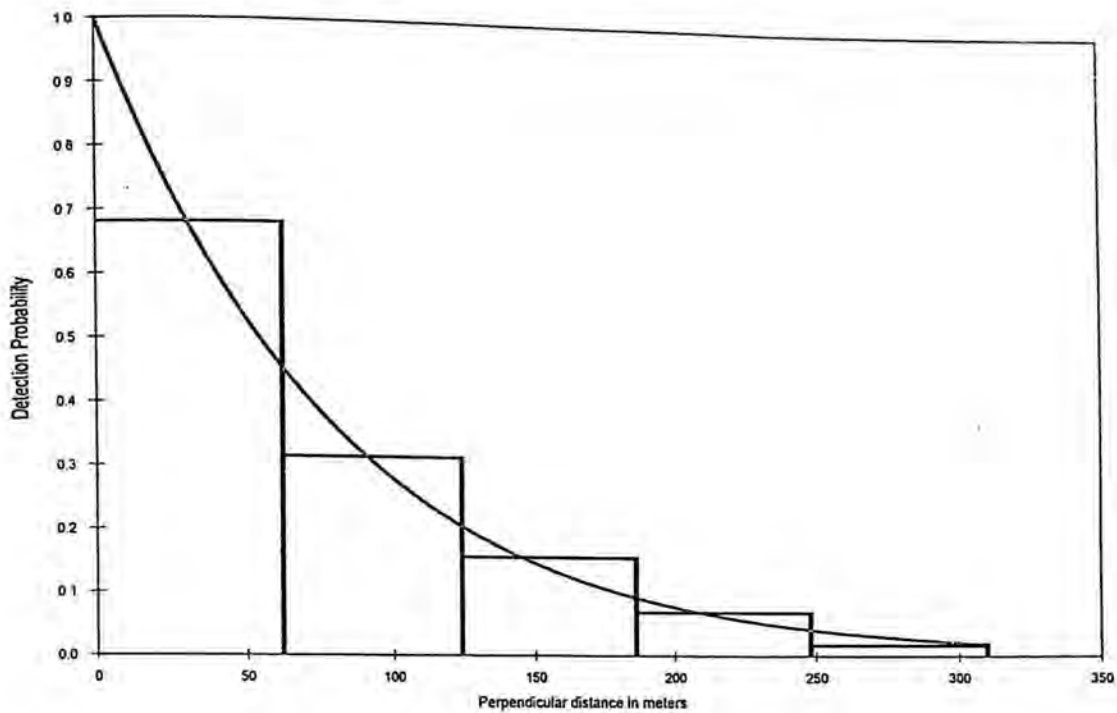


Fig 10. Detection probability of cattle in Point Calimere Wildlife Sanctuary, Tamil Nadu (January 2013 to April 2013).

2.5 Discussion

The line transect method (Burnham et al. 1980 and Buckland et al. 1993) is considered to be the most appropriate method for estimation of herbivore abundance and has been used extensively to determine animal abundance (Sunquist 1981). This method has been successfully used in Indian subcontinent in various habitats and is considered as one of the reliable measures for estimation of ungulate abundance. None of the assumptions were violated during data collection and a minimum of 40 sightings were considered for analysing the data as suggested by Burnham et al (1980) and Buckland et al (1993).

The results suggest that grassland had high abundance of blackbuck followed by mudflat. The reason for the same is attributed to available foraging areas with adequate food plants. Blackbuck prefers open grasslands and wastelands and avoid thick cover (Mungall 1978, Ranjitsinh 1989) and occasionally need drinking water (Jhala et al. 1991). During the present

study blackbuck were recorded in Tropical Dry Evergreen Forest only during the month of April and the reason for the same is attributed to search of water by the blackbuck in TDEF habitat.

The mudflats had certain succulent plants as well as the *Aleuopus lagopoides* grass throughout the study period and hence blackbuck largely utilized the mudflat area next to the grassland. Hence the density of blackbuck was second highest in the mudflats whereas grassland had the highest. During part of January and February, the forest area TDEF was filled with rain water and hence the blackbuck did not move into the forest habitat. The chital density was high in the Tropical Dry Evergreen forest when compared to the grassland. Maximum sightings of chital were obtained in the forested areas throughout the study period. Feral horse was observed all over the Sanctuary and domestic cattle were also observed throughout the Sanctuary but they were largely recorded in the grasslands.

The previous estimates of blackbuck in the Sanctuary had shown a density of 48.66 km² (Ali R 2006). Most of the studies in the past lacked temporal replication of line transects and the number of transects used were also high (23 transects) in the small study area of 22.5 sq.km which might have resulted in double count of animals, thereby resulting in high estimation of density of blackbuck. During the present study line transects were laid in proportion to availability of different habitats which was lacking in previous studies.

The largest concentration of blackbuck in south India is at Point Calimere (Daniel 1967, Seshadri 1969). Daniel (1967) estimated about 750-800 blackbuck. Johnson (1975) estimated 970 blackbuck while Nair (1976) estimated approximately 340 animals. In 1977 the wildlife Conservation Society of Tirchirapalli surveyed the population and reported 506 and in the following year the population dwindled to 270 individuals due to cyclone. A later survey in 1980 by the State Forest Department revealed a population of over 1100 blackbuck in the Sanctuary. Though the line transects were walked by the Forest department for estimating the overall blackbuck population over the years, density estimation under Distance sampling was not done, which is otherwise absolutely essential.

Chital is an introduced species in the Sanctuary and mostly restricted to the forest habitat. Their abundance when compared with black buck is less. The feral horse abundance in the Sanctuary has increased when compared to previous estimate (Ali 2006). The feral horses are found throughout the Sanctuary and their abundance when compared with black buck is less.

The estimated density (number of individuals $\text{km}^2 \pm \text{SE}$) of blackbuck during the present study i.e. 37.1 ± 5.2 , as compared with previous population estimation (Ali 2006), i.e. $48.66/\text{km}^2$ was low. The reasons for this decrease in blackbuck density, were attributed to increased competition for the available food resources by other sympatric herbivores such as feral horse and domestic cattle, predation of blackbuck fawns by Jackals and invasion of *P.juliflora* in grassland areas. Though there are no major predators in Point Calimere Jackal acts as sole predator on the black buck fawns. During my study period wild pigs were also seen predated on the fawns of the black buck. In Velvadar National Park wolves act as a major predator of the adults which kill about 35 to 39 blackbuck/wolf/year (Jhala 1993). The stray dogs act as a nuisance to the black buck as most of the time they roam in the forests and chase the blackbucks in Point Calimere.

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Chapter 3: Food habits and habitat use of the sympatric ungulates in Point Calimere Wildlife Sanctuary, Tamil Nadu

Abstract

Most ungulates show a temporal diet variation between monocot and dicot dominated diets. This study investigated the habitat use and diet overlap between wild ungulates (blackbuck, chital), domestic livestock (Brahmini cattle) and feral horse at Point Calimere Wildlife Sanctuary, Tamil Nadu during January 2013 to April 2013. The assumption of the study was that black buck has high degree of food and habitat overlap with other sympatric ungulates in the study area. The food habits and diet overlap of ungulates were estimated using feeding site method (Lovaas, 1958). The line transects that are laid for estimating the densities of the herbivores were used for studying the ungulate- habitat interactions. Two types of analysis were used for the assessment of habitat use, one- way analysis of variance (ANOVA) and multiple regression analysis. Levin's measure of Niche breadth showed highest for feral horse (0.89), followed by cattle (0.72), blackbuck (0.48) and lowest for chital (0.26). Pianka's index (Pianka 1973) showed high diet overlap between blackbuck and cattle (95 %) followed by blackbuck and feral horse (81 %), blackbuck and chital (38.1%) and cattle and feral horse (91.3%). Forty three forage species were identified to be eaten by all target species out of which blackbuck utilized 23 food plants, chital 33, cattle 29 and feral horse 35 food plants. Dung/pellet analysis revealed that all the four species utilized monocots (graminoids) in high proportion where blackbuck utilized 82.12%, chital 74.63%, cattle 85.7% and feral horse 84.9%. The observed high competition for the available food resources especially for graminoids by the domestic livestock and feral horses is a matter of concern. Creation of livestock- free areas is necessary for the conservation of blackbuck.

Keywords: Habitat use, food habits, diet overlap, Point Calimere Wildlife Sanctuary.

3.1 Introduction

Most of the wildlife habitats in India are shared by a number of ungulate species. In some habitats the size of the species varies from mouse deer (*Tragulus memmina*) to elephant (*Elephas maximus*). Plant material generally consumed by large herbivores is mainly composed of soluble cell contents and the cell wall (Van Soest 1982). Nutrients available to an herbivore from a particular plant are determined by the ability of the herbivore to break down its chemical structure into digestible products. Morphophysiological characteristics such as salivary glands, body and mouth sizes, digestive system types and rumino-reticular volume to body weight ratios predispose ungulates to selectively harvest forages (Hanley 1982; Hanley and Hanley 1982; Hofmann 1989). However, ungulate diet selection is largely influenced by forage availabilities in spite of anatomical adaptations that facilitate selection for specific diets (Tueller and Monroe 1975; Ralphs and Pfister 1992). Dietary patterns and overlap indices for sympatric ungulates provide insights into potential interspecific competition, population nutritional needs and forage allocation and can be used to identify key indicator plants of rangeland health. The magnitude of diet overlap should indicate potential competition at high population densities. Conditions that must exist for forage competition among ungulates include 1) species sharing the same habitats, 2) less availability of forage plants and species sharing the same forage plants (Cole 1958; Holechek 1980). The common use of limited resources by two or more species can result in exploitative competition, or reduced performance in one species due to competition for limited resources (Wisdom and Thomas 1996).

Habitat is the place where an animal can live and reproduce. Food, water, cover and space are the basic requirements of an animal for the population to survive. Habitat use is the outcome of the foraging strategy of the herbivores, it is considered to be the expression of the way grazing animals resolve the conflict between their need for food and their intrinsic and extrinsic constraints (Ilius and Gordon 1993). Habitat selection by ungulates is a function of several factors, amongst which food availability, mate availability and predation are of major

importance (Jarman 1974). If the species are to be conserved, it is essential to know what habitat factors are influencing them. Two approaches can be used to quantify the habitat occupancy, one approach is based on the direct sighting of the target species and the second approach is based on indirect evidences such as pellet/dung. The quantification on direct sightings of animals only reflects the habitat usage at time of when monitoring is done. The dung reflects habitat use for 24 hours and assuming a uniform defecation pattern among all habitats may give better picture of the habitat use.

Food resources in the natural landscape are distributed in a mosaic of patches of variable size and shape with a fluctuating quantity and quality of food (WallisDeVries1994). The abundance of consumable material in the vegetation surrounding an herbivore varies enormously with regard to the nutritive value to the herbivore. An efficient foraging behaviour contributes to the consumption of sufficient food, both in a quantitative and qualitative way. It is widely accepted that forage abundance and forage quality play a major role in foraging behaviour. Forage quality is related to the availability of energy, proteins and minerals as well as to the absence of plant toxins. Plant species as well as individual plants within species and plant parts vary in these features.

The nutritive value of a plant usually has seasonal changes (Owen-Smith 1982). Morphological plant defences like thorns and spines, can hinder intake or decrease ingestion rate (Cooper and Owen-Smith 1986) and therefore can play a role in the selection of plant species. These morphological defences are especially present in species with a high nutritive value (Van Wieren 1987). Large herbivores do not forage at random but take many foraging decisions at different scales. Natural landscapes are mostly very heterogeneous in space and time. The more heterogeneous the environment, the more foraging decisions have to be made and the more complex the expressed foraging behaviour will be. Availability of grass and browse led to diversification of ungulates that were adapted in their digestive morphology and physiology to different forage types (Janis 2008). The difference in the tissue lignification and secondary chemical compounds led to the requirement of special adaptations in the physiology of

ungulates exploiting specific forage types (graze and browse) (Janis 2008). Grazers and browsers thus evolved to deal with their forage in different and specialised ways.

To achieve an ecological balance among communities of sympatric organisms, management must be based on knowledge of how species use and partition resources that is available to them (Hudson 1976). Four sympatric species the blackbuck, chital, feral horse and cattle occur in Point Calimere Wildlife Sanctuary. Out of the four species, chital is the one which has been introduced, blackbuck being endemic to this area, feral horse is a resident species and cattle that mostly come from the villages graze inside the Sanctuary during day time. In this study, whether interspecific competition exists among all the four species is evaluated along with how much diet overlap occur between these species. Further the habitat use by these sympatric species was studied and the nutrient content of the eaten plant species were analysed. Finally a monocot-dicot ratio of the plants from the dung/pellet of the ungulates was analysed to evaluate the usage pattern of the forage species.

3.2 Study area

Point Calimere wildlife Sanctuary is located in the Nagapattinam district of Tamilnadu and encompasses 22.50 sq. km of sandy coast fringed by saline swamps and thorny scrub around the backwaters. It is located between 10°17' – 10°22'N Latitude and 79°25' – 79°52'E Longitude. The Sanctuary receives rainfall from both the monsoons bulk from the North East Monsoon. The temperature ranges from 70° F (December – January) to 100° F (May-June). The area is exposed to tropical cyclones. The characteristic coastal expanse form one of the few extant habitats of blackbuck in India. The vegetation of the Sanctuary fall under two categories of forest: Tropical Dry Evergreen Forest (7/C1) and the Mangrove Scrub (4B/TS1) (Champion and Seth 1968). Three hundred sixty four species of flowering plants have been identified in the Sanctuary of which 50 % are herbs and the rest are climbers, shrubs and trees. *Manilkara hexandra*, locally called as *Palai*, is the dominant Dry Evergreen Species in the Sanctuary. Besides, there are many inlets in the forests, inundated and muddy during rains and bone dry during summer. *Aleuropus lagopoides*, *Cyperus arenarius* dominate in the grasslands and

Suaeda maritime along with *Aeluropus lagopoides* are found in the mudflats. The middle canopy is dominated by invasive *P. juliflora*. Some of the other important middle canopy trees include *Salvadora persica*, *Cassia fistula*, *Dichrostachys cinerea*, *Metinus emerginatus* and *Hemicyclia sepiaria*. *Cassia fistula* is also present but their abundance is less than *Prosopis juliflora*. *Memecylon umbellatum* is the most abundant shrub species followed by *Randia dumetorum*, *Maba buxifolia*, *Glycosmis emarginata*, *Zizyphus innophyllum*, *Carissa spinarum*, *Gmelina asiatica* and *Hemidesmus indicus*. *Memecylon umbellatum*, *Maba buxifolia* and *Manilkara hexandra* are referred to as the M³ species as they are generally found in the Tropical Dry Evergreen Forest.

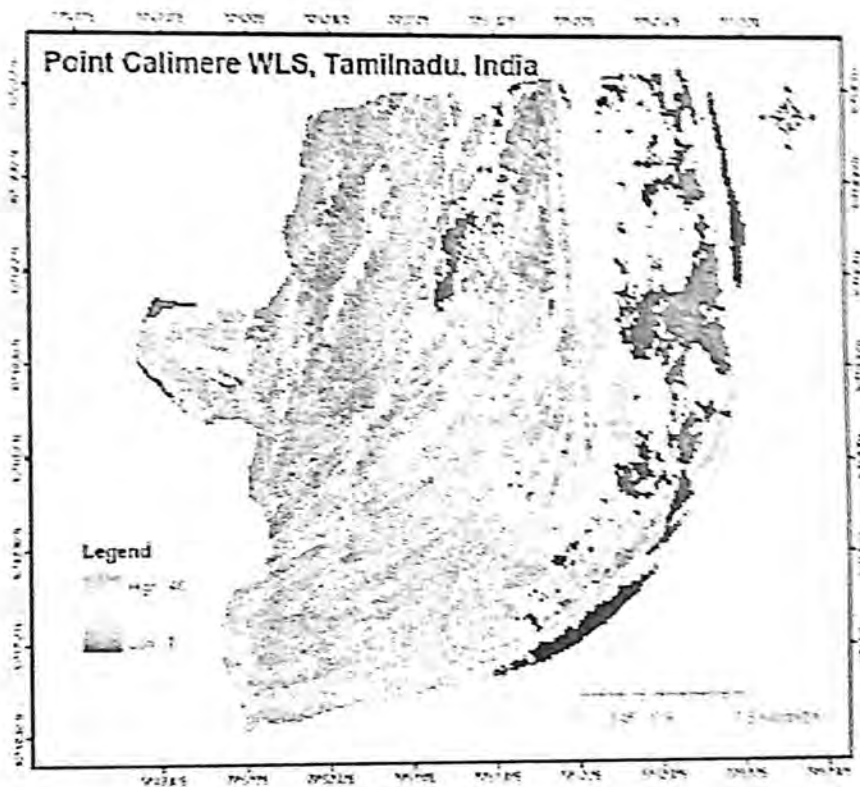


Fig.1 Study area map of Point Calimere wildlife Sanctuary, Tamil Nadu

3.3 Methodology

3.3.1 Food habits and diet overlap of herbivores

Feeding site method (Lovaas 1958) was used to collect information on the food plants selected by the herbivores. Feeding animal was located and observed from a distance varying from 30 to 80 meters and food plants eaten was identified. From an area of 1m radius around the freshly eaten plants, the number of species available and eaten was counted. In a month about 10 plots of 1m ×1m / food plants / species were investigated in order to get an insight on the food plants eaten and their preference by the study species.

3.3.2 Laboratory Analysis

Two type of analysis were done in the Laboratory,

- 1) To find out the nutrient components of the food plants of the target species (blackbuck, chital, feral horse and cattle)
- 2) To evaluate the monocot and dicot ratio of the plants from the dung/pellet samples.

3.3.3 Nutrient analysis of utilized food plants

The samples of eaten food plants collected were dried, ground and analysed for the following positive and negative nutrients:

Positive nutrients - gross energy (kcal/gm), fat, crude protein, total non-structural carbohydrates (TNC) and minerals (Ca, Na, Mg, k, Fe, Zn).

Negative nutrients - Fibre in terms of neutral detergent fiber (NDF), acid detergent fiber (ADF) and crude lignin. Gross energy (Kcal/gm) was estimated by bomb calorimetry. Ash content was estimated by heating the sample to 600°C in a muffle furnance (Horwitz 1980). Total nitrogen was measured by the Kjeldahl method (Horwitz 1980). Crude protein values were calculated by multiplying the total nitrogen values by 6.25 (Maynard and Loosli 1969). Total lipid content was determined by Soxhlet extraction using diethyl ether (Horwitz 1980). Mineral analyse (Ca, Mg, Na, K, Fe, Zn) was performed using an atomic absorption spectrophotometer. Neutral detergent fiber, acid detergent fiber and lignin were determined by the procedure of Goering and Van

Soest (1970). Tannin was determined using a bovine serum albumin (BSA) assay (Wilson 1984). Samples were tested qualitatively for the presence of alkaloids with dragendorff's and Meyer's reagents using extraction procedures and tests for false positive reactions recommended by Gartlan et al (1980).

3.3.4 Habitat use of herbivores

Dung/pellets are considered to be a reliable indicator of animal presence and have been used in Indian subcontinent to quantify the habitat use (Berwick 1974, Dinerstein 1979). The line transects that are laid for estimating the densities of the herbivores was used for studying the ungulate- habitat interactions. These transects were walked from January 2013 to April 2013 along with estimating densities of the herbivores and at every 200 m on each transect herbivore dung groups were counted in a belt transect of 30 × 2 m. Two types of analysis were used for the assessment of habitat use, one- way analysis of variance (ANOVA) and multiple regression analysis. The dung densities within habitat types were subjected to one- way of analysis of variance to find out the significant differences in the distribution of mean dung densities among the broad vegetation types. Multiple regression analysis which is commonly used as parametric method was done on blackbuck, chital, feral horses and cattle mean dung densities to establish a partial correlation and significance level against the independent variables (Habitat variables).

3.3.5 Diet Spectrum of Wild Ungulates and Livestock

Individual species diet breadth was assessed using **Levin's measure** (Levins 1968), standardized to a scale of 0-1 following Hurlbert (Hurlbert 1978). Overlap in diet of different pairs of species can be assessed using the Piankas index (Pianka 1973). Levin's niche-breadth was calculated by using the formula,

$$B = 1 / \sum p_i^2$$

Where p_i = proportion of pellets found in each habitat; and the standardized niche breadth can be calculated using the formula $B_s = (B-1)/(n-1)$, where n = total number of habitats. Niche overlaps can be calculated using **Pianka's index** of niche overlap (Pianka 1973)

$$\text{Pianka index} = \frac{\sum p_{ij} * p_{ik}}{\sqrt{(\sum_i (p_{ij})^2 * \sum_i (p_{ik})^2)}}$$

P_{ij} = percentage of plant eaten i of species j .

P_{ik} = percentage of plant eaten i of species k

Jacob's index (Jacob 1974) was used to study the plant preference of the target species,

$$D = r_i - p_i / r_i + p - 2r_i p_i$$

Where r_i is the proportion of eaten plant in the plot and p_i is the proportion of available in the plot

The value of Jacob's index ranges from +1 (Maximum preference) to -1 (Maximum avoidance)

3.3.6 Collection of plant samples

For nutrient analysis the plants that were fed by the target species was identified. These plants were then collected from the field and were sun dried in order to avoid moisture. These samples were then weighed each around 500 g and were labelled properly. The dried samples were then brought to Wildlife Institute of India's laboratory (WII) and oven dried to remove the moisture contents. The samples were then powdered and were subjected to further analysis. A total of 43 plant species were identified during the study period as principal food plants of the target species which consisted of grasses, herbs, shrubs and trees.

3.3.7 Collection of dung/pellet samples

In order to evaluate the food composition of the plants that were eaten by the target species and to assess the Monocot and Dicot ratio in the dung/pellet sample that were collected from the field. During the study period dung/pellet samples of the target species were collected

across the study area representing all the habitats i.e.) grassland, mudflat and TDEF. A total of ten dung/pellet samples for each study species were collected for each month i.e. from January 2013 to April 2013. A total of 40 samples representing all the four target species i.e. 10 samples/species/month were collected from the field. Thus a total of 160 samples of dung/pellet samples were collected during the study period. The collected samples were then sundried in the field and were brought to WII laboratory for analysis.

3.3.8 Slide Preparation

Methodology followed for the preparation of slides is according to Cavender and Hansen (1970) and Scott and Dahl (1980). Four duplicate slides were prepared for each pellet/dung samples. For preparing slides, a small amount of pellet/dung sample was boiled on a microscope slide in a few drops of Hertwig's solution over an alcohol lamp. The material was spread evenly. A few drops of Hoyer's mounting medium was placed on the material, boiled again and while the solution is still hot and a 20 x 50 cover slip was placed over the material. The slides were then placed in a dust free environment and dried. Hoyers and Hertwig's solutions were prepared using the methodology described by Scott and Dahl (1980). Hoyer Solution clears the pellet/dung samples of pigments. It consists of 270 g chloral hydrate crystals, 10 ml of 1N HCL and 60 ml glycerine. The glycerine and HCL are combined and then chloral hydrate crystals were added. The mixture is then warmed over a alcohol lamp until the crystals dissolve. Hertwig's solution is a mounting medium consisting of 200g chloral hydrate, 50 ml water, 20 ml glycerine and 30 g photo purified gum Arabic. The glycerine and water are combined and the chloral crystals were added. The mixture is warmed until the crystals dissolved. The gum Arabic was then added and the solution is placed until the gum completely dissolved (up to 1 week).

3.4 Results

Analysis of Variance (ANOVA) showed that habitat use by blackbuck, chital, feral horse and cattle was significantly different ($F=76.71$, $df= 3$, $P< 0.001$). Blackbuck significantly preferred grassland ($F=94.35$, $df=2$, $p< 0.001$). Chital significantly preferred forest habitat ($F=57.87$, $df=2$, $p<0.001$) as compared to mudflat and grassland. Feral horse significantly preferred grassland ($F=8.8$, $df= 2$, $p<0.01$) and cattle significantly preferred grassland ($F=12.1$, $df=2$, $p<0.01$).

Blackbuck was found to be negatively associated with canopy cover, disturbance, herb cover and shrub cover, whereas grass cover was found positively associated with blackbuck preference (Table 1). Chital preferred high canopy cover, less disturbance and high shrub cover (Table 2). Feral horse and cattle did not show any relationship between any of the tested variables (Table 3 and 4)

Table.1 Result of multiple regression analysis for blackbuck habitat utilization in Point Calimere Wildlife Sanctuary, Tamil Nadu (January to April 2013).

| | Estimate | Std. Error | t value | Pr(> t) |
|--------------|----------|------------|---------|-----------------|
| (Intercept) | 2.401837 | 0.422166 | 5.689 | 2.94e-07 *** |
| canopy.cover | -0.0221 | 0.008533 | -2.59 | 0.0117 * |
| Disturbance | -0.51495 | 0.428739 | -1.201 | 0.2339 |
| Grass.cover | 0.017708 | 0.007879 | 2.248 | 0.0278 * |
| Herb.Cover | -0.00292 | 0.009951 | -0.293 | 0.7703 |
| Shrub.cover | -0.56636 | 0.25082 | -2.258 | 0.0272 * |

Table 2 Result of multiple regression analysis for Chital habitat utilization in Point Calimere Wildlife Sanctuary, Tamil Nadu (January to April 2013).

| | Estimate | Std. Error | t value | Pr(> t) |
|--------------|----------|------------|---------|-----------------|
| (Intercept) | -0.07103 | 0.240373 | -0.296 | 0.768503 |
| canopy.cover | 0.894254 | 0.239461 | 3.734 | 0.000387 *** |
| Disturbance | -0.0072 | 0.004721 | -1.524 | 0.132131 |
| Grass.cover | 0.004409 | 0.004266 | 1.034 | 0.305017 |
| Herb.Cover | -0.00299 | 0.005598 | -0.534 | 0.595103 |
| Shrub.cover | 0.695372 | 0.135142 | 5.145 | 2.45e-06 *** |

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Multiple R-squared: 0.4234, F-statistic: 9.987 on 5 DF, p-value: 3.402e-07

Table 3 Result of multiple regression analysis for Feral horse habitat Utilization in Point Calimere Wildlife Sanctuary, Tamil Nadu (January to April 2013).

| | Estimate | Std. Error | t value | Pr(> t) |
|--------------|----------|------------|---------|----------------|
| (Intercept) | 1.884997 | 0.447457 | 4.213 | 7.6e-05 *** |
| canopy.cover | -0.01407 | 0.00888 | -1.584 | 0.118 |
| Disturbance | 0.26447 | 0.44724 | 0.591 | 0.556 |
| Grass.cover | 0.003567 | 0.007983 | 0.447 | 0.656 |
| Herb.Cover | 0.000224 | 0.010331 | 0.022 | 0.983 |
| Shrub.cover | 0.023257 | 0.25978 | 0.09 | 0.09 |

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Multiple R-squared: 0.0512, F-statistic: 0.7339 on 5 DF, p-value: 0.6006

Table 4 Result of multiple regression analysis for Cattle habitat utilization in Point Calimere Wildlife Sanctuary, Tamil Nadu (January to April 2013).

| | Estimate | Std. Error | t value | Pr(> t) |
|--------------|----------|------------|---------|-----------------|
| (Intercept) | 2.155482 | 0.55777 | 3.864 | 0.000251 *** |
| canopy.cover | -0.01711 | 0.010013 | -1.709 | 0.092078 . |
| Disturbance | 0.442334 | 0.24747 | 1.787 | 0.078324 . |
| Grass.cover | 0.007829 | 0.00922 | 0.849 | 0.398799 |
| Herb.Cover | 0.011279 | 0.012264 | 0.92 | 0.360963 |
| Shrub.cover | -0.15728 | 0.303144 | -0.519 | 0.605554 |

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Multiple R-squared: 0.1387, F-statistic: 2.191 on 5 DF, p-value: 0.06528

Levin's measure of Niche breadth showed highest for feral horse (0.89), followed by cattle (0.72), blackbuck (0.48) and lowest by chital (0.26) Fig.2.

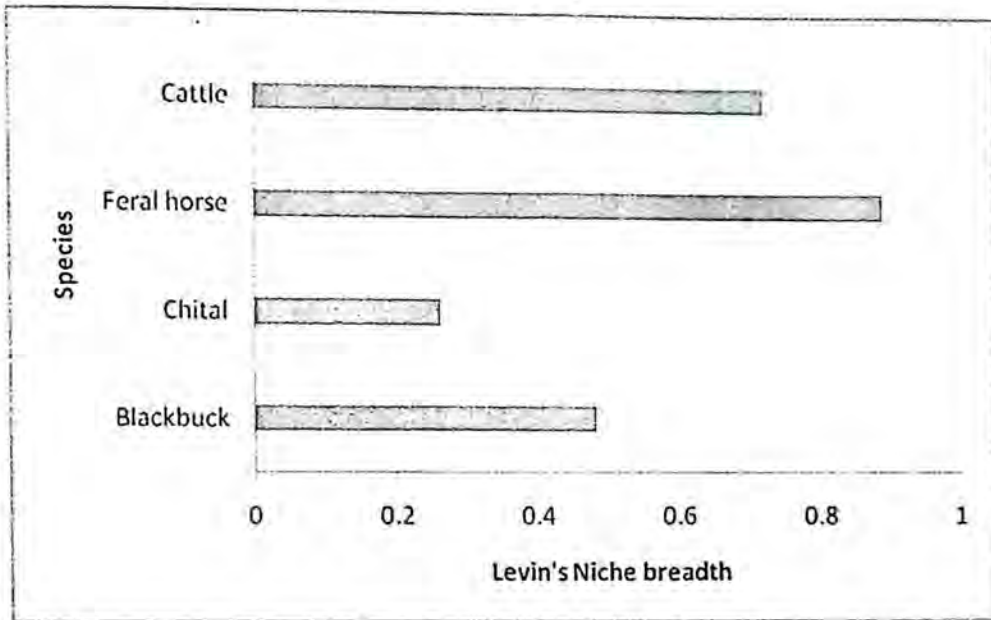


Fig.2 Levin's Niche breadth for wild and domestic ungulates in Point Calimere Wildlife Sanctuary, Tamil Nadu (January to April 2013).

3.4.1 Diet composition and overlap

In total 43 plants were identified as food species of all the target species viz. blackbuck, chital, feral horse and cattle during the study period of four months (Table.5). Of these, 23 plant species were observed to be eaten by blackbuck, chital fed upon 33 species of the plants, cattle utilized 29 species of plants and feral horse fed upon 35 plant species. Analysis of the dung/pellet samples revealed that blackbuck utilized 82.12% of monocotyledons and 16.90% of dicotyledons. Chital pellet analysis consisted of 74.63% of monocotyledons and 22.97% of dicotyledons. Cattle dung analysis revealed that it had utilized 85.7% of monocotyledons and 13.35% of dicotyledons and feral horse dung samples consisted of 84.9% and 14.9% of monocot and dicot respectively Fig 3. Among the 23 plant species eaten by blackbuck, 21 species were eaten in proportion to their availability. Fig 4.

Jacob's index was done to study the plant species preferred by the ungulates. The value of Jacob's index ranges from +1 (Maximum preference) to -1 (Maximum avoidance). Blackbuck

preference was high towards *Aleropus lagopoides*, *Cyperus kylinga*, *Naripayir kodi*, *Cyperus bulbosus*, *Cyandon dactylon*, *E.tennella* whereas chital showed its preference towards *Fimbistylis barbata*, *Cyperus difformis*, *Cyandon dactylon*, *Cyperus bulbosus*, *E.alba* and *Tinosporia cordifolia*. In case of cattle and feral horse both of them showed preference towards the plants which were eaten by blackbuck largely. The results of this are shown in the Fig.5.

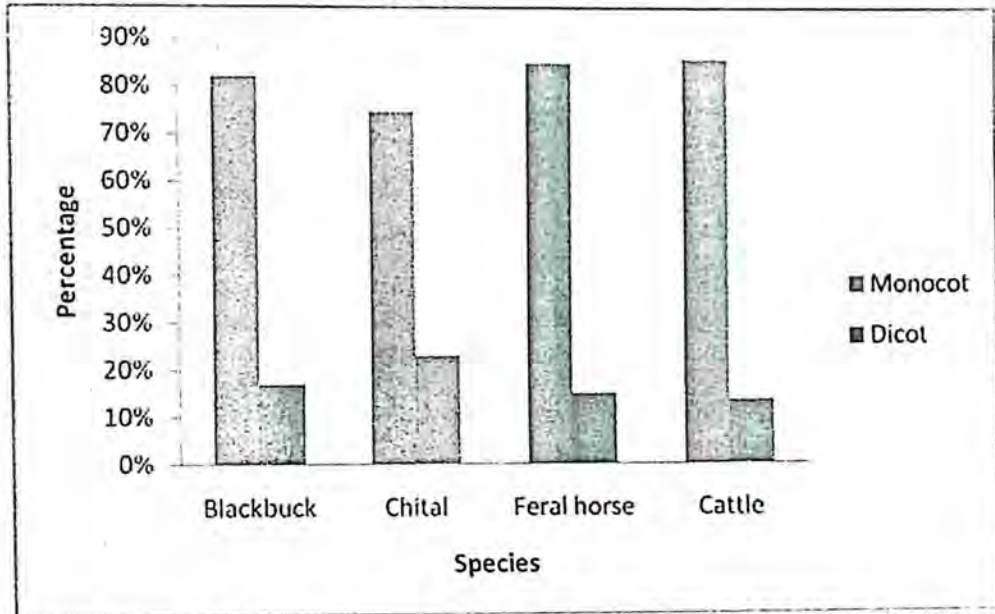


Fig.3 Monocot and Dicot ratio of plants from dung/pellet analysis of ungulates in Point Calimere Wildlife Sanctuary, Tamil Nadu (January to April 2013).

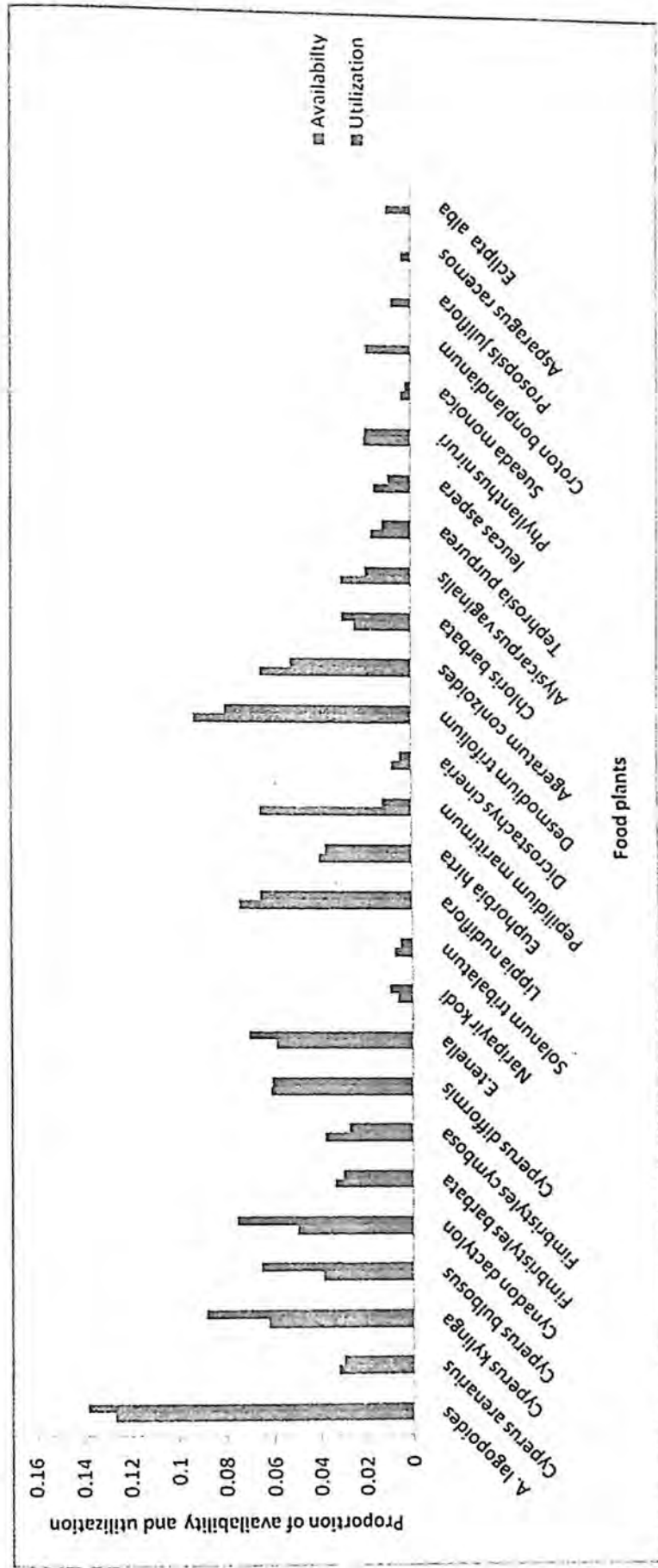


Fig 4. Availability and utilization of plant species by blackbuck in Point Calimere Sanctuary, Tamil Nadu, January 2013 to April 2013.

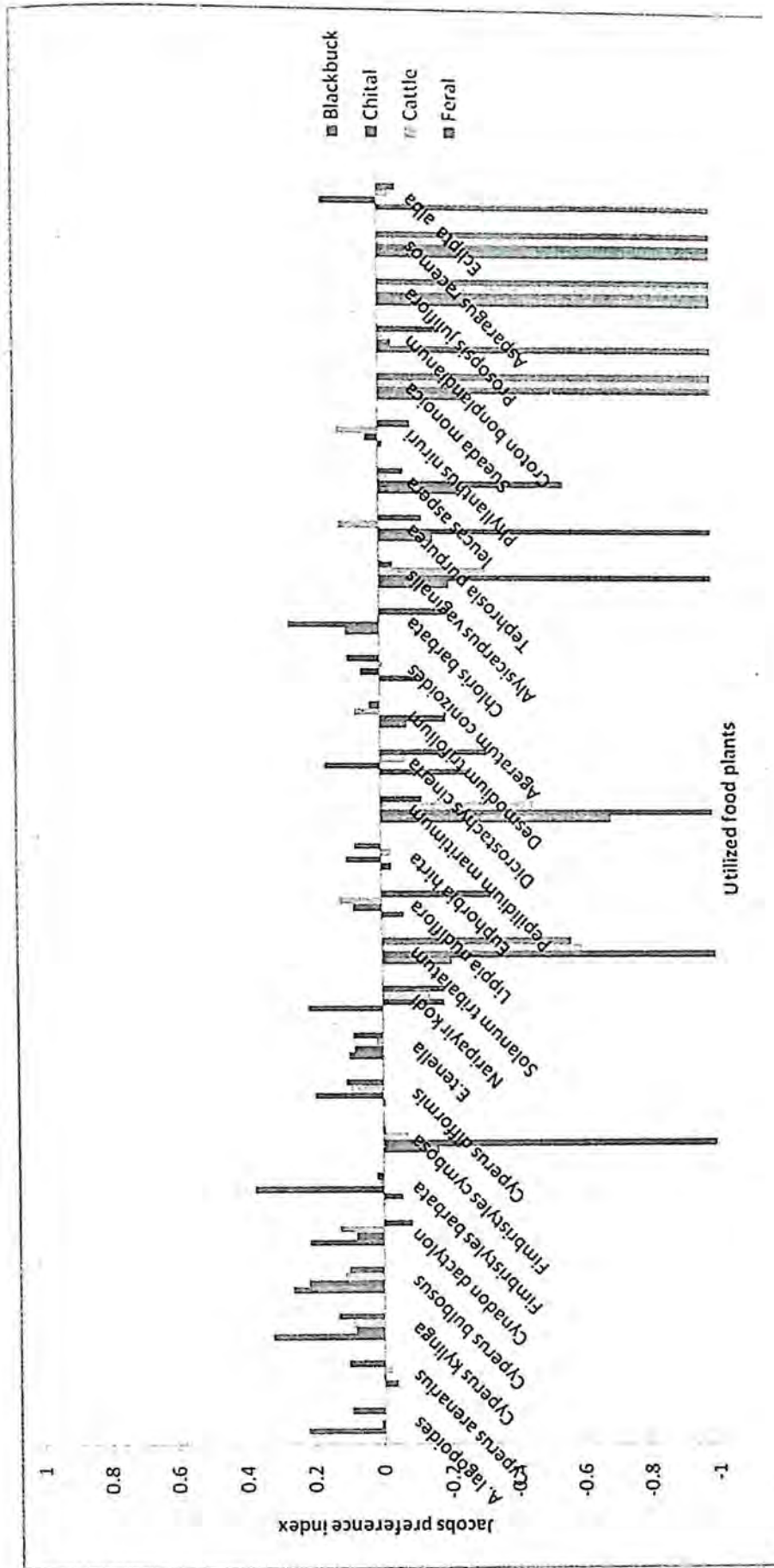


Fig. 5 Jacob's preference index for utilized plant species by wild and domestic ungulates in Point Calimere wildlife Sanctuary, Tamil Nadu (January to April 2013).

3.4.2 Diet overlap and nutrient analysis

Pianka's index showed that the diet overlap between blackbuck and cattle was highest (95 %) followed by blackbuck and feral horse (81%), blackbuck and chital (38.1%). Cattle and feral horse had a diet overlap of 91.3% Fig.6.

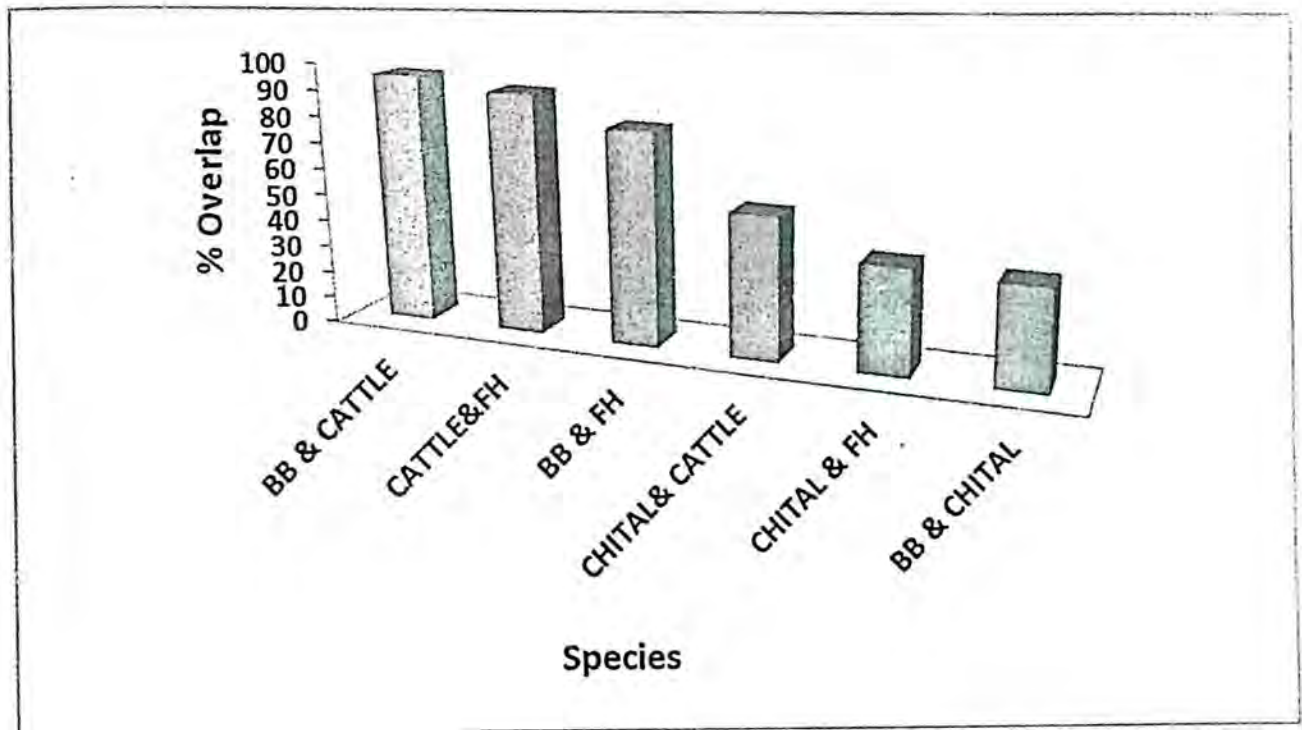


Fig.6 Diet overlap (Pianka's index) between the wild and domestic ungulates in Point Calimere Wildlife Sanctuary, Tamil Nadu (January to April 2013)

Altogether 43 forage species were preferred by the four target species. Multiple regression showed that blackbuck did not show any significant difference towards the nutrient contents of the utilized food plants ($R^2=0.31$ $F=0.61$ $df=8$ $p>0.05$) Table 6

Table 6. Multiple regression analysis for nutrient contents of utilized plant samples preferred by blackbuck in Point Calimere Wildlife Sanctuary, Tamil Nadu (January to April 2013).

| | <i>Coefficients</i> | <i>Standard Error</i> | <i>t Stat</i> | <i>P-value</i> |
|---------------|---------------------|-----------------------|---------------|----------------|
| Intercept | 0.143797021 | 0.451745411 | 0.318314 | 0.755302459 |
| Nitrogen | 0.012279482 | 0.109127892 | 0.112524 | 0.912127108 |
| Crude protein | 0.007270311 | 0.020028595 | 0.362997 | 0.722441407 |
| Phosphate | -0.098534206 | 0.360389479 | -0.27341 | 0.78883333 |
| Sodium | 0.154205142 | 0.228105347 | 0.676026 | 0.510872322 |
| Potassium | 0.158791706 | 0.233352095 | 0.680481 | 0.508138669 |
| Calcium | 0.00556485 | 0.020158235 | 0.276058 | 0.786842994 |
| Mg | 0.015162551 | 0.339227172 | 0.044697 | 0.965027847 |
| Zn | -0.005527075 | 0.006030689 | -0.91649 | 0.376097967 |

Signif.codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

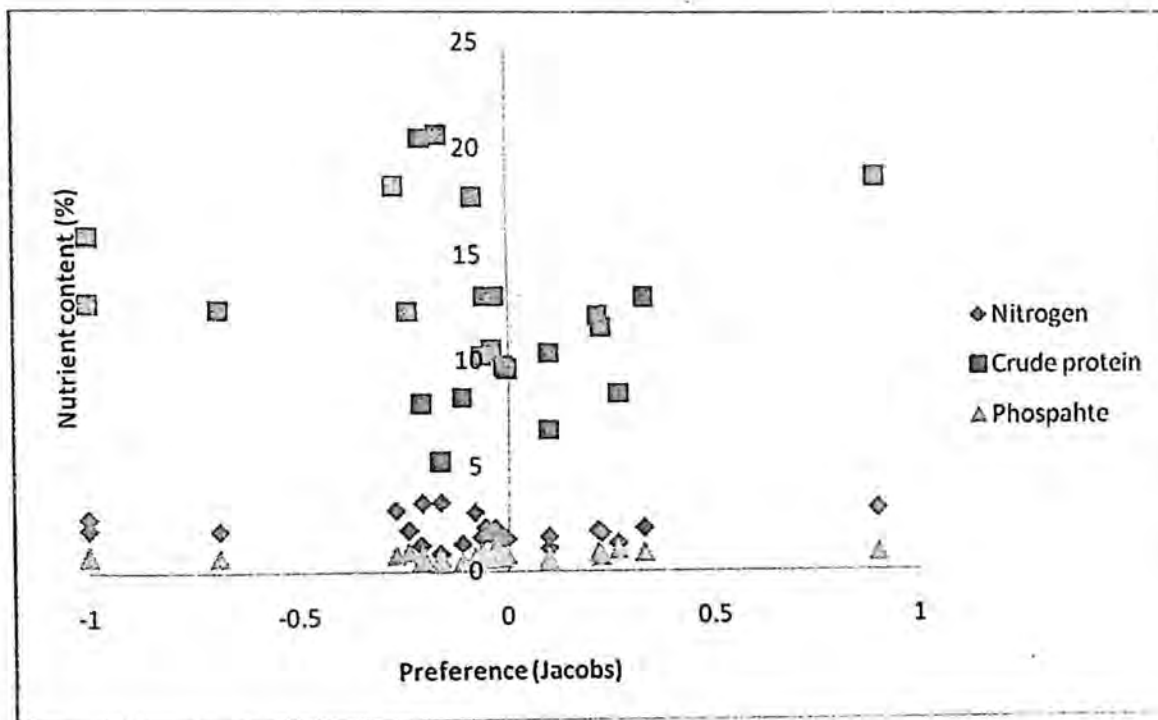


Fig.7 Preference of Nitrogen, crude protein, phosphate by black buck in Point Calimere Wildlife Sanctuary, Tamil Nadu. (January to April 2013)

3.5 Discussion

Assessing resource partitioning and co-existence in ungulates has received research attention in many parts of the world (Hoesten et al. 2007, Coe et al. 2005) and in India (Sankar and Johnsingh 1999, Bagchi 2003). Food selection by the wild ungulates is strongly influenced by the availability of choice i.e.) food plants diversity, nutritional status of forage species during various seasons, diet spectrum of the species and competition from domestic livestock (Bhattacharya et al 2012). In Point Calimere Wildlife Sanctuary blackbuck mostly utilized grass species followed by herbs. They did not feed on shrub species during the initial period of the study (January – March 2013). In the later part of the study period it was observed that blackbuck feed on certain shrub species especially *Dichrostachys cinerea*, *Azema tetragantha*, and *Salvadora persica*. The reason for the same may be attributed to drying up of the grasses during March and in order to compensate the nutritional requirement (Berwik 1967) blackbuck started utilizing browse species as well. Chital was mainly observed in the forest habitat and mostly feed on grass (Sankar and Johnsingh 1991), shrubs and certain climbers especially *Tinospora cordifolia* and *Grewia rhamnifolia*. Cattle and feral horse mainly fed on all the plants which they came across. Cattle mostly fed on grasses and herbs whereas feral horse both grazed and browsed.

The analysis of pellet/dung samples showed that blackbuck diet comprised mainly of monocots when compared with dicots during the entire study period of four months. Blackbuck is essentially grazers (Schaller 1967, Oza 1973 and Mungall 1978). They nibble the fresh blades of grasses and at times they browse on a variety of other plant parts at all times of the year in general and in summer in particular (Prasad 1981). A herd of blackbuck forages either widely scattered or as a compact unit (Schaller 1967). While grazing the animals move very slowly within the feeding ground. They gnaw at the green material they come across. While doing so they frequently raise their heads, scan around and once again stoop their heads. They leave clear impressions of the bite on the fresh grasses. Chital is an occasional browser (Sankar and Johnsingh 1991). The dung analysis revealed that they had a higher preference towards dicots when compared with blackbuck in Point Calimere. In Point Calimere Wildlife Sanctuary chital

was largely restricted in the Tropical Dry evergreen forest rather than in the grassland or mud flat. Domestic cattle being a grazer had a high preference towards monocots rather than dicot. Feral horse diet mainly composed of monocots. Forbs and shrubs may be locally important in diets of free- ranging horses (Hansen 1976, Krysl et al. 1984) and cattle (Uresk and Rickard 1976, Johnson 1979). Most studies concluded that these ungulates are primarily grass consumers throughout the year (Skiles 1984). Most workers found substantial dietary overlap between these herbivores in a variety of vegetation types (Olsen and Hansen 1977, Salter and Hudson 1979, Hanley and Hanley 1982).

The observed diet overlap was very high for blackbuck and cattle (95%) followed by blackbuck and feral horse (81%), blackbuck and chital (38.1%) and cattle and feral horse (91.3%) during the study period, in Point Calimere. Earlier studies had pointed out that the blackbuck usually moves away when cattle or feral horse visit the grassland (Nedumaran 1987). In my observation it was found that none of the animals shy away. It was interesting to find that at times all the four ungulate species feed in the same area without disturbing each other and consumed the same forage species. Hence there seem to be high dietary overlap between these ungulates since they shared the same food resources. Cattle and feral horse act as biggest competitor for the blackbuck as they fed on most of the plant species that is being utilized by the blackbuck.

In case of habitat use blackbuck mainly preferred grassland. Apart from grassland they also tend to prefer mudflat. In the mudflats they mainly fed on the *Aleuopus lagopoides* species. Blackbuck usually avoided the forest area during January- Mid March 2013. The reason for the same may be due to rainwater availability in the patches of grassland inside forest habitat. But during the month of April blackbuck was found using forest habitat. In case of chital they mostly preferred the thick forested area. In the evening hours they were seen in the grassland that too for a shorter period of time. During the study period chital was observed most of the time inside the forest area rather than in the grassland. They also used to move outside the Sanctuary and enter in to village and non- forested areas. Cattle and feral horse were found throughout the Sanctuary thus having a wide habitat use. Usually cattle were found in a large group size comprising of 30 to 40 animals. The dung of cattle and feral horse were found in

most of the part of the Sanctuary. Levin's measure of niche breadth showed that feral horse had a very high niche breadth of (0.89) followed by cattle (0.72), blackbuck (0.48) and lowest niche breadth was achieved by chital (0.26).

Blackbuck mainly preferred grass species whereas chital also preferred grass species but they were different from blackbuck's preference. Blackbuck showed a special preference to a plant Naripayir kodi (local name) and this plant is usually found in the sand banks. The plant had a high percentage of crude protein (18.6 %) Fig.7. Though *Solanum tribolatum* has thorns in its leaves it showed its preference in the diet of blackbuck because it might of high crude protein content (20.4 %). *Dichrostachys cinerea* which was fed by the blackbuck in the month of April also had high protein content (18.6%). Black buck showed complete avoidance of *Croton bonplandianum*, *Asparagus racemosus*, *Prosopis juliflora* during the study period. Cattle fed on the species which is common for blackbuck also. They fed on species such as *Croton bonplandianum* and *Asparagus racemosus* which were totally avoided by the blackbuck. Feral horse mostly showed preference towards *Cyperus arenarius* and tree species *Cassia fistula*. I observed that most of the feral horse dung consisted of *Cyperus arenarius* seedlings.

It was observed that during the study period both blackbuck and feral horse did not show their preference to *P. juliflora*. The reason may due to availability of other plant species during this period and moreover it was not the season for pod growth. Though seedling of *P. juliflora* were found in the dungs of feral horse during the month of December they did not show any preference for *P. juliflora* during the study.

Due to limited area of foraging, the nutritional factors are likely to act in a density-dependent manner. The equilibrium would be determined by forage production and quality, available area and grazing pressure (Jhala, 1997). Due to stochastic nature of forage production (Jhala, 1991) the equilibrium would be dynamic one and the population would fluctuate about the mean. Nutritional factors act in synchrony with climate (Jhala 1991), predation (Jhala 1993) and poaching pressure to limit the population. The interaction of the blackbuck population with any of these factors would be different in time and space, thereby prohibiting a simple explanation of the mechanisms regulating population dynamics (Jhala 1997).

In Velavadar National Park, Gujarat prior to the introduction of *P.juliflora*, grasslands would have been the most critical foraging habitat (Jhala 1997). Due to the low quality of forage in summer, blackbuck has to be extremely selective in feeding to obtain adequate intake of nutrients. Due to limited area available for grazing and continuous grazing pressure a point would be reached where selective feeding would have reduced the density of palatable forage to such low levels so as to make its consumption unprofitable (Hanks 1981).

During the period of study the availability of forage species for the target species in the study area were found adequate and it decreased after the mid-March. The plant species availability which blackbuck feed on also decreased after mid-march. For example species such as *Cyperus bulbosus*, *Cyandon dactylon* and *Cyperus kylinga* preferred by blackbuck usually occur only in the wet areas. Once water gets dried up these species die off. During this time feral horse as well as blackbuck feed upon the *P.Juliflora*. There are incidents as reported by the Forest department wherein blackbuck strayed outside the Sanctuary in search of water during summer. In terms of management issue there should be a complete ban on the movement of domestic cattle into the Sanctuary. Since feral horses are not native to this Sanctuary it is recommended that they should be shifted out from the Sanctuary. These management interventions would ensure the long term survival of blackbuck in Point Calimere Sanctuary.

Table.5 List of Nutrient values of food plants eaten by wild and domestic ungulates in Point Calimere Wildlife Sanctuary, Tamil Nadu. (January to April 2013)

| S. No. | Name of sample | Nitrogen% | Crude protein% | Phosphate % | Sodium % | Potassium % | Calcium% | Mg % | Cu % | Zn % | ADF | NDF | LIGNIN |
|--------|-----------------------------|-----------|----------------|-------------|----------|-------------|----------|--------|---------|------|-------|-------|--------|
| 1 | <i>A. lagopoides</i> | 1.846 | 11.5375 | 0.725 | 0.7344 | 0.325 | 7.81 | 0.4106 | 0.00423 | 27.4 | 53.31 | 77.82 | 7.12 |
| 2 | <i>Cyperus kyllinga</i> | 2.0722 | 12.95125 | 0.9 | 0.6215 | 0.8549 | 2.38 | 0.3738 | 0.00288 | 18.4 | 51.42 | 78.16 | 8.45 |
| 3 | <i>Cyperus arenarius</i> | 1.678 | 10.4875 | 0.775 | 0.378 | 0.4073 | 1.862 | 0.3974 | 0.00323 | 23.3 | 46.25 | 70.85 | 10.31 |
| 4 | <i>Cyperus bulbosus</i> | 1.3463 | 8.414375 | 1 | 0.2121 | 0.6646 | 3.23 | 0.3874 | 0.00218 | 32.7 | 44.61 | 70.52 | 9.42 |
| 5 | <i>Cynodon dactylon</i> | 1.9371 | 12.106875 | 0.925 | 0.2125 | 0.8593 | 3.808 | 0.218 | 0.00322 | 34.2 | 45.11 | 73.54 | 8.56 |
| 6 | <i>Fimbristyles barbata</i> | 2.0777 | 12.985625 | 0.575 | 0.1136 | 0.9515 | 2.378 | 0.7682 | 0.0034 | 58.7 | 54.6 | 68.54 | 8.39 |
| 7 | <i>Fimbristyles cymbosa</i> | 0.8302 | 5.18875 | 0.375 | 0.1916 | 0.8083 | 3.7 | 0.2272 | 0.00203 | 50.6 | 43.35 | 77.36 | 14.42 |
| 8 | <i>C. difformis</i> | 1.533 | 9.58125 | 0.775 | 0.1163 | 1.1292 | 3.412 | 0.437 | 0.0036 | 46.5 | 51.29 | 62.29 | 8.61 |
| 9 | <i>E. tenella</i> | 1.0729 | 6.705625 | 0.525 | 0.12 | 0.4295 | 0.01 | 0.1996 | 0.00169 | 41.1 | 53.38 | 77.06 | 13.29 |
| 10 | <i>Naripayir kodi</i> | 2.9771 | 18.606875 | 0.85 | 0.1184 | 1.0331 | 6.7 | 0.3958 | 0.00201 | 28.2 | 49.28 | 75.55 | 12.11 |
| 11 | <i>Solanum tribolatum</i> | 3.2692 | 20.4325 | 0.75 | 0.2018 | 1.4123 | 8.52 | 0.714 | 0.00405 | 27.7 | 51.41 | 76.09 | 7.12 |
| 12 | <i>Lippia nudiflora</i> | 1.6308 | 10.1925 | 0.9 | 0.3467 | 0.8411 | 12.058 | 0.6014 | 0.00327 | 34.7 | 55.26 | 69.24 | 11.54 |
| 13 | <i>Eclipta alba</i> | 2.0228 | 12.6425 | 0.825 | 0.6039 | 1.4855 | 8.246 | 0.5678 | 0.0029 | 47.6 | 25.54 | 34.79 | 13.89 |
| 14 | <i>Euphorbia hirta</i> | 2.081 | 13.00625 | 1.175 | 0.6016 | 0.9586 | 7.682 | 0.0012 | 0.00225 | 39.7 | 52.26 | 68.28 | 16.24 |
| 15 | <i>Pepilidium maritimum</i> | 1.9756 | 12.3475 | 0.725 | 1.044 | 0.5514 | 11.886 | 0.6486 | 0.00326 | 24.8 | 45.23 | 66.19 | 9.68 |
| 16 | <i>Maba buxifolia</i> | 1.2991 | 8.119375 | 0.325 | 0.1435 | 0.5297 | 7.092 | 0.3348 | 0.00119 | 17.4 | 56.38 | 64.01 | 12.43 |
| 17 | <i>Tinospora cordifolia</i> | 2.7805 | 17.378125 | 0.875 | 0.4124 | 0.8403 | 9.082 | 0.4554 | 0.0016 | 19.1 | 50.81 | 75.21 | 16.29 |
| 18 | <i>Carissa spinorum</i> | 1.3046 | 8.15375 | 0.725 | 0.1389 | 0.4949 | 5.018 | 0.2772 | 0.00002 | 42.2 | 50.2 | 71.97 | 14.54 |
| 19 | <i>Gmelina asiatica</i> | 2.4961 | 15.600625 | 0.75 | 0.0969 | 0.6948 | 7.884 | 0.6056 | 0.00166 | 67.7 | 29.32 | 72.73 | 8.52 |
| 20 | <i>Randia dumetorum</i> | 1.6604 | 10.3775 | 0.525 | 0.1606 | 0.5559 | 9.718 | 0.6196 | 0.00207 | 17.9 | 46.32 | 41.04 | 11.68 |
| 21 | <i>Dicrostachys cineria</i> | 2.9068 | 18.1675 | 0.8 | 0.0803 | 0.4798 | 8.438 | 0.2548 | 0.00117 | 24.7 | 45.52 | 67.26 | 13.29 |
| 22 | <i>Ehretia microphylla</i> | 1.5846 | 9.90375 | 0.45 | 0.1453 | 0.9766 | 11.256 | 1.4324 | 0.00007 | 49.4 | 46.62 | 70.17 | 10.56 |

| S. No. | Name of sample | Nitrogen% | Crude protein% | Phosphate % | Sodium % | Potassium % | Calcium% | Mg % | Cu % | Zn % | ADF | NDF | LIGNIN |
|--------|-------------------------------|-----------|----------------|-------------|----------|-------------|----------|--------|---------|------|-------|-------|--------|
| 23 | <i>Desmodium trifolium</i> | 2.8266 | 17.66625 | 0.675 | 0.276 | 0.428 | 7.704 | 0.2928 | 0.00245 | 23.4 | 32.74 | 38.12 | 12.34 |
| 24 | <i>Ageratum conizoides</i> | 1.3145 | 8.215625 | 0.5 | 0.5109 | 0.6937 | 8.652 | 0.3188 | 0.00008 | 53.2 | 32.18 | 43.71 | 11.51 |
| 25 | <i>Chloris barbata</i> | 1.6516 | 10.3225 | 0.65 | 0.0744 | 0.4516 | 2.726 | 0.372 | 0.00217 | 13.7 | 39.95 | 48.12 | 9.29 |
| 26 | <i>Sexcurinica leucopyrus</i> | 2.3039 | 14.399375 | 0.425 | 0.1337 | 0.5353 | 8.25 | 0.3446 | 0.00136 | 12 | 26.24 | 39.24 | 15.1 |
| 27 | <i>Scutia myritina</i> | 1.8526 | 11.57875 | 0.5 | 0.1106 | 0.6269 | 0 | 0.3128 | 0.0015 | 23.5 | 41.38 | 41.27 | 13.29 |
| 28 | <i>Clitoria ternatea</i> | 2.8903 | 18.064375 | 0.675 | 0.1106 | 0.8795 | 11.702 | 0.444 | BDL | 41.9 | 45.33 | 47.36 | 14.51 |
| 29 | <i>Alysicarpus vaginalis</i> | 1.2695 | 7.934375 | 0.5 | 1.1725 | 0.5869 | 9.63 | 0.5792 | 0.00141 | 39 | 44.35 | 73.73 | 8.91 |
| 30 | <i>Clerodendron inerme</i> | 2.3599 | 14.749375 | 0.95 | 0.5093 | 0.9946 | 7.736 | 0.3248 | 0.00207 | 19.4 | 40.4 | 71.21 | 11.26 |
| 31 | <i>Cassia fistula</i> | 2.6345 | 16.465625 | 1.225 | 0.0901 | 0.3607 | 7.676 | 0.306 | 0.00211 | 22 | 24.38 | 41.25 | 13.41 |
| 32 | <i>Salvadora persica</i> | 2.3522 | 14.70125 | 0.375 | 0.7213 | 0.5664 | 12.244 | 0.5442 | 0.00249 | 51.4 | 54.68 | 75.92 | 15.48 |
| 33 | <i>Azarna tetragantha</i> | 1.5341 | 9.588125 | 0.225 | 0.5088 | 0.7965 | 11.848 | 0.7228 | 0.00134 | 13.8 | 58.29 | 77.28 | 9.46 |
| 34 | <i>Tephrosia purpurea</i> | 3.2977 | 20.610625 | 0.675 | 0.0879 | 0.6449 | 4.532 | 0.3514 | 0.00211 | 22.4 | 42.63 | 47.39 | 18.25 |
| 35 | <i>Croton bonplandianum</i> | 2.5257 | 15.785625 | 0.725 | 0.3201 | 0.6239 | 36.28 | 0.0016 | 0.00311 | 20.5 | 48.7 | 38.43 | 11.63 |
| 36 | <i>Leucas aspera</i> | 1.9679 | 12.299375 | 0.95 | 0.0933 | 1.1232 | 7.058 | 0.3272 | 0.00166 | 28.9 | 55.04 | 42.69 | 13.75 |
| 37 | <i>Zizypus jujuba</i> | 2.1293 | 13.308125 | 0.425 | 0.0813 | 0.6402 | 10.704 | 0.222 | 0.00108 | 21 | 26.92 | 58.14 | 16.29 |
| 38 | <i>Karal</i> | 1.4649 | 9.155625 | 0.475 | 0.1733 | 0.9626 | 4.622 | 0.3856 | 0.00084 | 13.7 | 57.23 | 49.23 | 12.29 |
| 39 | <i>Zizypus innophyllum</i> | 1.148 | 7.175 | 0.55 | 0.0986 | 0.8456 | 5.658 | 0.289 | 0.00084 | 27.5 | 51.21 | 55.51 | 11.51 |
| 40 | <i>Grewia rhamnifolia</i> | 2.2973 | 14.358125 | 0.525 | 0.1073 | 0.6541 | 6.65 | 0.4274 | 0.00117 | 22.3 | 44.54 | 61.29 | 10.81 |
| 41 | <i>Manilkara hexandra</i> | 1.4309 | 8.943125 | 0.325 | 0.2121 | 0.404 | 7.658 | 0.3322 | 0.00244 | 23.5 | 34.63 | 52.68 | 16.44 |
| 42 | <i>Metinus emerginata</i> | 1.3979 | 8.736875 | 0.725 | 0.2093 | 1.3771 | 8.004 | 0.4162 | 0.00134 | 28.7 | 61.79 | 44.82 | 13.69 |
| 43 | <i>Phyllanthus niruri</i> | 1.5561 | 9.725625 | 0.6 | 0.0905 | 0.344 | 7.442 | 0.4212 | 0.00129 | 50.8 | 56.24 | 51.13 | 12.29 |

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Chapter 4: Conclusion and Conservation Implications

1. Our results suggested that cattle have high degree of overlap in terms of food and space during the study period from January-April 2013 when food resource is in abundance. Resource availability in summer, is known to get reduced which may cause intra and inter specific competition among the wild and domestic ungulates. During seasons of low resource availability, high stocking densities of domestic ungulates will impose resource limitations to wild ungulates.
2. Entry of cattle in to the park should be prohibited by fencing the entire area. This Sanctuary is only 22.5 km² and it can be done easily by forest department. Meanwhile, regular cattle vaccination of domestic livestock around the Sanctuary is important to reduce the spread of contagious disease such as rinderpest and foot and mouth disease to the wild ungulates.
3. Feral horse also have considerable amount of diet overlap with blackbuck. The owners of feral horses are still present in the nearby villages. The feral horses should be completely removed from the Sanctuary by giving notification to owners. Our preliminary results indicated that feral horses and cattle are the major dispersal of *P.juliflora* in the Sanctuary.
4. *P.juliflora* is gradually expanding in the grassland area which may reduce the available forage area for blackbuck, so *Prosopis* eradication is essential for the conservation of this threatened species. The *Prosopis* eradication currently being done by the forest department needs to be done more vigorously.
5. Public awareness and education is essential for the better understanding for the conservation, especially for *Adivasi* community who live next to the sanctuary.
6. There exists a knowledge gap of resource selection by these ungulates across different seasons and impact of high stocking density of domestic ungulates on wild ungulates. In order to fill this gap, a long term study needs to be taken up on priority to make informed management decisions that will aid in conserving the blackbucks and its habitat.

Plate 1 Study species In Point Callimere Wildlife Sanctuary



Blackbuck (*Antelope cervicapra*) in grassland habitat



Chital (*Axis axis*) in TDEF

Plate 1a Study species



Feral horses and cattle in Point calimere Wildlife Sanctuary, Tamil Nadu

Plate 2 Poaching and Predation in Point Calimere Wildlife Sanctuary



(a) Male black buck Poached in Point Calimere Wildlife Sanctuary



(b) Black buck male poached in Point calimere Wildlife Sanctuary

Plate 3. Predation on Black buck in Point Calimere Wildlife Sanctuary



Blackbuck fawn predated by Wild pig (*Sus scrofa*) in Point Calimere Wildlife Sanctuary
