BLACKBUCK OCCUPANCY IN MOYAR VALLEY, TAMIL NADU

Major Project Thesis

Submitted by

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For the partial fulfillment of the

Degree of Master of Science in

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Submitted to

Department of Natural Resource
TERI University

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DECLARATION

This is to certify that the work that forms the basis of this project "BLACKBUCK OCCUPANCY IN MOYAR VALLEY" is an original work carried out by me and has not been submitted anywhere else for the award of any degree.

I certify that all sources of information and data are fully acknowledged in the project thesis.

DEVIKA RATHORE

Date: 17/05/17

CERTIFICATE

This is to certify that DEVIKA RATHORE has carried out her major project in partial fulfillment of the requirement for the degree of Master of Science in Environmental Studies and Resource Management on the topic “BLACKBUCK OCCUPANCY IN MOYAR VALLEY” during January 2017 to May 2017. The project was carried out at the ASHOKA TRUST FOR RESEARCH IN ECOLOGY AND THE ENVIRONMENT (ATREE).

The thesis embodies the original work of the candidate to the best of our knowledge.

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List of Abbreviations

AIC	Akaike Information Criterion
GPS	Global Positioning System
km	Kilometer
NTFP	Non-timber forest products
SE	Standard Error
sq	Square
sp	Species
STR	Sathyamangalam Tiger Reserve

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Abstract

Endemic to the Indian sub-continent, the population of the Blackbuck (Antilope cervicapra) was estimated at 43,500 in India in 1989. Today, due to large-scale land use and land-cover change, poaching, and loss of habitat due to invasive species, their habitat has mostly been restricted to a few isolated patches of open grassland and agricultural fields. Living in close proximity to human settlements, these ungulates are worshipped in some places and have actually thrived in some protected areas. The alien invasive, Prosopis juliflora, which was introduced and now is wide-spread in semi-arid areas, has been known to drive substantial losses of native vegetation in savannas and grasslands, thereby resulting in the possible shrinking of blackbuck habitat. Confoundingly, blackbuck are also known to eat Prosopis juliflora seeds, and inadvertently aid in its dispersion through their dung piles in high density lekking aggregations.

This study seeks to explain the land-cover and land-use factors that influence the blackbuck occupancy in the Moyar valley in Tamil Nadu (with a special focus on the invasive Prosopis juliflora). This was done by combining detection probability data that accounts for imperfect detection of blackbuck occurrence with covariates hypothesized to influence site occupancy of blackbuck in the Moyar Valley. The Moyar Valley encompasses portions of the Sathyamangalam Tiger Reserve, Nilgiri North and Coimbatore forest divisions in the Western Ghats. This valley holds a large contiguous population estimated in the past to be 800-1000 individuals, although this estimate needs to be verified using rigorous line transect data that accounts for detection probability. Little is also known about factors influencing habitat for blackbuck in this landscape. This study generates baseline data and identifies factors affecting blackbuck distribution in the Moyar Valley.

Key words: Blackbuck, Habitat, Occupancy, Spatial replication, Prosopis juliflora

INTRODUCTION

According to the International Union for Conservation and Natural Resources (IUCN), the geographic range of the blackbuck (*Antilope cervicapra*) extended to almost all parts of the Indian subcontinent before the 20th Century. This range saw a sharp decline soon after, rendering the species extinct in Bangladesh, Nepal and Pakistan. They have been reintroduced in Pakistan, Nepal and introduced across the continent to Argentina and United States.

In some protected areas in India, their numbers have been increasing. There have been records on religious sentiments attached to the blackbuck in some parts of country. The Bishnoi communities in Rajasthan and Haryana are also known to protect the blackbuck, increasing their numbers. Similarly, according to Hindu mythology, blackbuck drew the chariot of Lord Krishna, and in Tamil Nadu, considered as the vehicle of the Hindu Goddess Korravai. These have helped in conservation of the species in religious sects in India.

The blackbuck is the state animal for Punjab, Haryana and Andhra Pradesh. It has been closely connected with Indian culture since the Indus Valley Civilization, as a source of food and later on, hunted during the Mughal era. These royal hunts often used Cheetahs which were considered the top predators of the blackbuck. After their extinction, they have been replaced by wolves, jackals and pariah dogs. During the British rule, blackbuck was also a heraldry symbol of a few princely states in India. It symbolized grace because of its slender build and was common in most parts of the country, mesmerizing all who laid eyes on the ungulate.

The population of blackbuck at the time of independence was estimated at around 80,000 by the India Environment Portal. The figures, if documented, for the population trend of blackbuck are extremely ambiguous and contradictory. There is a need for a population count, on a macro as well as micro-scale for the purpose of studying the population trend. In 1989, the population stood at 43,500 individuals (M.K. Ranjitsinh, 1989). An account of state-wise blackbuck population was estimated, and forms the basis for most literature on blackbuck available currently. According to IUCN, the population increased in the 1970s from 22,000-24,000 to 50,000 individuals. Rajasthan, Maharashtra, Gujarat, Punjab and Madhya Pradesh have been mentioned as the states with the largest numbers of blackbuck. Furthermore, USA and Argentina numbers are estimated at 35,000 and 8,600 respectively, although these numbers are representative of introduced populations in these countries.

Today, due to large-scale cultivation pressure, poaching, invasive species and cattle grazing, their habitat has been restricted to a few isolated patches of open grasslands. With the agrarian demands on the rise, the blackbuck has been facing habitat fragmentation in a lot of areas. The availability of less fodder for the Indian antelope has driven it to nearby agricultural fields. This has led to blackbucks recorded as raiding crops in Gujarat and Nepal, thereby increasing man-animal conflict.

Another possible factor that aids in shrinking blackbuck habitat is the highly invasive species, *Prosopis juliflora* or mesquite, which has been known to convert grasslands to scrublands (Herlekar, 2013). This invasive species has been a major problem in many regions and its management is debated owing to its conflicting perceptions as valuable or as an invasive weed. *Prosopis juliflora* has the ability to spread over large areas from a few trees or even a single introduction as seen in semiarid Asia and Africa (Pasiecznik et al., 2001). With no actual records of the native range of *Prosopis juliflora*, assumptions are made that the weed was spread by prehistoric man moving beyond the Americas or by the domesticated animals. “Native American invasions date from the 1800 and are in the advanced stage and it was introduced to the southern hemisphere countries around 1900s” according to NM Pasiecznik et al. (2001) in *The Prosopis juliflora-Prosopis pallida Complex: A monograph.*

An attempt to eradicate the weed has been carried out in USA, South Africa, Australia and Argentina but unsuccessfully, be it partial or complete removal. The only method of control is known to be sustainable agroforestry systems to increase productivity in the colonized areas. Deliberate introduction of the species in the last 100-150 years occurred due to its value as it produces quality timber, provides fuel, fodder, tolerance of drought and high yields in the poorest condition. In 1878, this was also the justification for introducing *Prosopis juliflora* in India by the Conservator of Forests of Northern Circle, Madras (Pasiecznik et al., 2001). Blackbuck are known to eat *Prosopis juliflora* seeds, which are not easily digested and hence aid in its dispersion through dung piles. This has been a cause of concern which threatens the habitat of blackbuck in semi-arid areas with *Prosopis juliflora* colonization.

This is a sub-project which comes under the Adaptation at Scale at Semi-Arid Regions (ASSAR) which focuses on climate change hotspots in Asia and Africa, devising long term resilience from these harsh challenges. The Moyar Valley lies in the Sathyamangalam Tiger Reserve, Nilgiri North and Coimbatore Division in the Western Ghats. The top species found in this region are Prosopis juliflora, Acacia catechu, Acacia planifrons, Catunaregam spinosa and Albizia amara. For the past three years, it has been experiencing drought, receiving an average annual rainfall of 762.59 mm. This is an important biodiversity hotspot and is also a UNESCO world heritage site.

Blackbuck numbers have been recorded as significant in the reserve, but no actual scientific study has been conducted on the species in that area. In fact, there is very little published work on blackbuck in India, with this being the first study conducted on blackbuck in the landscape. This work shall estimate the status of blackbuck in the Moyar valley and the likely factors that influence its occupancy, in the peek blackbuck mating season from February to March.

I seek to explain the factors that affect its occupancy, in order to generate baseline data and assist in better management of the Moyar Valley.

BACKGROUND

The Indian antelope or the blackbuck (*Antelope cervicapra*) is endemic to the Indian sub-continent, found in India, Pakistan and Nepal. In India, it was known to be distributed across the entire country, mostly in dry arid regions. It comes under the category of 'Near Threatened' in the International Union for Conservation and Natural Resources (IUCN) Red List and is listed under Schedule I of the Wildlife Protection Act of 1972, which prohibits the hunting of blackbuck. Since their sense of smell and hearing is not highly developed, they prefer grasslands, which gives them adequate visibility to outrun predators (Mahato et al., 2010). Their top predator prior to Indian independence, was the Cheetah, which is now extinct. The blackbuck is also known to run at 70 kmph, making it one of the fastest of all surviving species (Kumar and Zutshi, 2013). Grasslands are one of the least protected habitat in India which has made the conservation of blackbuck very problematic. (Prashanth et al., 2016). Furthermore, intense habitat destruction of grasslands and open forests to fulfill the agrarian needs of the Indian community may have been exacerbated by exotic species plantations. The depleting grasslands have been covered with scrubs or invasive species which results in the habitat becoming unsuitable for the species to thrive.

Home range

WH Burt (1943) was the first to define the concept of home-range as "that area traversed by an individual in its normal activities of food gathering, mating, and caring for young ones. Occasional sallies outside the area, perhaps exploratory in nature, should not be considered part of the home range". Darwin (1869) and Seton (1909) were among the first to notice this concept, but it was Burt who defined the concept by gathering data about mammals observed and plotting the same on maps. With advancement in technology, the home-range estimators use telemetry data which provides a vast amount of literature on the home ranges of most animals (Powell et al., 2012).

Blackbuck, being herbivores that require vast grasslands and fodder, with occasional water requirements, have a large home-range depending on the group (Mahato et al., 2010). In their book, Mahato and others (2010) estimated the home-range of blackbuck to be 5.4 sq km, with the smallest home range was of 3.15 sq km using minimum convex polygons around the data which tends to overestimate the result. They also concluded that male blackbucks occupy large, non-overlapping home ranges demarcated by marking (urination/defecation/rubbing the ground, bush or trees), whereas females showed substantial overlapping in their home ranges.

The home range for the groups of blackbuck recorded at Gajner sanctuary, Rajasthan was 19.62 sq km (Kumar et al., 2016). It was also noted that this estimate was subjected to change with the season, type of vegetation and food availability. Another study in Nepal found that the home ranges of blackbuck additionally may also vary according to the size of the herd, intra-specific competition and topography of the terrain. In Kanha National Park the home range was 0.4 sq km for a herd of 12 animals, whereas in Wankaner National Park it was estimated at 2.5 sq km for a herd of 28 animals (Khanal et al., 2002).

Prasad (1983) had also given figures for the home range of blackbuck at 3.25-13.5 km sq (mean home range – 7.66 sq km) by investigating 11 male blackbuck individuals in Mudmal, India. This was done between a period of 6-22 months, where he found that certain grids were used more intensively and that the blackbuck shared resources, either simultaneously or at different time spans.

Covariates

A highly invasive species, *Prosopis juliflora*, is a major threat to grassland habitats in the country. This species is native to Central and South America, and is known to covert grassland habitats to scrubland or woodlands. Historically, it was deliberately spread to many parts of the world for fuelwood, high-quality charcoal and aid in the prevention of drought, curbing desertification. (Jadeja et al., 2013). There are contrasting accounts given about the introduction of *Prosopis juliflora* to the Indian sub-continent in the nineteenth century. In one such instance, it was considered 'desirable for the fuel plantations in dry districts' by the Conservator of Forests of Northern Circle, Madras to the Secretary of the State. It was received and sown in 1877 (Pasiecznik et al., 2001). With the advent of the twentieth century, Prosopis was a widespread invasive in drought-prone areas. Being the dominant ungulate species in semi-arid regions of India, the blackbuck has been known to consume the pods of *Prosopis juliflora* and spread the seeds through their dung. This has led to the colonization of this woody weed in open grasslands, rendering them unsuitable habitats for their dispersers (Herlekar, 2013).

Mating season for blackbuck have also been known to affect seed dispersal of *Prosopis juliflora* seeds as they display lekking behavior during the peak mating season (February-March and September-December; Jadeja et al. 2013). The male blackbucks come together in a cluster to form small territories around themselves, defending it constantly from other males. The females then visit the clusters to choose a mate. These are also dependent of female density and distribution (Isvaran, 2005). Lekking aids in the dispersal of seeds through massive dung piles deposited by territorial male blackbucks.

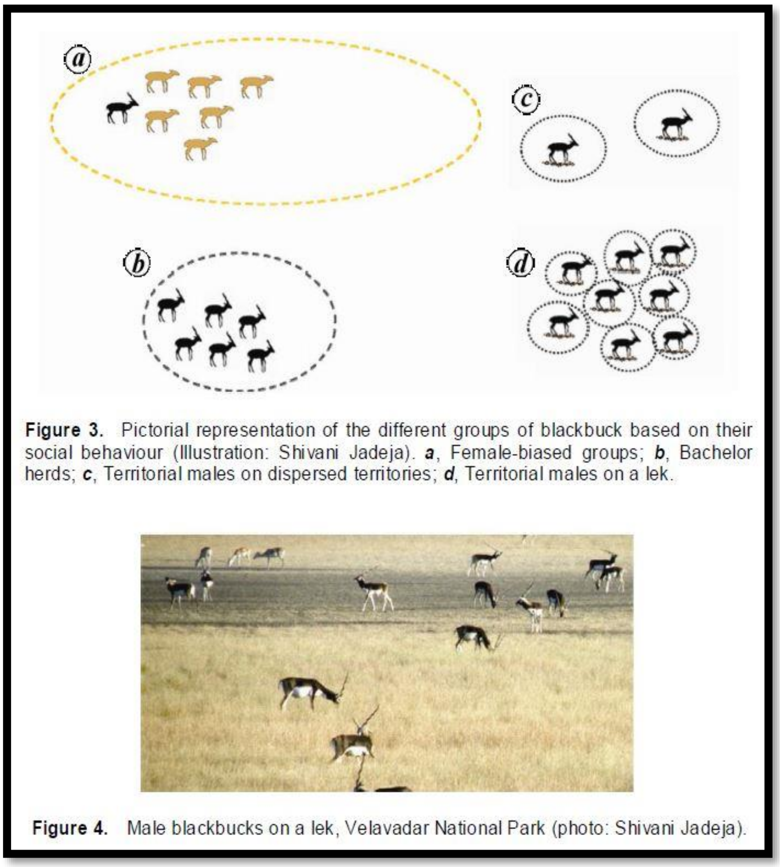

Figure 1 Pictorial representation of blackbuck groups and lek formation

(Image credit: Ipshita Herlekar in *Architect of one's own destruction)*

Three types of blackbuck herds have been divided by Jadeja et al. (2013): (1) female-biased herd which include female individuals with few juvenile males and one or more adults, (2) Bachelor herds with non-breeding male individuals and (3) Territorial males in a cluster within their defined spaces, forming a lek. The conclusions drawn were that the first two types of herds move over larger distances, as compared to the territorial males. The male blackbuck also consumed more *Prosopis juliflora* seeds than the female individuals. Furthermore, the territorial males exhibited scent-marking behavior in which they deposited enormous piles of *Prosopis juliflora*-containing dung at particular locations, thus facilitating their dispersal and establishment in new areas.

Grassland Conservation

The vegetation communities that are dominated by grasses and grass-like plants (graminoids) are referred to as grasslands. They serve a variety of micro and macro fauna, apart from their role as a major producer biome. The pampas of South America, the prairies of North America, the savannas of Africa, Caucasian steppes, veldts of South Africa, terai grasslands, alpine meadows of Himalayas and shola grasslands of the Western Ghats are all unique representations of this habitat across the world. In India, there have been no efforts to revise the classification of grassland communities recently and there is a lack of national policy on grassland management (Rawat et al., 2015). Inadequate management practices and revising the classification of grasslands has been listed as some of the major focus areas for the conservation of this habitat. The general perception is that grasslands are wastelands, which has led to the conversion of several grasslands into woodlands or croplands. Invasive species such as *Prosopis juliflora*, have dominated many grassland habitats not only in India, but in most grasslands of the world due to this mistaken perception. Furthermore, instead of harvesting the grass manually after the monsoon season, the forest state departments lease out the grasslands to many local graziers. Excessive grazing by livestock has further led to degradation of grasslands in the country (Rawat et al., 2015).

Moyar Valley

In 2008, the Sathyamangalam forests of north western Tamil Nadu gained the status of being a wildlife sanctuary under the Wildlife Protection Act 1972. However, it was only until 2013 that it came under Project Tiger and became the largest of the four tiger reserves in the state, under the provisions of the Act. It acts as a significant wildlife corridor between the Western and Eastern Ghats in the Nilgiri Biosphere Reserve. It also provides a genetic link between the four adjacent protected areas of the Sigur Plateau, Bandipur National Park, Billigiriranga Swamy Temple Wildlife Sanctuary and Mudumalai National Park. The study area comes under Project Tiger and Project Elephant, run under the Government of India. In the most recent Management plan of Sathyamangalam Tiger Reserve (2010-2020), blackbuck population has been estimated at 800-900 individuals.

The forests in this area are said to have been managed since the 17th century under the famous Mysorean ruler, Tipu Sultan (1782-1799). He had given Sandalwood the status of 'Royal tree' which was a vital move for the protection of these forests in his day. The forest Department was organized under Dr. Cleghorn for the first time in 1856. The earliest areas of the valley – Sathyamangalam, Bhavani and Talamalai were placed under Capt. W.H. Morgan with Ootacamund as the the Head quarter. In 1909, the Coimbatore North Division was constituted and it was only in 1980, that the Sathyamangalam division was formed. Since the pre-independence era in the 960s, this area provided the state with its fuel wood needs. Bamboo coupes and selection felling was only stopped around 1980, but by then habitats were disturbed and the activities had caused severe land degradation. For almost two decades, the notorious bandit Veerappan was also known to carry out his activities of smuggling ivory (wanted for poaching over 200 elephants worth 2.6 million USD) and sandalwood (10,000 tonnes worth 22 million USD) from these forests, bordering the states of Karnataka, Tamil Nadu and Kerala. It was only after his death that the division was explored and the existence of many endangered species was brought to the limelight such as the four-horned antelope, hyena, tiger, White backed vulture and flying squirrel.

Reports of poaching and electrocution of elephants, are sporadic, but pose a threat to the species. Agricultural fields are frequently raided by deer, wild pigs and elephants. Anti-poaching camps have been established in recent times and anti-poaching watchers are employed from the local youth for protection.

Occupancy Model

Occupancy modeling was first introduced by Mackenzie et al. (2002) in which, occupancy (denoted by the greek symbol psi, Ψ) is defined as the probability of species presence. The main focus was to estimate the fraction of the sites that is actually occupied by the species. It is similar to mark capture-recapture model for a closed population as replication is used to estimate detection and probability of occurrence. This was proposed by a likelihood based model for estimating site occupancy rates when detection probabilities are <1. Binary data is recorded for detection/non-detection at each site and additional modeling of occupancy can also be investigated by including covariate information for psi (at the site-level) and p (detection).

These four concepts best describe presence and absence data in occupancy modeling:

True presence- species present and detected

False presence- species absent but detected

True absence- species absent and not detected

False absence- species present but not detected

Occupancy studies are preferred over other models, largely because they take imperfect detections into consideration. In comparison to abundance estimation, these models allow data collection which is less intensive. It is also more suitable for certain objectives which covers a larger area, is cost-effective and also adheres to time constraints. Additionally, occupancy models are preferred over logistic regression models because the former estimate detectability through repeated observations at each site, whereas the latter assume that non-detection is absence, whereas occupancy takes true and false absence into consideration.

Correlated Detection

The MacKenzie et al. model assumes that the occupancy status does not change within each site or in this case, grid cell. In this study, the spatial replicates have not met this assumption as presence of blackbuck in one replicate, did not always mean that the rest of the replicates within the cell were also occupied by blackbuck (Jathanna et al., 2015)

The Hines et al. model, 2010 takes 'spatial correlation' and imperfect detections into consideration, unlike the standard occupancy model (MacKenzie et al., 2002). It accounted for lack of closure or independence. This model is used extensively for tiger surveys in India.

The Hines et al. model (2010) includes the following parameters:

p = Pr (detection at a segment | sample unit occupied and species present on segment)

Ψ = Pr (Sample unit occupied)

θ = Pr (species present on segment | sample unit occupied and species not present on previous segment) θ’ = Pr(species present on segment | sample unit occupied and species present on previous segment)

MATERIAL AND METHODS

Study area

Administration

The Moyar Valley comprises of the Sathyamangalam Tiger Reserve, Nilgiri North and Coimbatore divisions. The areal extent of the study area in the Moyar valley is 120 sq km which lies between 11°61’80” N, 77°74’51” E and 11° 45’56”N, 77°10’99” E. It is situated on the North-Western most part of Tamil Nadu and is bordered by Karnataka in the North. The Western Ghats of India is one of the most important landscapes and is categorized as a biodiversity hotspot of the world as given by Norman Myers in 1988.

Topography

With elevation ranging from 960m to 1266m, the study area has an undulating terrain. Interestingly, it lies in the area where the Western Ghats meet the Eastern Ghats, making it a common ground for two very distinct biogeographic features of the Indian peninsula.

Hydrology

The landscape is drained by the Moyar river, which is a perennial tributary of the Bhavani. The Bhavani River is a major tributary of the Kaveri and is the second longest river in Tamil Nadu. The Moyar is checked by the Bhavanisagar dam, which is said to be one of the largest earthen dams in the world.

Rainfall

Being a region that falls in the rain shadow area, it receives very low rainfall. The average annual rainfall is 762.59 mm, which was calculated using data acquired for the past 40 years, from Mettupalayam and Sathyamanagalam weather stations. The rainfall trend has been shown in figure 2 and 3 below, respectively. For the past three years, the landscape has been experiencing severe drought.

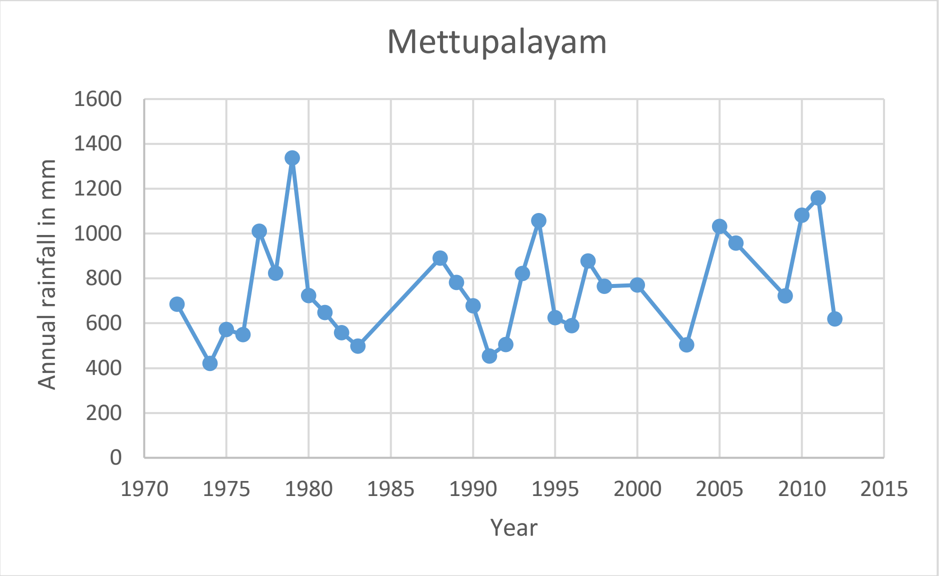

Figure 2. Annual rainfall (in mm) at Mettupalayam from 1972-2013

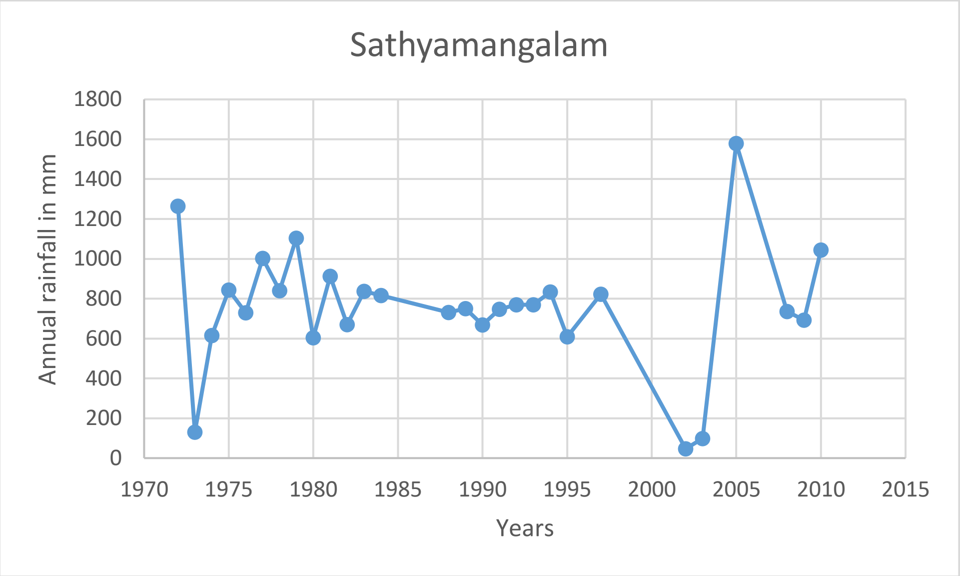

Figure 3 Annual rainfall (in mm) at Sathyamangalam from 1972-2013

Flora and fauna

The terrain is mostly dominated by scrub and also falls under the category of semi-deciduous forests, owing to erratic and unreliable rainfall. However, along the Moyar river, the riparian forest includes common tree species such as *Terminalia arjuna* and *Pongamia pinnata*. Other plant species include *Acacia spp, Albizia amara, Catunaregam spinosa, Fluggea leucopyrus, Cordia monoica, Mundulea sericia, Atalantia monophylla, Ziziphus mauritiana, Chloroxylon swietenia Canthium parviflorum, Syzygium cumini, Grewia spp. and Solanum spp.*

Highly invasive species, such as *Prosopis juliflora* and *Lantana camara* are spread throughout the study area. Herbivores such as elephants and antelopes, along with birds are known to aid in dispersal of their seeds.

The Moyar Valley has a high diversity of fauna which includes carnivores like tigers, leopards and dholes; herbivores such as the majestic elephants, the elusive four horned antelope, the graceful blackbuck, shy sambar deer, gaurs and the ever-so-eager scavengers such as hyenas and vultures that tread the landscape. It also holds significant populations of the common langur, wild pigs, sloth bears, otters and jackals. Some of the common reptiles include monitor lizards, mugger crocodiles, Indian rock python, and the saw-scaled viper, which were encountered during field sightings.

People

There are 138 villages within the five-kilometer radius surrounding the Sathyamangalam Tiger Reserve, who are dependent on the reserve forest for their livelihood. The communities include *Kurumbas, Soligas, Irulas and Ooralis*. They are dependent on Non Timber Forest Products (NTFP) and collect fuelwood and occasionally graze their cattle in the region.

The limited resources and dry conditions have resulted in human-animal conflict, especially with respect to elephants and wild pigs. Although no reports of blackbuck-human conflict has been noted, it is known to graze agricultural land and induce crop damage in Velavadar National Park, Gujarat and Nepal (Bhatta 2008).

Soil and Agriculture

The soil types that were commonly found were red soil, black cotton soil, laterite and alluvial soils in the area. Areas around the Bhavanisagar reservoir are being seasonally occupied for cultivation of banana and coconut. Other plantations include brinjal, tomato, beans, corn and capsicum.

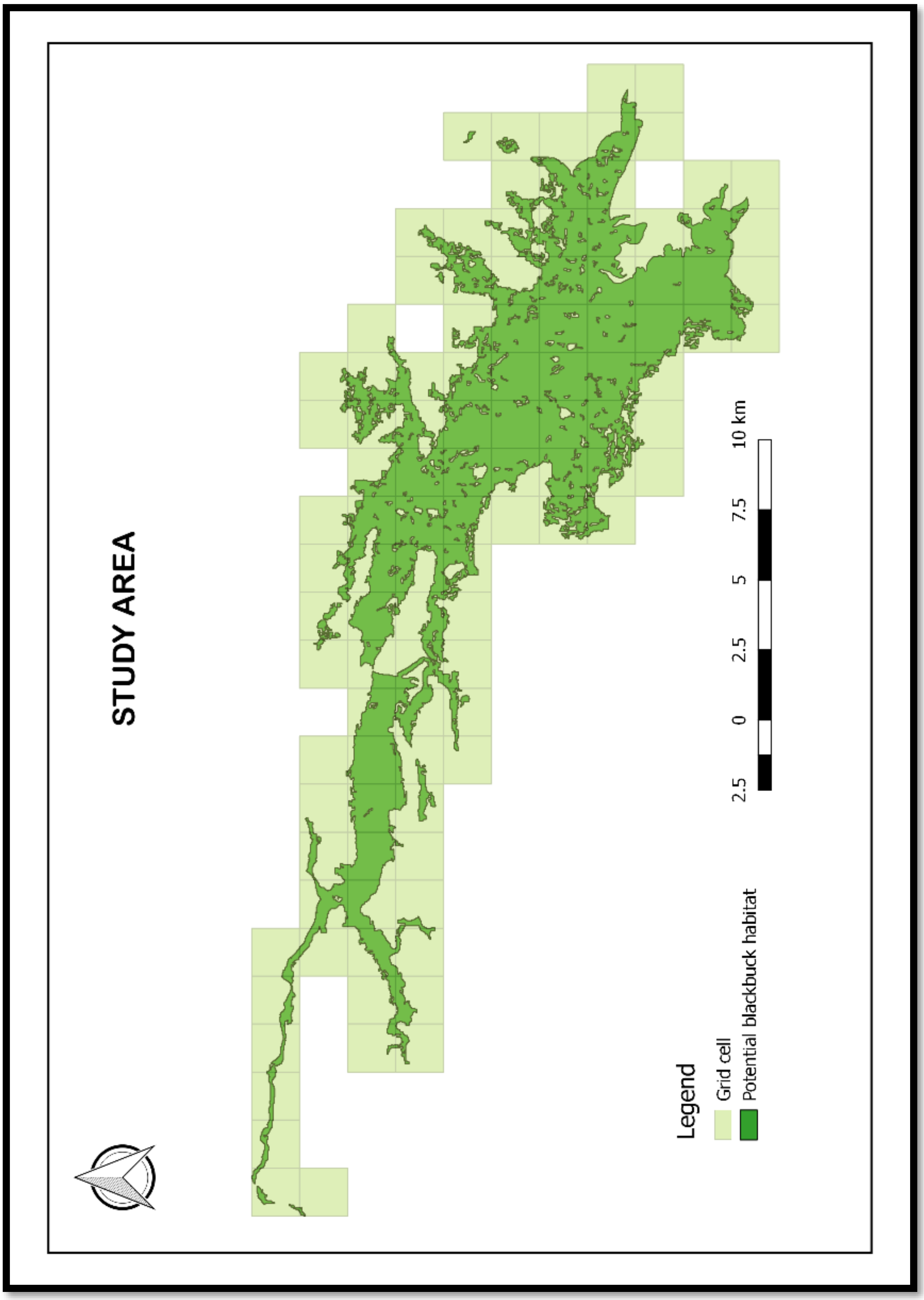

Figure 4 Map of the Moyar Valley, Western Ghats, India

Objectives

1. To assess the occupancy status of the blackbuck in Moyar Valley
2. To determine the factors that influence blackbuck occurrence with a special focus on *Prosopis juliflora*

Materials and Methodology

Objective 1: To assess the occupancy status of the blackbuck in Moyar Valley

The study area comprises of approximately 200 sq km, which has been delineated after eliminating steep slopes (above 10 degrees) within the study area using QGIS (v2.18, citation). The area has been overlaid with 105 grids, with 3 sq km as the area for each cell, which was determined based on the seasonal home-range of blackbucks. Since no information regarding this exact home-range was documented, a safe estimate of 3 sq. km was assumed.

A length of 2 km was walked in each grid cell, with 20 spatial replicates of 100 m each as the segment length. However, this was subjected to change according to the potential habitat for blackbuck covering each grid cell. This was the finest resolution of walking effort that could be realized in this landscape due to the nature of the terrain. The path chosen is in a zig zag pattern along the diagonal to cover maximum area in a grid cell, which was walked with the help of a Global Positioning System (GPS) device.

The observations were based on direct sightings, where the detection history has been recorded in binary digits as present or absent data for each segment. Inaccessible areas such as thickets of impenetrable *Lantana camara* or *Prosopis juliflora* or steep rocky surfaces were recorded as '-', as the preliminary survey had ruled out these areas as potential blackbuck habitat. The group sizes and groups per segment were noted to generate baseline data. Waypoints were also marked for the dung piles (latitude and longitude per segment) on the GPS and then transferred to QGIS version 2.18 for mapping the naïve occupancy.

Objective 2: To determine the factors that influence blackbuck occurrence with a special focus on Prosopis juliflora

The covariates hypothesized to influence blackbuck occupancy were invasive species, such as *Prosopis juliflora* and *Opuntia spp*; the dominant native vegetation, cattle dung, track, land cover and crop type (if applicable). A preliminary field survey was conducted to verify the selection of the covariates. Other potential factors that affected blackbuck habitat occupancy, which were noted from literature, include topographical features of the landscape such as slope and distance from the river. However, these were not included in this study due to time constraints. The probability of detection and occurrence were estimated and PRESENCE version 11.5 was used for detection and occupancy modelling.

Deduction of Covariates

Based on the data collected in the Moyar valley, the detection history for blackbuck sightings (direct and non-direct) and each covariate was recorded in binary digits for detection and non-detection. These were aggregated per grid, to estimate the proportion for each grid cell while estimating occupancy.

Vegetation

The dominant vegetation per grid cell noted included several species such as *Acacia catechu, Acacia planifrons, Albizia amara, Catunaregam spinosa, Fluggea leucopyrus, Cordia monoica, Mundulea serecea, Solanum, Chloroxylon swietenia, Atalantia monopyhla, swietenia, Canthium parviflorum, Syzygium cumini, Grewia sp*. Some grids were also found dominated by thickets of *Prosopis juliflora, Lantana Camara* and *Opuntia sp*- which are invasives that have spread like wildfire since decades in the landscape.

Out of these, the vegetation covariates for occupancy and detection modelling were deduced by short-listing the most commonly occurring species. These included *Acacia spp, Albizia amara, Catunaregam spinosa, Fluggea leucopyrus and Solanum spp*. To avoid redundancy while estimating occupancy, the data was analysed through box-plots as it best explained the distribution.

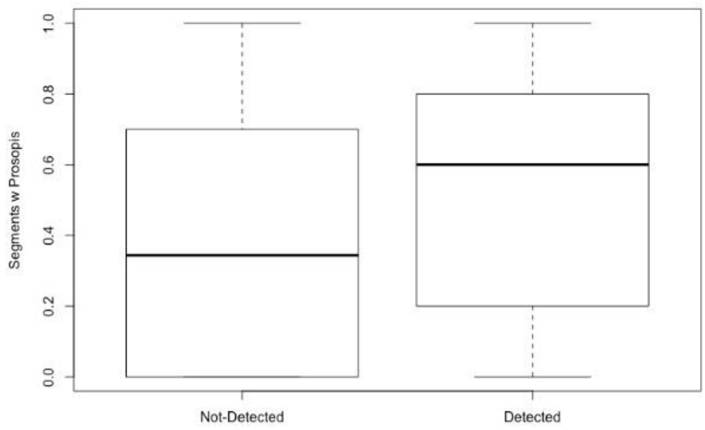

Figure 5 Blackbuck detection in relation to Prosopis juliflora

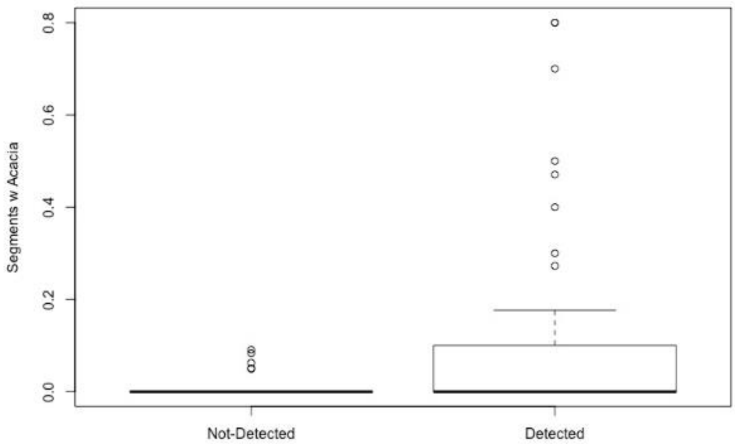

Figure 6 Blackbuck detection in relation to Acacia spp

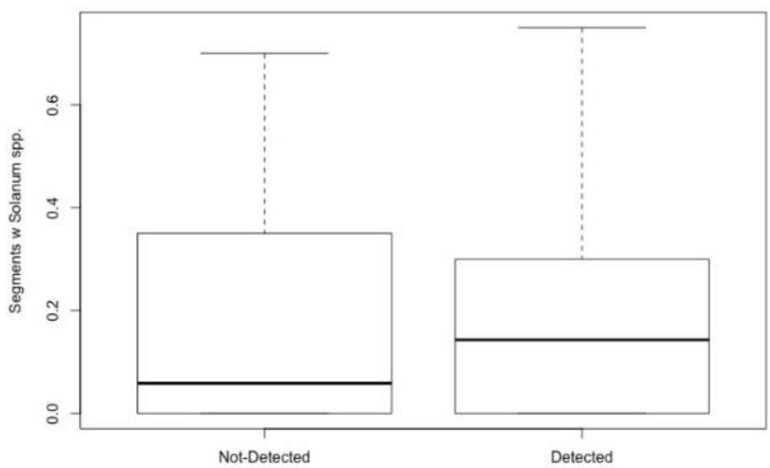

Figure 7 Blackbuck detection in relation to Solanum spp

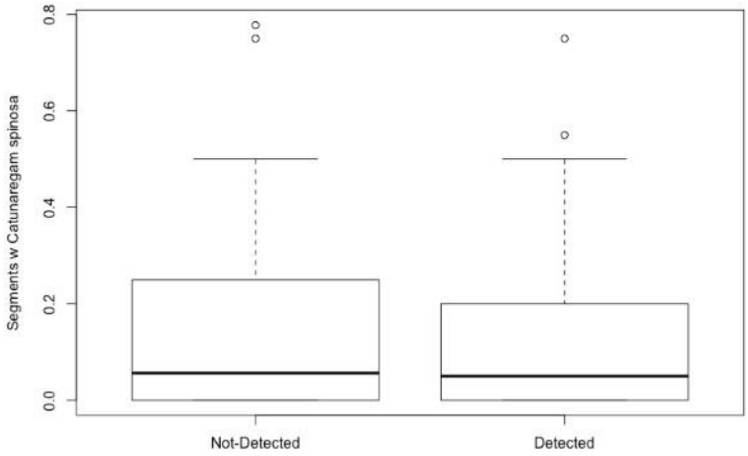

Figure 8 Blackbuck detection in relation to Catunaregam spinosa

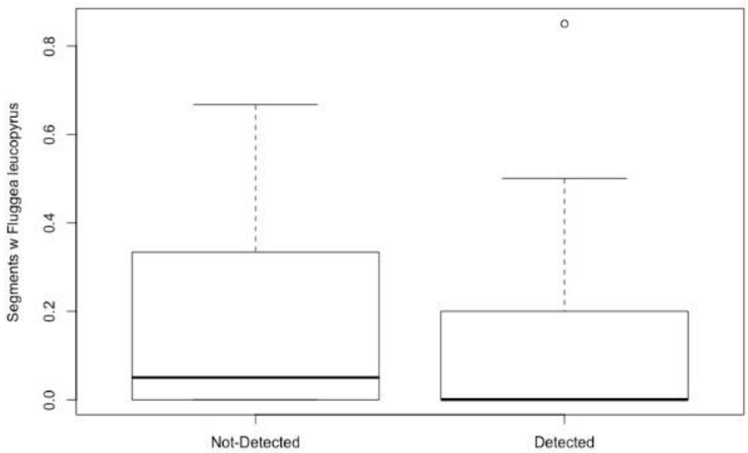

Figure 9 Blackbuck detection in relation to Fluggea leucopyrus

The box plots are a statistical representation of data in which the second and third quartiles can be easily depicted by the rectangle. The line inside the box indicates the median value, whereas the lower and upper quartiles are distinguished by the lines on either side of this median value. The spread is shown by the spacing of the parts, which measure the degree of dispersion in the data. The outliers have been denoted by the circles outside the box-plot.

As shown in the box plots above, detection and non-detection data was segregated for each covariate to see its relation to occupancy. *Acacia spp*. and *Prosopis juliflora* show maximum coverage for detection per grid cell. Occupancy was higher for grids with *Prosopis* and *Acacia* than the other three covariates, which actually showed lower values for detection.

As shown in Figure 5, detection was higher where *Prosopis juliflora* covered 0.2-0.8 (20-80%) of the grid, whereas *Acacia* in Figure 6, showed 0.1 (10%) coverage for detection with outliers ranging up to 0.8 (80%). The spread of *Acacia* shows that at least 0.8 (80%) of the grid cell with blackbuck detection was covered by the species. This shows a positive effect of *Acacia* on occupancy of blackbuck in the habitat.

Hence the two covariates that were used for occupancy modelling were *Prosopis juliflora* and *Acacia spp*.

Land cover

The landscape was mostly dominated by scrub forests, followed by dry deciduous forests along the Moyar River. The catchment area of the Bhavanisagar reservoir was used for agriculture by the villagers within the reserve. Banana, coconut, brinjal, capsicum, chillies were some of the commonly noted plantations in the study area during the field survey months of February-March. Fallow land was recorded as they were presently not in use and had to be considered for potential blackbuck habitat. Some plots were also left barren due to either topographical features such as rocky terrain or the removal of invasive species like *Prosopis juliflora* by the Forest Department.

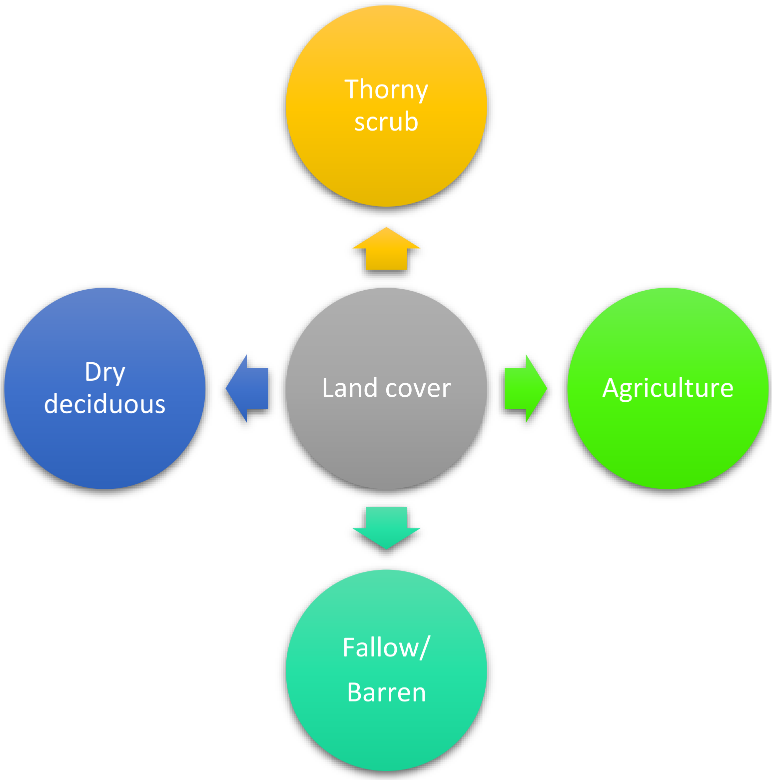

Figure 10 Flowchart representing land cover categories found in the Moyar Valley

Figure 11 Thorny scrub vegetation dominating the landscape

Figure 12 Riparian habitat in the Moyar Valley

Figure 13 Banana plantation in the catchment area

Figure 14 Fallow or uncultivated land in the Moyar Valley

As shown in Figure 15, data collected through cattle dung/track was insufficient to derive any conclusive evidence for human influence on blackbuck occupancy because the areas with cattle were limited to the reservoir catchment area.

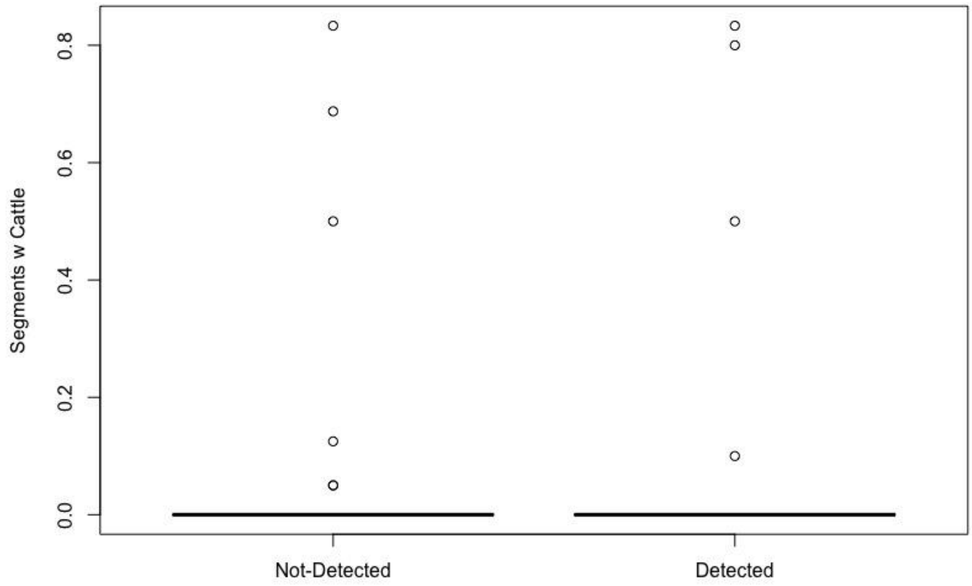

Figure 15 Blackbuck detection in relation to cattle sign

Since the land cover was aggregated per grid to display proportion of area covered by a particular land cover category, the values ranged from 0 to 1 (1 being entirely covered by the category and 0 as completely absent from the grid). Hence, to avoid data redundancy, only thorny scrub was chosen to represent land cover for modelling detection and occupancy.

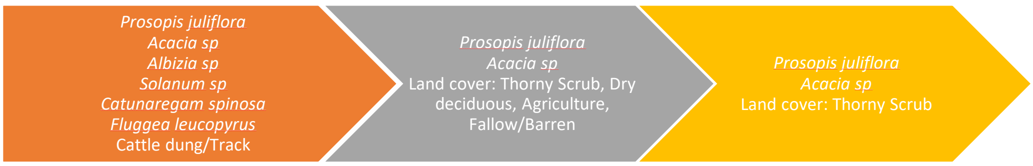

Figure 16. Stages of deducing covariates

Input data and Model selection

The first step was to pick the best-fitting model for the data collected to give the estimate for occupancy of blackbuck in my study area. For this, a null model was initially run using Simple single season model and then the same parameters for Correlated detection model.

Table 1 Selection of correlated detection over simple single season occupancy model

Occupancy model	Input	AIC	DeltaAIC	AICwqt	Model likelihood	No.of Parameters	2loglikelihood
Simple single-season	Null	797.37	62.48	0	0	2	793.37
Correlated detection	Null	734.89	0	1	1	5	724.89

As shown in Table 1, the correlated detection occupancy model performed better than the Simple single-season model (AIC value = 734.89 > 797.37). The correlated detection model is based on autocorrelation and takes space into consideration. Hence, only this model was chosen to include covariates for occupancy modeling in the future.

Input Data summary for 15 replicates

Number of sites	= 75
Number of sampling occasions	= 15
Number of states	= 0
Number of missing observations	= 179
Data checksum	= 55824

Input Data summary for 20 replicates

Number of sites	= 75
Number of sampling occasions	= 20
Number of states	= 0
Number of missing observations	= 431
Data checksum	= 61538

Input Data summary for 21 replicates

Number of sites	= 75
Number of sampling occasions	= 21
Number of states	= 0
Number of missing observations	= 505
Data checksum	= 7683

Figure 17 Input data trimming to reduce errors

For the data input in PRESENCE software, data trimming was conducted to reduce the number of missing observations. The number of spatial replicates were reduced from 21 to 15 and the missing observations dropped drastically (from 505 to 179). This was done for the detection history and for each covariate so as to control the abnormal error estimates while running the occupancy model.

RESULT AND DISCUSSION

Occupancy status of the blackbuck in Moyar Valley

Naïve occupancy refers to the proportion of sites where the species was detected at least once. Out of the 105 grids overlaid on my study area, 75 grids were surveyed as the rest of the sites were inaccessible. The naïve occupancy estimate was 0.5467 as 41 grids, out of the 75 showed blackbuck signs. Direct sightings of blackbuck were recorded only in 10 grids, while the dung piles served as indirect signs of blackbuck presence.

Naïve occupancy = 41/75= 0.5467

As shown in the naïve occupancy map, a little less than half the grids surveyed recorded blackbuck sightings which shows a significant habitat preference in the valley. From my field observations, I noticed that blackbuck prefer areas with open habitat, sufficient water availability and share their habitat with cattle.

The average sampling effort of 2 km (each 100m in length) was invested along the diagonal of each grid cell. According to the potential habitat area for blackbuck, the spatial replicates chosen, ranged from 4-21. The data was collected for every 100 m segment but then aggregated to 2 km (and later 1500 m) spatial replicates as shown in figure 11.

The eastern slopes of the Sigur plateau were avoided as there was no detection of blackbuck presence in the *a priori* analysis on such steep slopes. The grids comprising of the Moyar gorge were also excluded for the same reason.

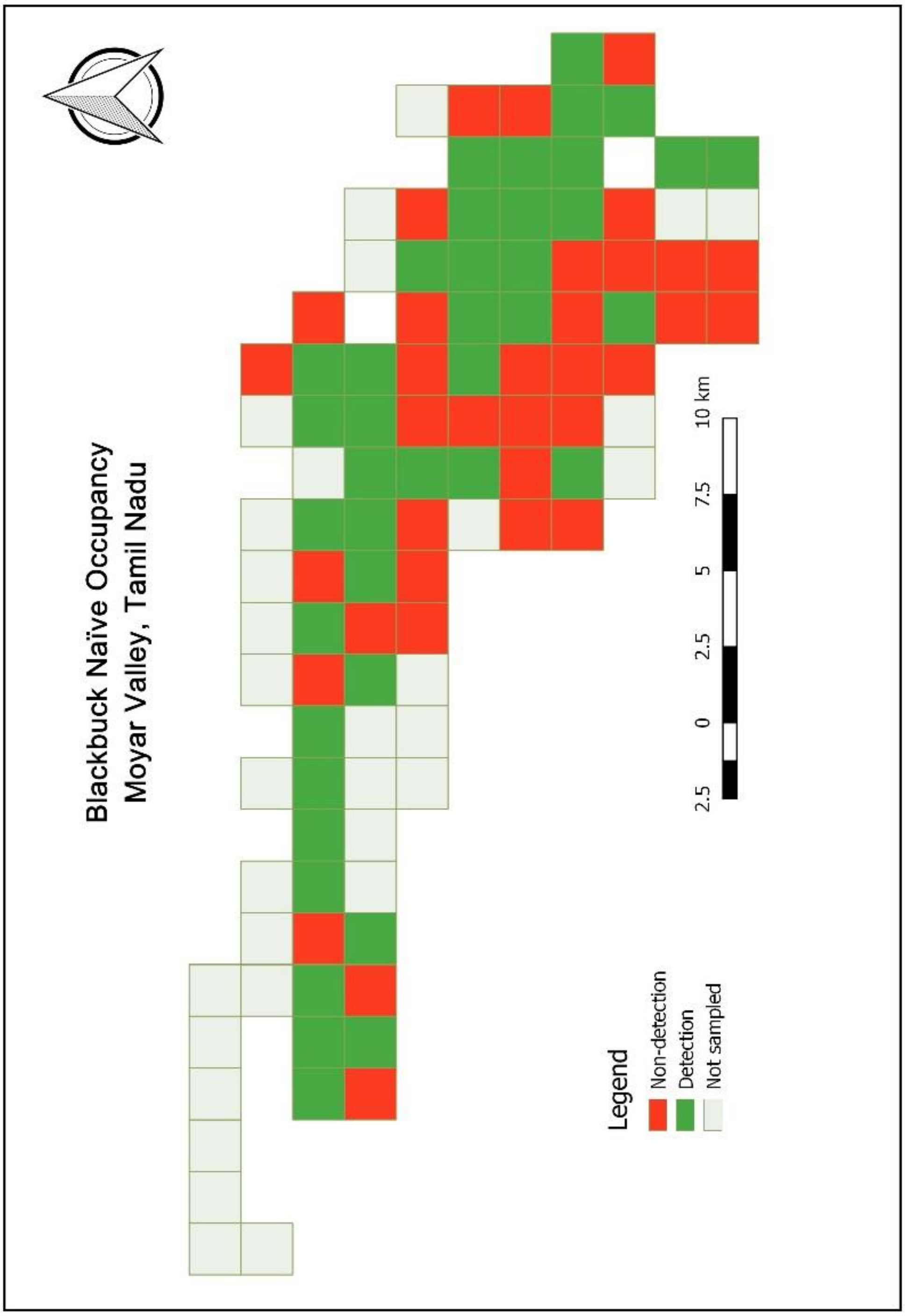

Figure 18 Map showing naive occupancy of blackbuck in Moyar Valley

Determining the factors that influence blackbuck occurrence with a special focus on *Prosopis juliflora*

This study seeks to identify the potential factors that influence blackbuck occupancy, with the following covariates: *Acacia sp*, *Prosopis juliflora* and Thorny scrub.

Table 2 Comparison of correlated detection models with different covariates

Model	AIC	deltaAIC	AIC wgt	Model Likelihood	No. of Parameters	-2*LogLike
Acacia	660.64	0	0.5553	1	6	648.64
Prosopis and Acacia	662.09	1.45	0.2689	0.4843	7	648.09
Acacia, Prosopis and Thorny scrub	664.09	3.45	0.0989	0.1782	8	648.09
Null	666.02	5.38	0.0377	0.0679	5	656.02
Prosopis	667.03	6.39	0.0227	0.041	6	655.03
Thornyscrub	667.68	7.04	0.0164	0.0296	6	655.68

Result browser analysis

Model - This is the model name which explains the covariates used for detection and occupancy. These were defined in the 'design matrix' after selecting the custom model, instead of the pre-defined models.

Akaike's Information Criteria (AIC)-This is the statistic derived to choose the simplest and best fitting model. The models with a low AIC score were considered.

deltaAIC- This is the difference between the rest of the models and the best-fit models, in this case, the null model.

AIC weight- It is the probability of the measure of uncertainty which provides weight for decision-making. Models with the high Akaike weights were chosen as top models.

Model likelihood-It represents the likelihood that a model is the best model, given the rest of the models

-2*LogLikelihood- It is a relative measure of how well the model fits the data, using the least parameters

From Table 2, we can see that the model with occupancy as a function of Acacia ranks the highest amongst the rest of the models. Untransformed parameter estimates (betas) and associated standard errors were checked to understand the effect of covariates on blackbuck occupancy. The null model was run first to set as a baseline for comparison after inclusion of the covariates.

Acacia sp

The best model to define occupancy of blackbuck in the Moyar valley was noted in which occupancy was a function of Acacia sp. Acacia sp included *Acacia catechu* and *Acacia planifrons*, which were found during the survey. Acacia has a highly positive effect on occupancy as shown by the untransformed beta parameter estimate:

$$\beta \text{ (Acacia)} = 8.9244 \pm \text{SE } 5.8040$$

The positive effect of acacia on blackbuck occupancy was expected as blackbuck are known to browse these species (Schaller 1967; Ranjitsinh 1989; Jhala 1997 and Das et al., 2013). It is known to provide browse and mast when grass quality is low in the summers, due to its deep tap-root system (Jhala 1997).

However, the true effect is not accounted for in this occupancy model as the detection was not calculated at this stage of the analysis. Acacia is likely to affect detection probability (p) negatively as it hinders detection at the replicate-level. This effect could have been overlooked by psi as it would tend to underestimate the effect of acacia on blackbuck occupancy.

Prosopis juliflora

The highly invasive tree, *Prosopis juliflora*, was an interesting covariate to be modelled for blackbuck occupancy. From my field observations, *Prosopis juliflora* seeds were indeed consumed by blackbuck and the species were possibly responsible for their dispersion as there were seeds present in their dung piles. This was in line with the study conducted in Velavadar National Park, Gujarat (Isvaran, 2005). The untransformed beta parameter estimate showed that *Prosopis juliflora* has a weak positive effect on occupancy. This was given by:

$$\beta \text{ (Prosopis)} = 0.8884 \pm \text{SE } 0.8980$$

Thereby, confirming my initial hypothesis of the invasive species having an influence on blackbuck occurrence. However, there was no instance of blackbuck displaying lekking behavior, which is also known to influence seed dispersal of *Prosopis juliflora* (Jadeja et al., 2013). A possible explanation for this could be that the lack of open habitat hindered the bucks to form leks during the mating season. *Prosopis* was initially seen as beneficial and over time, its negative consequence became more apparent (Shackleton et al., 2014). For the blackbuck population in Moyar Valley, it has most likely served as respite from the sun and a source of fodder which has possibly outweighed its negative role of reducing their habitat.

Thorny scrub

The land cover used was thorny scrub which dominated the landscape. Blackbuck prefer grasslands which provide visibility to outrun predators. They do not rely on their sense of smell or hearing, but their sight, which is highly developed (Schaller, 1967; Ranjitsinh, 1989 and Mahato et al., 2010). Thorny scrub has a no effect on occupancy as shown by the untransformed beta parameter estimate:

$$\beta\text{(Thorny scrub)} = 0.4439 \pm 0.7502$$

Being the dominant ungulate species in semi-arid regions of India (Ranjitsinh, 1989), blackbuck occupancy was expected to be affected by the land cover in terms of water availability, open habitat and availability of nutrition. From the three covariates included for occupancy, *Prosopis juliflora* showed a weakly positive effect (or even no effect), but Acacia showed a highly positive figure (mean 8.92 ± SE 5.80). Thorny scrub as a land cover category had almost no effect as the standard error was relatively high, compared to the actual estimate. No covariates were used for detection modelling as the model chosen accounts for spatial correlation.

CONCLUSION

The study aimed to assess the status of blackbuck occupancy in the Moyar Valley. Furthermore, it aimed to assess the potential factors that influence blackbuck occupancy, with a special focus on *Prosopis juliflora*- being a highly invasive species which strongly influences blackbuck occupancy. The three covariates that were modeled for habitat occupancy, namely- Acacia spp, Prosopis juliflora and Thorny scrub land cover were found to be positively affecting blackbuck occurrence to having no effect. The average site occupancy estimate was calculated at 0.63 ± SE 0.13 which was higher than the naïve occupancy estimate (0.54) as it took covariate effect into consideration.

Currently, the study indicates that the benefits of *Prosopis juliflora* still exceed the cost for the blackbuck population in the Moyar Valley. However, this is subject to change in the future, especially in combination with climate change and hence the influence of Prosopis on blackbuck in the Moyar valley, must be regularly monitored.

Limitations

The present study did not include covariates for detection which could negate the true effects of the covariates which were modeled for site occupancy. Furthermore, the actual home range of blackbuck is not known which could have resulted in a more effective sampling strategy for estimating the grid-size.

Future scope

Baseline data was not available as very few studies have been conducted on blackbuck in the valley. More research needs to be carried out on the population count and abundance of blackbuck in this landscape. Remotely sensed proxies for land cover such as the Normalized Difference Vegetation Index (NDVI) could also be included to observe the anthropogenic effect on blackbuck occupancy, as the ungulate species are known to live in close proximity to human settlements. More covariates, such as distance from the Moyar River and slope gradient, could be included to determine the factors that influence blackbuck occupancy in the area.

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Annexures

Figure 19 A male with two female blackbuck grazing

Figure 20 Fresh blackbuck dung pile

Figure 21 Uprooted Prosopis juliflora showing signs of regeneration

Figure 22 Prosopis juliflora sprouting from blackbuck dung pile

Figure 23 Prosopis juliflora seeds found in elephant dung

Figure 24 Image showing blackbuck habitat dominated by Prosopis juliflora

Figure 25 Carrying out field survey

Figure 26 Tengumarhada- the largest settlement within the reserve

Figure 27 Local villagers fetching water from the reservoir

Figure 28 A male blackbuck amidst a Prosopis dominated landscape

Figure 29 Fresh blackbuck dung pile in an open habitat

Figure 30 Scarce Prosopis with indirect blackbuck sighting

Figure 31 Invasive Opuntia spp.

Figure 32 Banana plantation in the Moyar Valley

Figure 33 Cattle grazing in the reservoir area