

**SPATIO-TEMPORAL ABUNDANCES AND RESOURCE
SELECTION OF INDIAN WILD ASS (*Equus hemionus khur*)
AND NILGAI (*Boselaphus tragocamelus*) WITH SPECIAL
REFERENCE TO CROP-DEPREDATION AND PEOPLES'
ATTITUDE IN LITTLE RANN OF KACHCHH, GUJARAT**

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Submitted to the



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For the award of the Degree of
**DOCTOR OF PHYLOSOPHY
IN
WILDLIFE SCIENCE**

By
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Under the guidance of
**DR. SUSHANT CHOWDHURY
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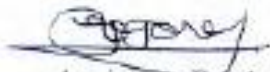
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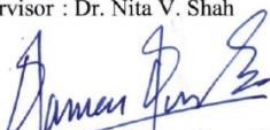
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SUMMARY

The harsh climatic condition and unpredictable resource availability like water is the nature of arid and semi-arid ecosystems which is epitomised by the Little Rann of Kachchh (LRK) landscape. Indian wild ass (*Equushemionuskhur*), a sub-species of Asiatic wild ass, idiosyncratically represent the LRK landscape which has been holding its last remaining population after it had become extinct from its previous home ranges. In comparison to its other counter parts, Indian wild ass or Khur is the least studied equid and till late 80's we only had information on number of surviving individuals. Shah (1993) had started the first meaningful assessment on Khur population, its habitat requirements and behaviour providing the much lacking baseline information on Khur ecology which later lead to some important management interventions towards conserving the species and its habitat.

Due to the resource limitations associated to the landscape coupled with changing land use practices to support the growing human population, it was imperative to monitor the population density of Khur and its decisions towards selecting available habitats which was assumed to vary seasonally. In my study, I emphasised on estimating population density of Khur and Nilgai, which is the other sympatric ungulate in the landscape using widely accepted and robust scientific method. Also, intensive monitoring was very challenging due to logistic limitations and large study area.

I had designed my study focusing on the southern fringe of the sanctuary as the intensive study area (ISA) and conducted temporal replicates to see the density of Khur in both summer and winter. In 2015-16, the entire sanctuary was sampled to compare the density estimates between the selected sampling site and the entire sanctuary and finally compare these estimates with the overall population of Khur reported in the forest department census. The population density of Khur was observed to be similar in both southern fringe (ISA) and the entire landscape including all the fringe habitat. The density of Khur was observed to have total population estimate close to that of total count from 2014 census conducted by forest department. This will largely help the sanctuary management to adopt the sampling design instead of total count which is logistically expensive and unreliable. This will ensure effective monitoring of Khur with limited work force of the sanctuary.

The monitoring of resource availability is equally important and available information were from the late 19th century. In my study, I have filled that gap by identifying and mapping present habitat categories available for Khur and Nilgai population. The pattern of resource

selection of available mapped resources by both Khur and Nilgai is another important addition from my study in filling the knowledge gap. This will certainly help the management to identify its priorities in managing crucial habitats.

In this study, I have developed habitat suitability map of Khur and Nilgai. Apart from the resource rich areas, it is imperative to see how the habitat model suggesting potential sites based on selected environmental variables which actually shaping their distribution in the landscape. This study identified northern part of the sanctuary connected by a bottle neck with the Greater Rann of Kachchh as a potential site which demands management intervention at large scale involving other line departments ensuring a safe corridor between LRK and GRK for Khur and Nilgai. This will ensure the long term conservation of the species.

Finally, I have studied the perception and attitude of local farmers in the southern fringe towards crop-depredation. Although, with growing rural population and increase in intensive farming, the overall attitude of farmers were observed to be mixed with both positive and negative attitude reflected in their perspective towards crop-depredation by Khur. Although, I did not quantify the damage caused by individual species, I have observed certain exaggeration towards crop-depredation by Khur. Moreover, I have found that the traditional conservationist outlook of Indian society is prevalent among the rural respondents as well in spite of observed crop-depredation by Indian wild ass, Nilgai and Wild pig and it should be capitalized by involving them in policy making by the management and formulate the mitigation measures to reduce conflict. Since, peoples' attitude towards conservation largely affected by the socio-economic well being of their households, future studies on estimating actual crop-damage from both crop-depredation and weather issues.

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Chapter 1 Introduction and Study area

Introduction

The most meaningful insight for a conservationist is to identify the key attributes of a landscape defining its heterogeneity which influence its dynamic nature and characterise species associated with that landscape (Sanderson *et al* 2002). It is important to identify the species of interest and the natural habitat the species represents. The long term conservation of a landscape of unique ecological importance can not be achieved without conserving the associated species responsible for regulating the ecological processes of the habitat and vice-versa. An understanding of abundance and distribution of ‘species of interest’ and the natural system it occupies is thus critically important for the ecologists and wildlife managers (Cappuccino, 1995) for effective conservation planning.

Arid and semi-arid ecosystems are unique entities which are fragile in the sense of unpredictable and extreme climatic conditions where resources like water, soil nutrient and plant biomass vary from high to low abundance and exhibit short periods of high resource abundance usually triggered by rainfall events (Schwinning and Sala, 2004). Large ungulate species are responsible for change in ground cover composition in arid and semi-arid ecosystem by influencing ecological succession through over grazing (Walker, 1981). They play a crucial role in shaping the habitat and the ecosystem at large by affecting the primary productivity as the annual rainfall fluctuates greatly in such habitats (Reading *et al.*, 2012). It is evident that over grazing in such habitat by large ungulate and livestock change the species composition as well.

The Indian wild ass population in Little Rann of Kachchh is known to change the species composition by ensuring expansion of *Prosopis* in the entire landscape through feeding on *Prosopis* pods and excreting undigested seeds in their dung that germinate into new *Prosopis* bush (Vaseed *et al.*, 2015). The mesowear signature in all the equids suggests that they forage upon fibrous and roughage foods which are the dominant palatable species in arid environments (Scultz and Kaiser, 2012). Mesowear is a widely applied tooth wear technique that could be used to determine the herbivore diet by scoring the height and sharpness of molar tooth cups with naked eye (Ackermans, 2020). *Equus africanus* and *E. Indian wild ass* inhabit the most arid environments of the world and have the most attrition-dominated mesowear signature (Scultz and Kaiser, 2012) besides the ability of thriving by depending on low quality pasture, Asiatic wild ass have been observed to select forage patches based on the

availability of food species rather than productivity (Kacsensky et al., 2008). The ability of sustaining on coarse and woody plants, like other Asiatic wild asses, has enabled Indian wild ass to flourish in Little Rann of Kachchh landscape by rising from 2980 individuals in 1998 to 6082 individuals in 2020 (Singh, 2000 and Forest department census report, 2020).

Nilgai (*Boselaphustragocamalus*) is the largest antelope of Asia and endemic to the Peninsular India and Indus division of the Indian sub-region where it is distributed along the foothills of the Himalayas in Nepal, North-eastern Pakistan and almost all of Northern and Central India except eastern Bengal, Assam and other North-eastern states and the Malabar coast (Chauhan and Singh, 1990; Leslie, 2008). In India, Nilgai have become locally overabundant in many places following conservation measures extended under Wildlife Protection Act (1972) and are considered as a serious pest of agricultural crops (Chopra and Rai, 2009).

It has been a challenging task for the management to monitor the population of Indian wild ass and Nilgai in such a vast open landscape with limited resource in terms of man-power and other logistics (Shah, 1993). A census is conducted at every 5 years intervals for counting the Indian wild ass population using direct count method by engaging both forest and non-forest staff in more than 5000 square kilometre area. In 2014, the Indian wild ass Sanctuary management has counted Indian wild ass within 15000 square kilometre area which was a mammoth task in itself (Forest department census report, 2014). However, such huge efforts are not enough to meet the accuracy in counting, since it is well assumed that detecting each and every individual in the population is not possible to achieve. Therefore, it is advisable to estimate the population using robust scientific methods instead of guessing the total population by overlooking possible human errors. Distance sampling is the most widely used technique to estimate abundance of biological populations (Buckland, 2005) not only for large mammals, it is used for a diverse range of population like whales, dolphins, seals, apes, deer, antelope, rabbit, seabirds, songbirds, fish, butterflies, trees, etc. (Buckland, 2005). In cases where distance sampling is not possible, capture-mark-recapture method has been applied which is a more labour intensive and often demands higher resources and is more sensitive to failure in fulfilling the assumptions in estimating abundance (Buckland, 2005). Harden et al., in 2009 surveyed diamondback terrapin at Kiawah Island of South Carolina following the head-count method and they described that distance sampling was not possible due to their elusive nature and other methods like mark-recapture were intensive in respect of time and resources and for rapid assessment of their population, they tried head-count method.

However, they argued that detection of terrapin varies seasonally and head-count method does not give actual estimate of their abundance but could be done as a less intensive and rapid monitoring technique. The population density of a species tends to differ in different places and the relation between the differences in the population densities and the differences in climate or other environmental conditions is fairly evident (Nicholson, 1933). The population density of any species is independent of its available resource and the population can grow to a certain limit only and not beyond (Chapman, 1915) irrespective of resource availability suggesting an equilibrium (Nicholson, 1933). It is therefore equally important to accurately monitor population density with minimal error and to determine their resource selection pattern. However, the species and its natural environment is not a closed entity and it is open to all other factors imposed by the human presence (Ewers and Didham, 2006). To achieve conservation goals for any species residing in a human-dominated landscape, it is also essential to know the perception and attitude of people towards conservation of the animal population and their natural habitat.

Global distribution of genus “Equus” and their natural history

There are several evolutionary hypotheses regarding the genus '*Equus*' suggested by many phylogenetic and molecular studies and the hypothesis vary over time. Following the studies in 1980's which is believed to be most recent study based on morphological phylogeny, it had been suggested that the present day *Equus* have evolved in Pleistocene period as the members of *Dinohippus*, such as *D. Maxicanus* (Bennett 1980; Hulbert 1989; Prado and Alberdi 1996; Kelly 1998). Most recent fossil records suggest that a form of *Dinohippus* migrated from North America to Eurasia during the Holocene period and gave rise to the present day Asiatic wild asses (Bennette, 1980). The North American fossil record is believed to be the most well documented which shows strong zoogeographic ties between North America and Africa and suggests that various members of the genus *Equus*, which are now endemic to Africa migrated from North America through Eurasia (Eisenmann, 1992). The modern day equids are now represented by eight extant species in the genus *Equus*, they are domestic horse (*E. caballus*), Przewalski's horse (*E. przewalskii*), Kiang (*E. kiang*), Asiatic wild ass (*E. hemionus*), African wild ass (*E. africanus*), mountain sebra (*E. sebra*), plains sebra (*E. quagga*) and Grevy's sebra (*E. grevyi*) (Moehlman, 2002 and Rosenbom et al., 2015). Moreover, the morphological characteristics from all the ancestral members of the genus *Equus* suggested a unique mode of life of present day equids, which represent adaptation for living in open arid and semi-arid habitats characterised by low quality and high fiber food

species such as grass and other coarse vegetation (Rosenbom et al., 2015). Asiatic wild asses formerly ranged from the Arabian peninsula to eastern Tibet and the surviving Indian wild asses are categorised into two distinct sub-genera, namely *E. hemionus* and *E. kiang* based on morphology, coat colour, geographical locations and chromosomal number (Bennette, 1980; Groves and Willoughby, 1981; Ryder and Chemnick, 1990; Rosenbom et al., 2015 and Barron-Ortiz et al., 2019).

Two distinct Asiatic wild ass species, *Equushemionus* and *E. kiang* were further subdivided into five and three different subspecies respectively based on their geographical distribution. The five sub-species of *E. hemionus* are *E. hemionushemionus* (Mongolian dziggetai), *E. hemionuskulan* (Trans-caspian wild asses), *E. hemionusonager* (Persian wild asses), *E. hemionus* (Indian wild ass) and *E. hemionushemippus* (Syrian wild ass, which has become extinct) (Ryder and Chemnick, 1990).

Status, taxonomy and distribution of Indian wild ass

The conservation status of Indian wild ass (*Equus hemionus khur*) is ‘Near Threatened’ according to the IUCN Red Data List, 2015 and Schedule-I species according to the Wildlife Protection Act, 1972 (Government of India, 1972).

The classification of Indian wild ass (*Equus hemionus khur*) according to Pallas, (1777), Lesson (1827) and Stehlin and Graziosi (1935) is as follow:

<u>Order:</u>	Perissodactyla
<u>Family:</u>	Equidae
<u>Genus:</u>	Equus
<u>Species:</u>	<i>E. hemionus</i>
<u>Sub-species:</u>	<i>E. h. Indian wild ass</i>

There are four sub-species of *Equushemionus* reported to be distributed in Asia (Gee, 1962). The Little Rann of Kachchh, Gujarat (India) is known for the only refuge for the Indian wild ass (*Equushemionus*). Like other members of equid groups, the Indian wild ass inhabit open, grass or shrub dominated habitats and are predominantly grassers (Shah, 1993; Moehlman, 2002). They are highly efficient hind-gut fermenters, adapted to compensate for low quality food by consuming large quantities (Janis, 1976; David et al., 1999; Kacsensky et al., 2008; Schulz & Kaiser, 2012).

Indian wild ass used to have a wider distribution to the far west of Afghanistan and Iran and in Thar Desert of India (Prater, 1980). They have become confined to the Greater and Little Rann of Kachchh in India (Shah, 1993; Prasad et al., 1994). The geographical range of all species of the genus *Equus* have significantly decreased in the past 200 years starting from the early 19th century owing to the loss of their choice of specific habitat types, competitive exclusion and anthropogenic factors (Schulz and Kaiser, 2012). After losing other global habitats, Indian wild ass population became restricted in Little Rann of Kachchh landscape and a very small population has been leaving in Greater Rann of Kachchh as the natural corridor between both the landscapes was cut by infrastructural development like highway, railway track and canal. In 1960, a drastic decline of Indian wild ass population was reported due to deaths from zoonotic disease called 'Surra'. After that a second major setback occurred following several droughts (Shah, 1993 and Singh, 2000), the population has since revived and has been showing steady growth. In a semi-arid ecosystem, population of large herbivore fluctuates due to the unpredictable weather change and change in forage quality and quantity (Caughley, 1993). A few years back, a small group was reported from Rajasthan (Census data, 2014) however, no information is available on the movement pattern of Indian wild ass from Gujarat to Rajasthan.

Status, taxonomy and distribution of Nilgai

The conservation status of Nilgai (*Boselaphus tragocamelus*) is 'Lower Risk' according to the IUCN Red Data List, 2015 and Schedule-III species according to the Wildlife Protection Act, 1972 (Government of India, 1972).

The classification of Nilgai according to Pallas, (1766) is as follow:

<u>Order:</u>	Artiodactyla
<u>Family:</u>	Bovidae
<u>Tribe:</u>	Boselaphini
<u>Genus:</u>	<i>Boselaphus</i>
<u>Species:</u>	<i>B. tragocamelus</i>

Nilgai is the largest antelope in Asia (Sankar et al., 2004). Sexual dimorphism is distinct where adult Nilgai are steel grey or brown-grey in colour with black legs (Sheffield et al., 1983). Only male Nilgai have a pair of horns. Adult females are light brown in colour (Sankar et al., 2004).

Nilgai is endemic to peninsular India and presently distributed starting from the Himalayan foothills towards south through the central India to the southern districts of Andhra Pradesh

(Chopra and Rai, 2004). They are absent in north-eastern India and in the southern most parts of the peninsula. Nilgai occur in a variety of habitats from flat land to undulating hills, savannah grassland and scrubland to cultivated plains but they avoid steep hills and dense forest (Prater, 1971). Nilgai population is thriving in India due to its adaptive nature and the ability to live in highly fragmented landscapes close to human habitation (Chauhan and Singh, 1990).

Origin of the work

After declaring Indian wild ass Sanctuary in 1972, the first ecological study of Indian wild ass and its habitat was initiated by the Wildlife Institute of India, Dehradun, in February, 1989. The objective of the study was to gather baseline ecological information on Indian wild ass and its habitat to prepare better management strategies for meaningful conservation practices (Shah, 1993). Following this, a large scale ecological study of Little Rann of Kachchh was carried out in 1998 by GEER Foundation, Gandhinagar. Apart from Indian wild ass and its habitat, all the major fauna and flora were studied during that period and came up with major recommendation towards a holistic conservation of the landscape and its species. In 2011, an ambitious project named Biodiversity Conservation and Rural Livelihood Improvement Project launched in LRK landscape funded by the World Bank and implemented by the Gujarat Forest Department was initiated. It was a long term project focusing on Indian wild ass and its habitat conservation by involving all the stakeholders and at the same time empowering the people of fringe villages to adopt alternative livelihood opportunities through various skill development training programs and financial help. This project had mobilised farmers, pastoralists, salt workers and fishermen from all the villages along the boundary of the sanctuary and highlighted the commitment of the management towards Indian wild ass, its habitat and people living with it through participatory conservation initiatives. Also, in 2012, the Wildlife Institute of India has initiated an important project to evaluate population estimation methods of Indian wild ass in the open LRK landscape to build up scientific efficiency of the management for future monitoring of the population. The present study is the part of this project.

Aim of the study

The LRK landscape is vast and highly dominated by human population and the associated anthropogenic activities. With limited manpower, it was difficult to monitor Indian wild ass population regularly by the sanctuary management. Therefore, a need for adopting a scientific

approach to monitor Indian wild ass population by estimating their population density using distance sampling method instead of total counting of the population was perceived. It was essential to produce a reliable method for abundance estimation of Indian wild ass which could be implemented by the management in future monitoring practices.

The protected area resources besides Indian wild ass, are also used by Nilgai, Wild Pigs and large number of livestock from surrounding villages that also forage in natural Indian wild ass habitats. Although, the natural resource selection pattern of Indian wild ass was established from studies in late nineties by Shah (1993), the understanding was lacking regarding crop-depredation patterns. After the improved irrigation facility in the landscape supported by Narmada Canal irrigation system, the pattern of both natural and crop resource selection by Indian wild ass and Nilgai needs better understanding to ensure better management strategies.

In the landscape, farmers, pastoralists and salt manufacturers are the major stakeholders. The attitude of resident people from the north-western part of the landscape was studied by Dave (2010) which gave us the understanding how perception and attitude of people is important to know to conserve Indian wild ass and its habitat. The other part of the landscape, especially the southern fringe villages are the most benefited from Narmada Canal and rapid agricultural developments were visible. In such scenario, where crop-raiding incidents are assumed to be increased with increased agricultural activities, it was important to know the perception and attitude of people towards crop-raiding by Indian wild ass and other sympatric herbivore.

Literature review

Monitoring abundance

One of the most important prerequisites for the conservation and management of wildlife are estimating their abundance, since it defines the need and scope of human action (Ransom et al., 2012). To address any ecological problem involving species interactions, it is imperative to have a robust estimation of its abundance which in turn largely assists in conducting a range of management tasks such as predicting prey population response to several environmental variables (habitat, terrain etc) and understanding the predator-prey relationship. Various methods for estimating ungulate numbers and monitoring their populations have evolved over time. These methods can be broadly classified into total count and sampling (Scwartz and Seber, 1999). Large herbivores are comparatively difficult to conserve in a human dominated landscape because of their unique tendency towards suitable habitat and crop raiding (Gee, 1964). The estimation of population density is important not

only from an economic point of view but also to conserve and manage their population and habitat (Crawley, 1983; Kortland, 1984; Panwar, 1987; Karanth et al., 1992; Motta, 1996).

The Indian wild ass population was estimated to be 4000 in 1946 which suffered a sharp decline with an estimated population of 800 individuals remaining during early 60's due to the outbreak of "Sura" and consecutive severe droughts (Ali, 1946; Gee, 1962; Shah, 1993; Shah and Qureshi, 2007). The ability to thrive in extremely human dominated landscape and protection measures taken up by declaring Indian wild ass Sanctuary in 1972 revived the population to 3000 individuals in 1998 and since then a steady growth in population has been documented (Shah, 1993 and Singh, 2000).

Nilgai, on the other hand has an overabundant population distributed across the protected and non-protected forested areas. This adaptive antelope has been thriving in all kind of habitats including arid and semi-arid landscapes (Chauhan and Singh, 1990).

Habitat mapping

Mapping the distribution of vegetation types and land use changes at the landscape level provides critical information for its biodiversity conservation planning and helps in management by maintaining the structural and functional ecosystems of that region (Helmer et al., 2002). Using field observations, aerial photos and multi-date, Landsat TM imagery they were able to develop a classification that mapped secondary forest, agricultural lands and old-growth forests for understanding succession in forested areas besides land use changes. In conservation initiatives at species level, a study design would not be effective without knowledge of the habitat area as it is of vital importance for species conservation and restoration activities. The probability of existence of a species is determined by the availability of suitable habitat (Sharma et al., 2004). Sharma et al. (2004), mapped Kiang (*Equushemionus kiang*) habitat based on their use preferences into primary, secondary and non-suitable habitat categories. He explained primary habitat as the habitat preferred by the Kiang population throughout the year for their basic habitat requirements such as food, shelter, water, etc., secondary habitat is the habitat used to support their specific needs such as breeding, bathing, etc. and non-suitable habitat as the type which serves no purpose for the Kiang. Habitat classification involves the grouping of habitat components into homogeneous habitat units on the basis of significant habitat characteristics of wildlife species. Giri et al., (2011), while working on mapping of global mangrove habitat stated that habitat is vital for survival of various ecological components and information about its distribution and status should be well documented. In Little Rann of Kachchh, apart from environmental and

ecological stochasticities, the highly human dominated landscape exhibit direct or indirect dependencies on the Indian wild ass habitat besides human added factors such as changing land use vary spatially and temporally could impact decision making on habitat selection by the species (Krishna et al., 2016). Therefore it is important to know the pattern of land-use and land-cover for long term sustainable conservation practice.

Natural resource selection and crop-depredation

Resource selection studies are implemented to gather information on habitat use and survival strategies of a species to understand how they meet their regular daily requirements (Manly et al., 2002). Manly et al. (2002), also asserted that studies on resource selection are done assuming the fact that species utilise resources based on their specific activities to support and instead of low quality resource they always prefer high quality resource. From conservation management point of view, efforts are required to understand the interactions between the species and their natural habitat (Marshall et al., 2010) and the most basic information to know is the distribution of animals and the characteristics of habitats where these animals are distributed (Morrison, 2001). Distribution of species in similar geographical range tends to have hierarchical resource use where species that are superior competitors may tend to concentrate their resource use in most favourable habitats (Macandza, et al., 2012). In arid and semi-arid environments, availability of water resource is highly seasonal and believed to be crucial factor that governs the distribution of species by further restricting their movement to access other available food resource (Western, 1975 and McKee et al., 2015). Radio-telemetry study of Indian wild ass (Shah, 1993) suggested that the solitary male, adult female of mixed group and bachelor herds tend to visit crop-fields during night and it was observed that the crop-raiding is mostly seasonal. Although, agricultural activities have increased many-fold since the previous study, mitigation measures taken by farmers have also evolved such as the use of solar fencing was observed in many farm lands (unpublished information from the present study). The perception of farmers towards different fencing types and species responsible for higher levels of crop-raiding is discussed in Chapter-IV of this thesis.

Attitude of people towards crop-depredation

It is evident that people have a certain tolerance level towards any crop-depredating animal and they won't accept those animal's presence if they damage crops above their tolerance level (Conover, 2010). Regular incidents of crop depredation by ungulates could make the farmers believe that ungulate population is increasing along the agricultural area and would

want immediate reduction of the ungulate species (Decker and Brown, 1982). People may perceive a negative attitude towards conservation to protect their livelihoods (Campbell-Smith et al., 2010). Studies have demonstrated clear linkage between local community concerns over their livelihood and their attitude towards conservation efforts (De Boer and Baquete, 1998; Ambarli and Bilgin, 2008). According to Hill (2004), peoples' perspective and expectations shape their attitude and responses towards crop raiding wildlife. While working with human-elephant conflict in Africa, he explored peoples' perceptions in the context of changing tolerance for wildlife activities on farms, implications of past conservation policies and how such issues influence peoples' expectations of who will protect crops from wildlife damage. Crop-depredation by wildlife is becoming a very contentious issue and due to the lack of effective mitigation efforts, such issues have contributed to feeling of alienation and lack of inclusion among the rural people staying adjacent to protected area (Newmark, Leonard, Sarike and Gamassa, 1993; Infield, 1998; Gillingham and Lee, 1999). Dependence on agricultural lands for income and livelihood (Naughton-Treves, 1999), land holding sizes and presence and absence of effective compensation schemes (Archbald and Naughton-Treves, 2001) are the major attributes towards tolerance among rural farmers. Perception of risk of crop damage among rural people may develop and be influenced by the visibility factor, i.e., size of the individual or the group, the degree to which the species is considered to be dangerous or not, whether the species is diurnal or nocturnal and the degree to which people thinks that they would have any control over that species (Mishra, 1997; Naughton-Treves, 2001).

Study Area

The Rann of Kachchh

The Little Rann of Kachchh (LRK), the present study area falls within latitude 23°10'-23°45' north and longitude 70°45'-71°45' east and is located in the state of Gujarat (Figure 1.1). It is just above the sea level adjoining the Gulf of Kachchh. The area of LRK is 4,953.70 Km² and is spread over five administrative districts i.e. Morbi, Surendranagar, Mehsana, Banaskantha and Kachchh of Gujarat.

Both Little and Greater Ranns, covering 30,000 km² are subjected to annual flooding during monsoon by Arabian Sea tidal water and seasonal rivers. Three major rivers flow from the east, namely the Banas, Saraswati and Rupen, for a period of three months (Prasad et al., 1994).

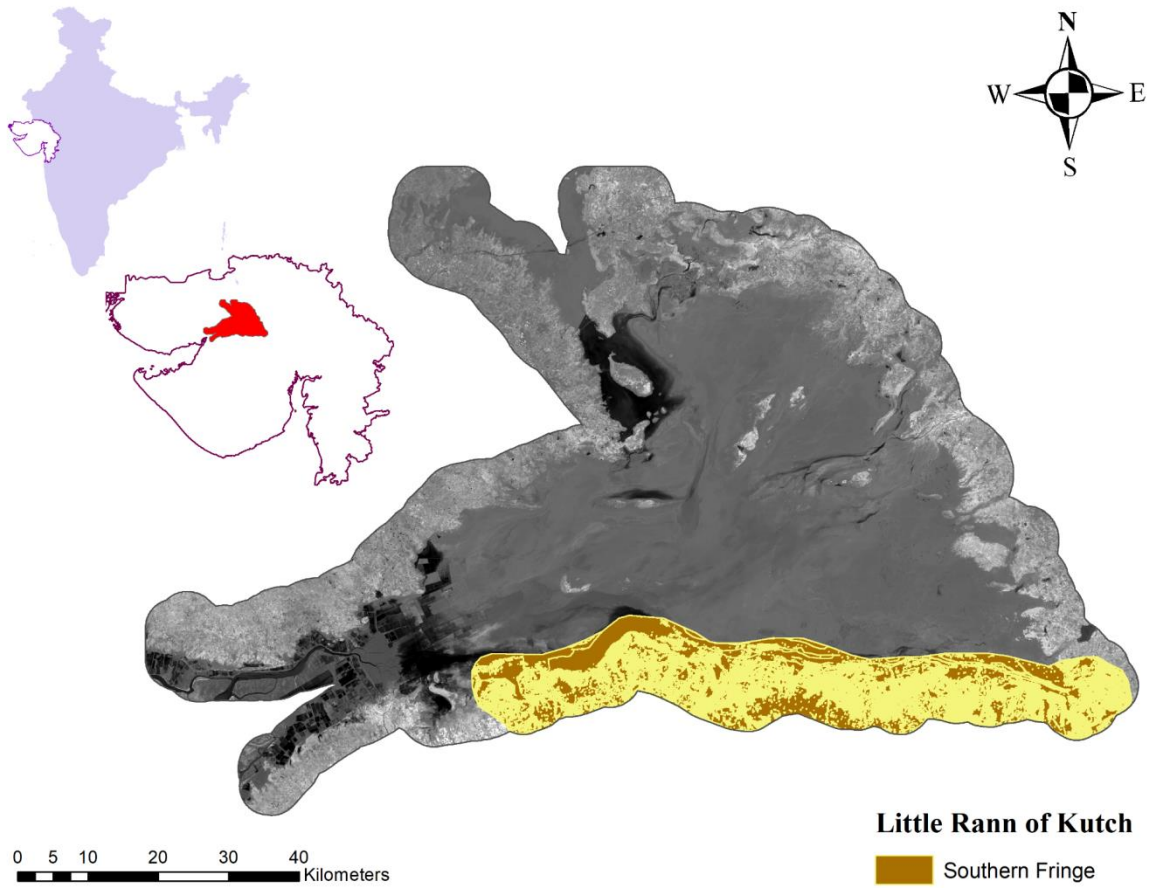


Figure 1.1: Little Rann of Kachchh landscape and southern fringe (intensive study area) with village trails sampled for line transect

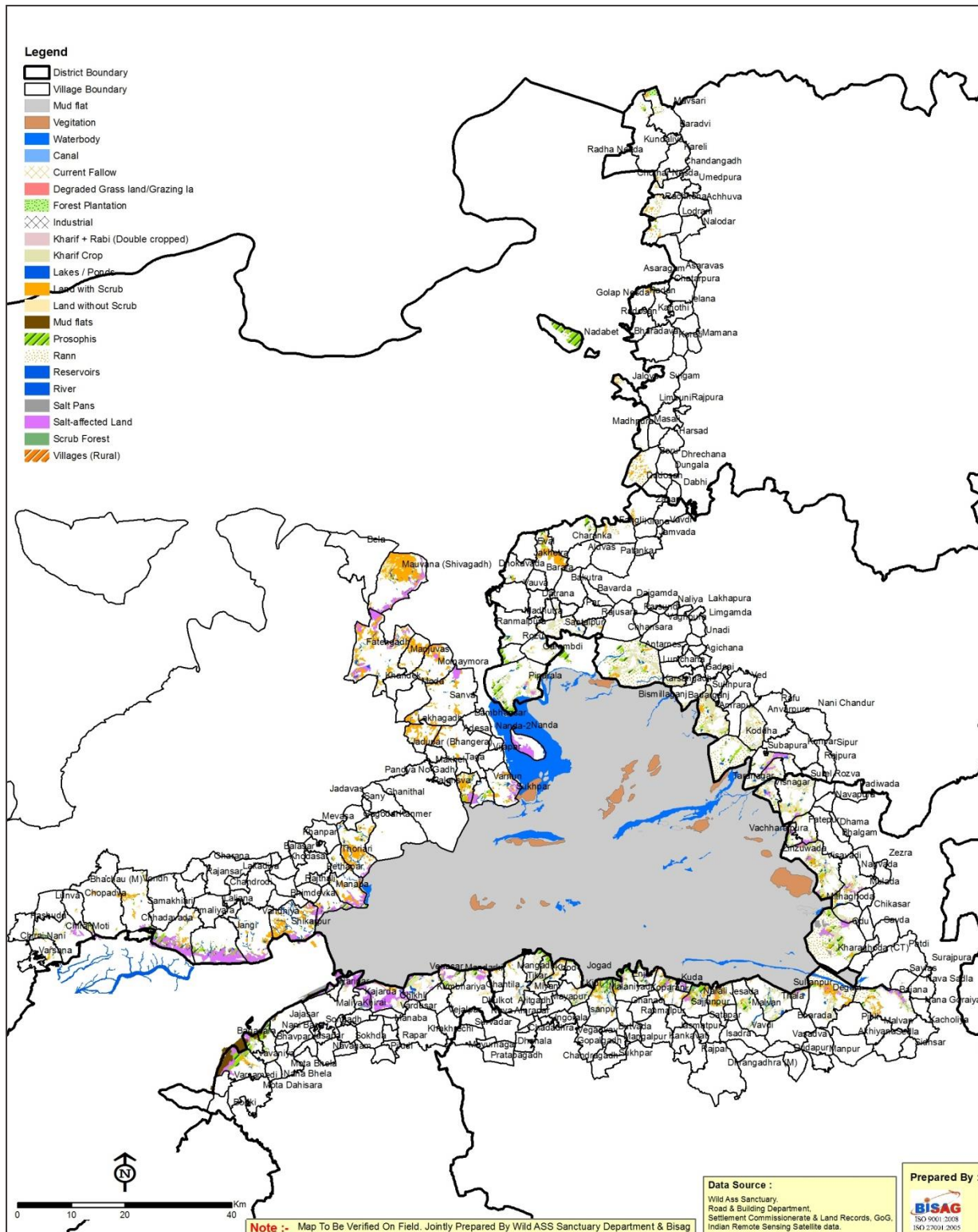


Figure 1.2: Draft landuse map of Indian wild ass Sanctuary and Little Rann of Kachchh landscape showing villages in the landscape (sourced from WAS department, 2014)

Geography

The Rann is a saline mudflat where majority of the area is plain without any vegetation (Figure 1.2). Rising only a few meters above the Rann are certain island like features called

Bets, that have sparse vegetation and are thus distinguishable from low lying barren Rann (Shah, 1993). The main *Bets* of LRK are Pung (largest Bet), Wasraj and its chain of islands- Andheri Wen, Khijadiya, Maharajwali, Miyan and Pancham. Other *Bets* are Dhut, Mardak (highest Bet), Shedwa, Nanda and Jhilandhar. The Little Rann has four fringes – southern, eastern, northern and western. The fringe areas are little elevated from Rann with vegetation and surrounded by villages. The western fringe is undulating with rocky highlands. Total 74 bets have been identified out of which 51 bets have vegetation (Pardeshi et al., 2005).

Main rivers carrying rain water into the Rann during the monsoon are Bhambhan, Kankavati, Godhra and Umari from the southern fringe, while Rupen, Saraswati and Banas from eastern fringe empty into the Little Rann.

Climate

The Little Rann of Kachchh has a semi-arid climate. Average maximum temperature is 44° C and sometimes reaches 50° C. Minimum temperature is recorded 5° C in January with occasional records of <1° C. Monsoon sets in by the month of June 15th and continues up to September (Shah, 1993). An average annual precipitation of 300 mm is recorded in the Little Rann of Kachchh and annual rainfall ranges between 125 to 400 mm. The Rann experiences relative humidity of 85% during the monsoon and it remains low up to 25% or less for rest of the year. Because of the high average temperature and low humidity, the potential rate of evaporation is very high.

Flora

The Little Rann of Kachchh is classified into three scrub types, i.e. Rann saline thorn scrub, *Salvadora* scrub and Tropical *Euphorbia* scrub. The dominant scrub in LRK is *Prosopis juliflora* (mesquite) introduced in the area in 1899 (Shah, 1993). The grass growing on the bets and on mainland includes species of *Aeluropus lagoides*, *Cyperus* spp., *Sporobolus indicus*, *Aristida* spp. and *Eragrostis* spp. A total of 253 flowering plants have been listed in Little Rann of Kachchh. Broadly eight different vegetation types are classified which are *Prosopis juliflora* scrub, *Salvadora persica - suaeda* scrub, *Cassia auriculata* scrub, *S. persica – tamarix* scrub, *Capparis* scrub, fringe grassland (*Eragrostis ciliaris*, *Dichanthium annulatum*, *Cynodon dactylon*, *Chloris montana*, etc.) and saline grassland (*Aeluropus lagoides*, *Suaeda nudiflora*, *Cressacretica*).

Fauna

In LRK, apart from Indian wild ass, the other ungulate species present are chinkara (*Gasellabennetti*), Nilgai (*Boselaphus tragocamelus*), wild boar (*Sus scrofa*) and black bucks (*Antelope cervicapra*) are the other ungulates found in LRK. Among the carnivores, the jungle cat (*Felischaus*), desert cat (*Felissylvestrisornata*), wolf (*Canis lupus pallipes*), desert fox (*Vulpesvulpespusilla*) and jackal (*Canis aureus*) are found (Shah, 1993). Among the birds, a variety of 178 species of migratory birds occur in the Indian wild ass Sanctuary of Little Rann of Kachchh. About 81 terrestrial and 97 water bird species have been recorded from different sites of the Sanctuary (Singh, 2001; Pardeshi et al., 2005). The houbara bustard (*Chlamydotis undulate macqueeni*), demoiselle cranes (*Anthropoidesvirgo*), common crane (*Grus grus*), lesser flamingo (*Phoeniconaias minor*) and greater flamingo (*Phoenicopterusroseus*) are among the most important species which visit Kachchh every year. Among herpetofauna, 4 species of amphibians, 2 species of turtles, 14 species of lizards and 12 snakes have been recorded from this region (Pardeshi et al., 2005).

People of Little Rann of Kachchh

The Indian wild ass Sanctuary and the fringe villages are together comprise the Little Rann of Kachchh landscape. The village people are categorised into Thakor, Bharwad, Darbar, Patel, Harijan and Muslim ethnic groups. The Thakor community is the majority in the landscape followed by Bharwad, Patel, Harijan and Muslims. The majority of people from all the communities are engaged in agricultural activities as the farmers or as agricultural labour. Bharwad community is traditionally called the “*Maldhari*” as their main livelihood activity is animal husbandry. In practice, any community could be called *Maldhari* if they do animal husbandry. The Bharwad community is also observed to have land and also do agriculture in parallel. Thakor community people are mostly farmers and agriculture labourers. A section of Thakor community is also engaged in Salt farming but many have shifted towards agriculture. Majority of Darbar and Patel community do agriculture for livelihood. These two communities have larger land holdings in the landscape. A section of them also do different types business such salt farming, agricultural products, etc. Historically, these two communities are considered as upper caste and are also employed in many government and private jobs like police, teaching, etc. The Muslim community of the area mostly does fishing for their livelihood. A section of them, who have land do agriculture. Since fishing is seasonal in the area, during off-season they work in agricultural fields and engage themselves in different daily wage jobs.

Intensive study area (ISA)

The study was carried out covering 4953.7 Km² area of Indian wild ass Sanctuary to include the entire population of Indian wild ass inside the protected area. Due to the large size of the area, inhospitable terrain, resource and time constraints, it was not possible to collect repetitive data from the entire area, it became necessary to identify an intensive study area (ISA) within the limits of the sanctuary. The ISA was selected along the southern fringe of the Little Rann. The ISA was of 213.4 Km² and includes 14 villages (Tikar, Mangadh, Ajitgadh, Khod, Kidi-Jogad, Enjar, Koparni, Kuda, Nimaknagar, Narali, Jesada, Krishnanagar, Malvan, Thala, Sultanpur, Degam and Pipli) and adjoining agricultural lands along with scrubland, fringe grassland and parts of Rann.

These villages were sampled for estimating abundance, crop-depredation patterns and socio-economic data.

Objective of the study

The overall objective of the study was to estimate the abundance of Indian wild ass and Nilgai, understand their distribution and their resource selection patterns across the study area. This would provide the basic idea on monitoring abundance of these two sympatric ungulates to make efficient management decisions for the long term conservation of the species and the habitat. Also, peoples' attitude was determined for understanding the perception of the community/ stakeholders towards Indian wild ass conservation and determining factors that govern their attitude in relation to the crop-depredation by these species. The major objectives of the study are as follows:

- To estimate the abundance and distribution pattern of Indian wild ass and Nilgai.
- To study the pattern of resource selection and habitat use of Indian wild ass and Nilgai.
- To study people's perception and attitude towards crop-depredation by Indian wild ass.

Structure and organisation of thesis

The thesis is organised into five chapters. Each of the chapters deal with the specific objectives stated. Chapter-I introduces the study, its background, study animal and the study area. Chapter II, III and IV deal with abundance and distribution of Indian wild ass and Nilgai, resource selection pattern and peoples' perception and attitude respectively. All the chapters give a short introduction to the rationale of the objectives; methodology adopted for achieving the stated objectives, results and discussion pertaining to the objective. Finally,

chapter-V gives summarises the whole study and includes the management recommendations based on the results of the study.

Chapter 2 Spatio-temporal abundance and distribution of Indian wild ass and Nilgai in Little Rann of Kachchh

Introduction

The estimate of population and its monitoring gives an understanding on the population dynamics of any particular species and the fundamental idea of larger conservation interests (Varman and Sukumar, 1995). Traditionally park managers had relied on direct counting method through opportunistic sightings and organised census to document herbivore and carnivore populations with poor level of spatial and temporal replications (Le Moullec *et al.* 2019). Indian wild ass (*Equus hemionus khur*) or Indian wild ass is a large ungulate adapted to live in extreme climatic condition. Indian wild ass, after losing all other global habitat in western arid landscapes of Pakistan, Baluchistan and Afghanistan was restricted to the Little Rann of Kachchh landscape (Duncan, 1992; Shah, 1993; Moehlman, 2002; Shah and Qureshi, 2007) which is a 5000 square kilometre of saline clay desert covered with brine and windblown sand. Their first population estimation was done by Salim Ali in 1949 and the Indian wild ass population was estimated to have 4000 individuals (Ali, 1949). The population suffered drastic decline to an estimated population of 700 individuals during early 1970's due to disease (Gee, 1963) and consecutive droughts for three years between 1985 to 1989 (Shah, 1993 and Singh, 2000) (Figure 2.1).

The ability to thrive in an extremely human dominated landscape and protection measures taken up by declaring the Little Rann of Kachchh as Indian wild ass Sanctuary in 1972 (4954km² area) brought the population up to 2940 in 1998 (Singh, 2000) and since then a steady growth in population has been documented (Shah, 1993; Singh, 2000). Nilgai (*Boselephus tragocamalus*) has a wide spread distribution across Gujarat state and other parts of Northern and Central India (Chauhan and Singh, 1990).

However, we have records of Indian wild ass population estimates since 1946, the Forest department has been conducting large scale population census of Indian wild ass since 2008 regularly at every five years' interval using traditional direct count method. In a semi-arid ecosystem, population of large herbivore fluctuates due to its unpredictable weather changes and associated change in forage quality and quantity (Caughley, 1993). The impact of decreased forage density is much higher on desert ungulates than any other resource. Drought in a desert ecosystem could cause catastrophic decline in large ungulate populations (Illius and O'Connor, 2002).

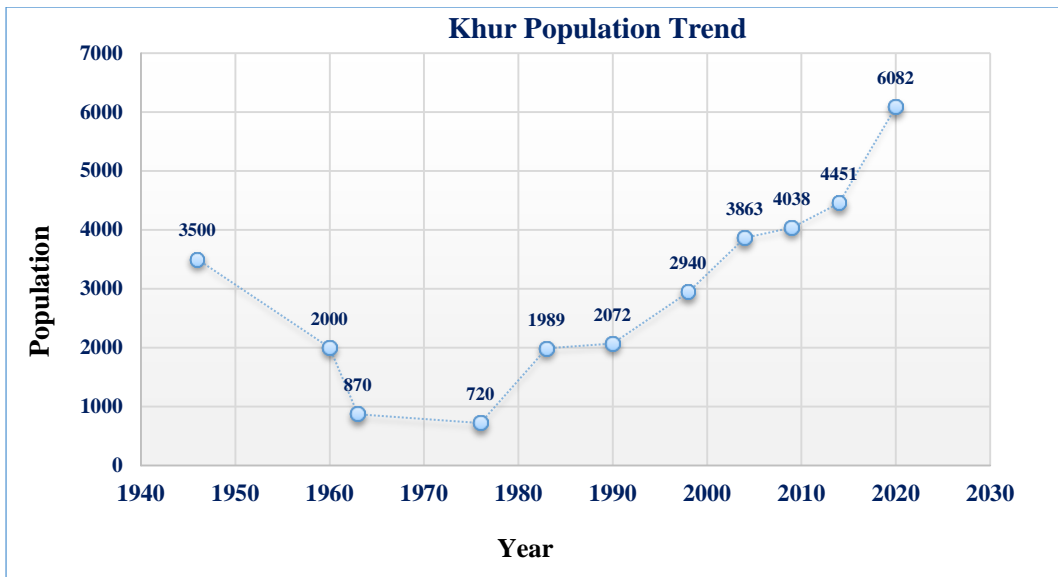


Figure 2.1: Indian wild ass population trend according to Gujarat Forest Department

Although, there is no natural predator of adult Indian wild ass (Shah and Qureshi, 2007), apart from predation of young ones by wolves and feral dogs (field observation) there could be other limiting factors regulating their population like grazing pressure from livestock, disease and droughts. The highly human dominated landscape where human added factors vary spatially and temporally that could impact decision making by animal population on habitat selection (Krishna and Isvaran, 2016). Traditional salt farming in LRK which had been contributing about 22 percent towards India’s total salt produce (Shah, 1993 and Sinha, 1993) has evolved with time to stand with commercial economy resulting in increased mechanised brine extraction and salt transportation with large number of heavy vehicles, causing disturbance to the fringe habitat. Narmada canal was built surrounding LRK and passing through it in several places, and it is still expanding with new branches and sub-branches being continuously added. It aims to reduce the scarcity of drinking water and facilitate irrigation to support growing human population and this has been contributing to rapid changes in land use from dry farming to irrigated farming (Goyal et. al, 1999; Dinesh et al., 2014 and Jagadeesan et al, 2016). This accelerated change in land-use pattern has largely contributed towards selection of crop-fields as their forage ground by Indian wild ass and Nilgai resulting in conflict with farmers. In such a situation, sanctuary managers need to follow the trend in population density and distribution pattern of Indian wild ass to ensure its long term conservation; however, studies regarding Indian wild ass has been largely confined with the assessment of its status (Ali, 1946; Gee, 1963, Shah & Qureshi, 2007 and Forest department records) using traditional method of direct counting and scanning. Temporally

spaced population estimation of the same area for several decades or simultaneous surveying of different sites has been adopted globally to draw meaningful inferences about population trends and ecological processes (Droege, 1990 and Pollock et al, 2002) to design future management strategies (Karanth and Sunquist, 1992). In this study we assessed population density at spatial and temporal scale using line transect method (Burnham et al., 1980) to generate population estimates.

Method

Study design

The line transect sampling was performed to survey the Little Rann of Kachchh (LRK) landscape. The southern fringe area of LRK was considered as the intensive study site where both spatial and temporal surveys were conducted. Line transect sampling was performed by foot and vehicle transect method. The other fringe areas of the larger areas of the landscape were surveyed during winter season only. In 2012-13, during winter season, the southern and eastern fringe was covered. Total 61 transects were sampled of which 44 transects were in southern fringe. Similarly, in 2015-16 winter, all the four fringes, i.e., southern, eastern, western and northern fringe were surveyed. Total 65 transects were sampled of which 22 transects were sampled in the southern fringe. During summer season, in 2014, the southern fringe was surveyed with 23 foot transect samples.

The southern fringe was also surveyed by vehicle transect method in 2014 and 2015 during winter season and in 2014 during summer season. Total 3 and 4 transects were sampled covering southern fringe during winter in 2014 and 2015 respectively. In summer, 26 transects were sampled following different survey design keeping shorter transects covering all major habitat types along the southern fringe.

In foot transect sampling, the fringe areas were walked whereas in vehicle transect, along with the fringe areas, the larger saline-plain including the major bays were surveyed. Foot transects were laid over the village trails that starts from village and ends into the Rann. Every village has 1 to 3 such trails which are used by the villagers to access the crop-fields, fringe areas and Rann. The starting point of each transect were randomly selected. The length of transects were not uniform and depended on the length of trails. The smallest transect was 1.63 kilometre and the longest one was 8.44 kilometre in length. The number of observers were limited to 2 to 3 persons. At every observation, the GPS co-ordinate of the observation point, the walk and animal bearing and radial distance (distance between first observer and

the animal or group-centre) were recorded. The equipment used for data collection were compass (Sunto Kb-20), range finder (Bushnell 6x24mm) and GPS (Etrex 10/20). Between two parallel transects, a minimum 1 kilometre gap was maintained. The vehicle transects were done by truck (Bolero pickup truck) where a team of 4 to 5 observers were present. One or two observers used to stand behind to get more visibility and one observer would sit inside the car to do the data recording. On every observation, the observer handling the compass would get out of the car to avoid influence on compass bearing due to the proximity of metallic body of the vehicle. The speed of the vehicle was kept at 20 km per hour. In 2015-16, during winter, entire landscape including all the fringe areas and major betas were surveyed. In 2014 winter and summer, the southern fringe was intensively surveyed. Transect were laid along the fringe following the established vehicular tracks. Surrounding the bet areas, the Rann remains dry during winter and summer and any possible paths were taken during transect. Length of transect was ranged between 8 to 60 km. The longest transects were in the bet areas where the Rann is vast, without any vegetation and Indian wild ass could be seen from 1 km distance. In open Rann, the vehicle speed was increased up to 40 km per hour to cover more areas.

Data analysis

The density of the animal in the surveyed area was estimated as $D = n.f(o)/2L$ (Buckland et al, 1993), where 'D' was the estimated density, 'n' was the number of observations made, 'L' was the length of transect and 'f(o)' was the probability density function. The data was analysed using DISTANCE 7.3 software (Thomas et al. 2010). In the software, the distance file was created with pooled effort for all the species including Indian wild ass, Nilgai and Livestock to run the analysis with higher number of observations to get better performance towards density estimates of each species. The estimator was stratified as 'species' to get separate density estimates for each species. The model was kept similar for all the species and run together keeping density and detection function as 'global' (Figure 2.2) and density, encounter rate and cluster sizes as 'stratified' estimates to be determined for each species.

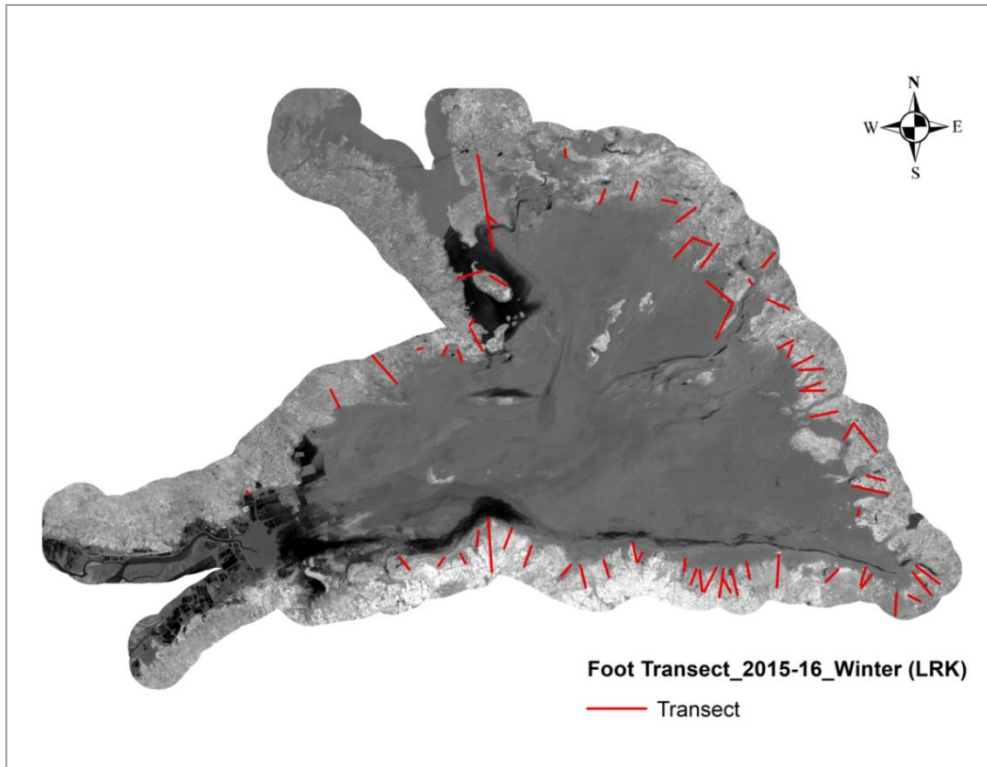


Figure 2.4: Foot transect in LRK landscape in 2015-16 in winter season.

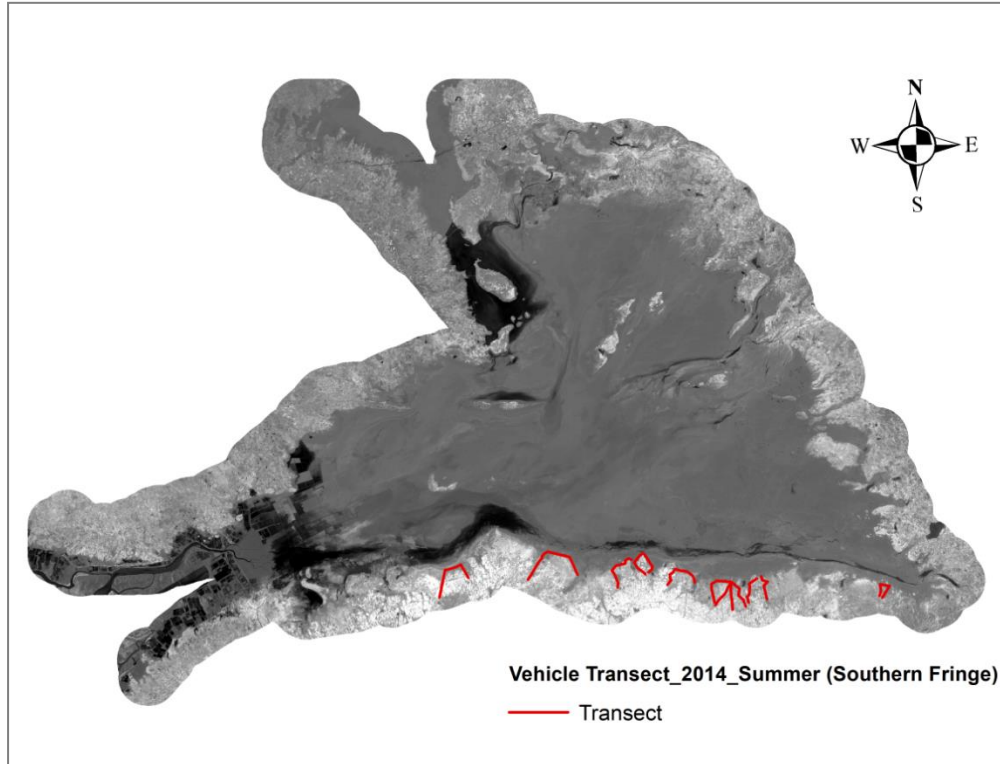


Figure 2.5: Vehicle transect in southern fringe during 2014 in summer season

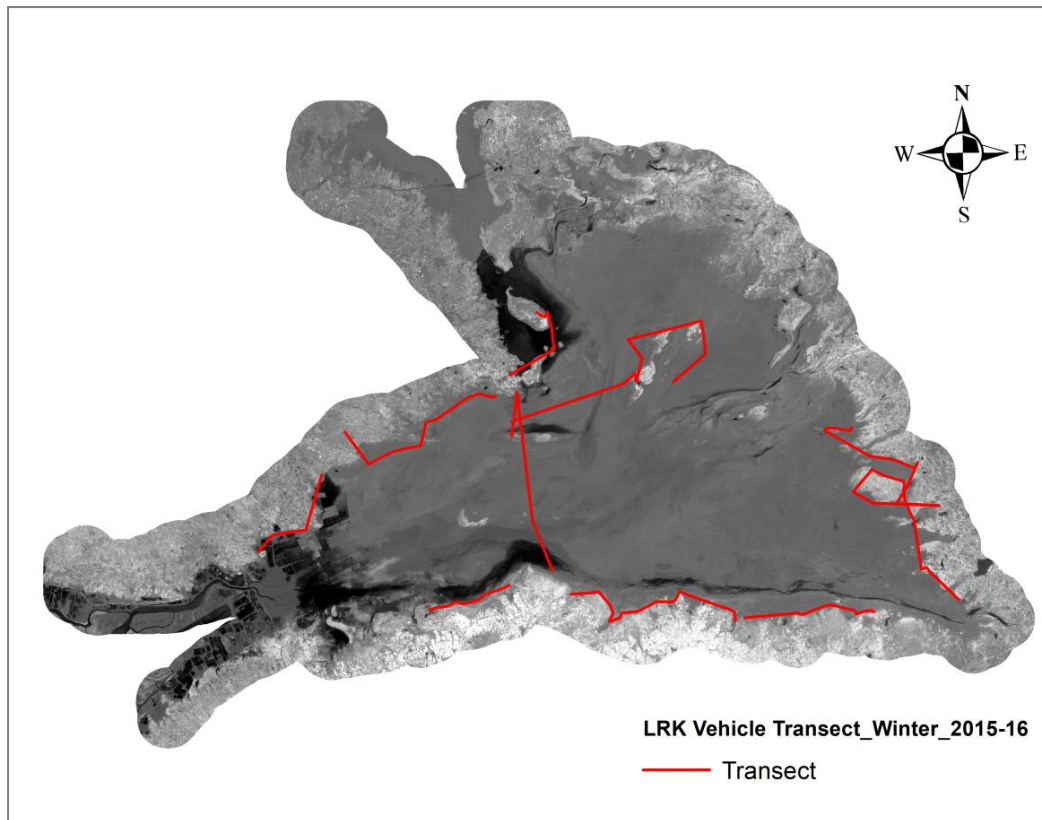


Figure 2.6: Vehicle transect in LRK landscape including southern fringe during 2015 winter season.

Result

Indian wild ass population density estimation in Southern Fringe (Intensive study area)

Winter season estimates

In 2012, a total 132 transects were sampled with a total effort of 511.71 km (Table 2.1) by pooling three different species observations in one file for analysis where the data was stratified based on species to get density estimates for Indian wild ass and other species (Figure 2.3). The analysis considered 132 transect samples (effort 511.71km) with 167 Indian wild ass observations including 35 and 218 observations of Nilgai and Livestock respectively. The density of Indian wild ass estimated was 3.68 (SE 0.74). Similarly, in 2015-16, a total of 66 samples were considered with a total effort of 226.59 km (Figure 2.4). Total observations were 78, 18 and 54 of Indian wild ass, Nilgai and Livestock respectively. The estimated density of Indian wild ass was 3.58 (SE 1.04). The encounter rates of Indian wild ass were 0.37 and 0.31 in 2012-13 and 2015-16 respectively.

Summer season estimate

In 2014 summer, total samples were 69 with total effort as 247.41 km (Figure 2.5). Total observations were 56, 14 and 33 of Indian wild ass, Nilgai and Livestock respectively. The estimated density of Indian wild ass was 1.74 (SE 0.52).

Indian wild ass population density estimation in LRK landscape (larger area)

In 2012-13, eastern fringe apart from southern fringe was sampled. In winter of 2015-16, all the sanctuary fringes were sampled (Figure 2.6). In 2012-13, total foot transect sample size was 185 and total effort calculated was 687.28 km. In 2015-16, total 195 foot transects were sampled during winter season along southern, eastern, northern and western fringes (Figure 2.4). The effort was 700.59 km. Pooled estimate comprising of both the winter surveys had 369 samples and 343 observations with a total effort of 1345.5 km (Table 2.2). The density was estimated at 4.99 (SE 0.91) and 4.13 (SE 0.87) in 2012-13 and 2015-16 winter season surveys respectively. The pooled density estimate was 4.45 (0.61).

Table 2.1: Population estimation of Indian wild ass and Nilgai in Southern Fringe area of Little Rann of Kachchh landscape using foot transect method

Species	Parameters	2012-13 (Winter)		2015-16 (Winter)		2014 (Summer)	
		Estimate	%CV	Estimate	%CV	Estimate	%CV
	Sample	132		66		69	
	Effort	511.71		226.59		247.41	
	Detection Function	Half normal - Cosine					
	ESW	185.51±9.36	5.04	172.06±13.09	7.61	174.31±15.9	9.12
Indian wild ass	Observations	167		78		56	
	Density of cluster	0.84±0.15	10.59	0.92±0.23	25.43	0.58±0.16	27.29
	Mean cluster size	5.07±0.55		4.9±0.67		2.78±0.30	
	Density	3.68±0.74	20.35	3.58±1.04	29.16	1.74±0.52	29.95
	Encounter rate	0.37		0.31		0.2	
Nilgai	Observations	35		18		14	
	Density of cluster	0.21±0.05	25.89	0.21±0.09	30.81	0.17±0.06	37.98
	Mean cluster size	2.84±0.48		4.71±1.37		4.40±1.2	
	Density	0.61±0.81	30.15	0.60±0.31	51.78	0.94±0.49	52.17
	Encounter rate	0.076		0.075		0.06	
Livestock	Observations	218		54		33	
	Density of cluster	1±0.22	22.5	0.70±0.20	28.53	0.43±0.13	31.07
	Mean cluster size	9.84±1.38		4.38±0.60		6.11±1.60	
	Density	9.02±2.26	25.09	2.98±0.96	32.19	2.04±0.80	39.1
	Encounter rate	0.31		0.24		0.15	

Table 2.2: Population estimation of Indian wild ass and Nilgai in larger area of Little Rann of Kachchh landscape using foot transect method

Species	Parameters	Foot 2012-13 (Winter)		Foot 2015-16 (Winter)		Foot Pooled (Winter)	
		Estimate	%CV	Estimate	%CV	Estimate	%CV
	Sample	185		195		369	
	Effort	687.28		700.59		1345.5	
	Detection Function	Half normal-Cosine					
	ESW	175.24±7.41	4.23	163.39±11.87	7.27	175.26±5.96	3.4
	Indian wild ass	Observations	202		149		343
	Density of cluster	0.84±0.13	14.99	0.65±0.12	18.02	0.73±0.08	11.48
	Mean cluster size	6.17±0.64		6.62±0.74		6.36±0.49	
	Density	4.99±0.91	18.27	4.13±0.87	21.05	4.45±0.61	13.82
	Encounter rate	0.29		0.21		0.25	
Nilgai	Observations	51		25		76	
	Density of cluster	0.21±0.04	20.45	0.11±0.03	31.23	0.16±0.03	17.08
	Mean cluster size	2.66±0.4		4.76±1.07		3.36±0.45	
	Density	0.54±0.13	24.27	0.41±0.17	41.31	0.47±0.09	21.11
	Encounter rate	0.07	18.88	0.04		0.06	
Livestock	Observations	233		110		343	
	Density of cluster	0.97±0.18	19.24	0.48±0.11	22.58	0.73±0.11	14.93
	Mean cluster size	10.58±1.2		7.63±1.67		9.64±0.99	
	Density	10.14±2.21	21.83	2.97±0.77	25.79	6.38±1.08	16.96
	Encounter rate	0.34		0.16		0.25	

Nilgai population density estimation in Southern Fringe (Intensive study area)

Winter season estimates

Nilgai density was very low owing to very low encounter rates in each survey. To allow DISTANCE to perform better with lower observation data, Indian wild ass and Livestock observations were pooled together and better estimates were achieved than running Nilgai observations alone in the software. Pooled density estimates of 2012-13 and 2015-16 winter season foot transect survey of southern fringe was estimated at 0.61 (SE 0.81) and 0.60 (SE 0.31) respectively. The pooled estimate of winter combining both the surveys was observed to be 0.47 (SE 0.09). The encounter rates observed were 0.076, 0.075 and 0.06 for 2012-13, 2015-16 and pooled estimates respectively.

Summer season estimates

In 2014 summer foot transect in southern fringe, total observations were only 15 and the density estimate was found as 0.94 (SE0.49) with encounter rates of 0.06 animal/km.

Livestock population density estimation

In 2012-13 winter foot transect survey in southern fringe, density estimate was observed to be higher with 9.02 (SE 2.02) where as in 2015-16 survey, it was estimated at 2.98 (SE 0.96) with encounter rates as 0.34 and 0.21 respectively. For larger area of the landscape including all fringe areas, the density estimate in 2012-13 and 2015-16 were 10.14 (SE 2.21) and 2.97 (SE 0.77) respectively. Pooled winter season estimate was 6.38 (SE 1.08) with a total effort of 1345.5 km at 0.25 encounter rate. In summer, only the southern fringe was surveyed and estimated density was 2.04 (SE 0.80) at 0.15 encounter rate.

Distribution of Indian wild ass in Southern Fringe

Winter distribution

The southern fringe distribution was uniform and all the fringe areas of respective villages of the fringe have herds of Indian wild ass. The observations were made with group size having 1-6 to 30-40 individuals of Indian wild ass and the groups were present in close proximity in the southern fringe (Figure 2.7).

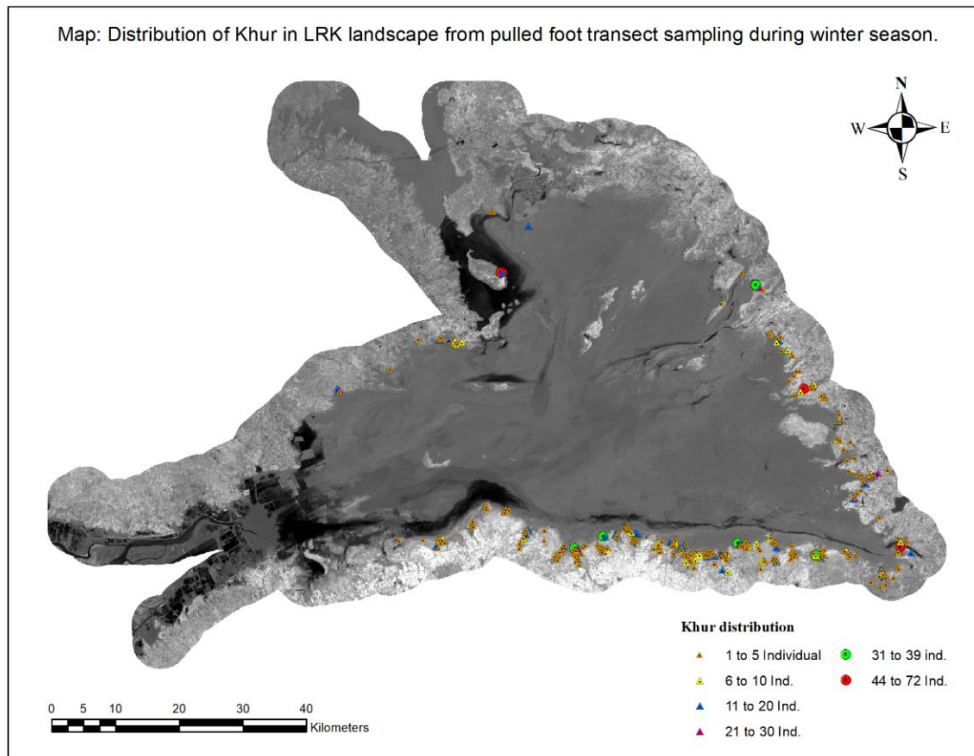


Figure 2.7: Indian wild ass (*Equus hemionus khur*) distribution showing cluster sizes in LRK from pooled foot transect sampling during winter season in 2012-13 & 2015-16.

Summer distribution

During summer foot and vehicle transect (Figure 2.8), cluster sizes were smaller and were categorised as 1, 2 to 3, 4 to 10 or 12 based on the distribution of clusters. In foot transect, 12 was the higher cluster size observed where as in vehicle transect 22 was the higher cluster in southern fringe.

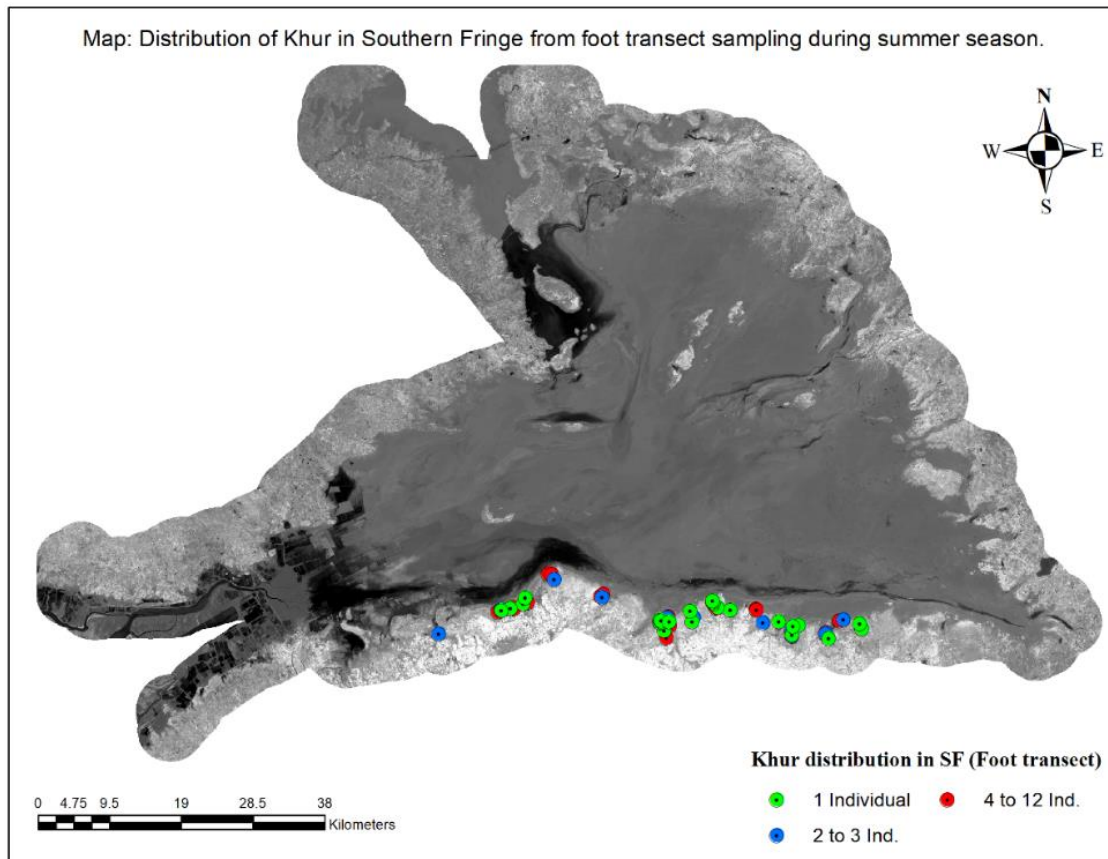


Figure 2.8: Indian wild ass (*Equus hemionus khur*) distribution showing cluster sizes in Southern Fringe from foot transect sampling during summer season in 2014.

Distribution of Indian wild ass in LRK landscape

Indian wild ass population was observed to be distributed all across the landscape during winter (Figure 2.9). In summer from the foot transect sampling, the pooled data of winter season from two different surveys showed that southern fringe had higher distribution of groups of different sizes from one individual to more than 50 individuals. Larger herds with nearly 70 to 100 individuals were observed in southern, north-eastern and north-western fringe areas of LRK landscape. Observations were made at Pung bet area (the largest island) and cluster size of 20 individuals was recorded. The illustrations were shown in the series of distribution maps. Heat maps were also generated showing most favoured areas of the landscape. Indian wild ass distribution was nearly absent from the northern fringe in both the vehicle and foot transect sampling in 2015-16 year in winter season (Figure 2.9). On the other-hand the southern fringe showed consistent congregation in all the surveys during winter season.

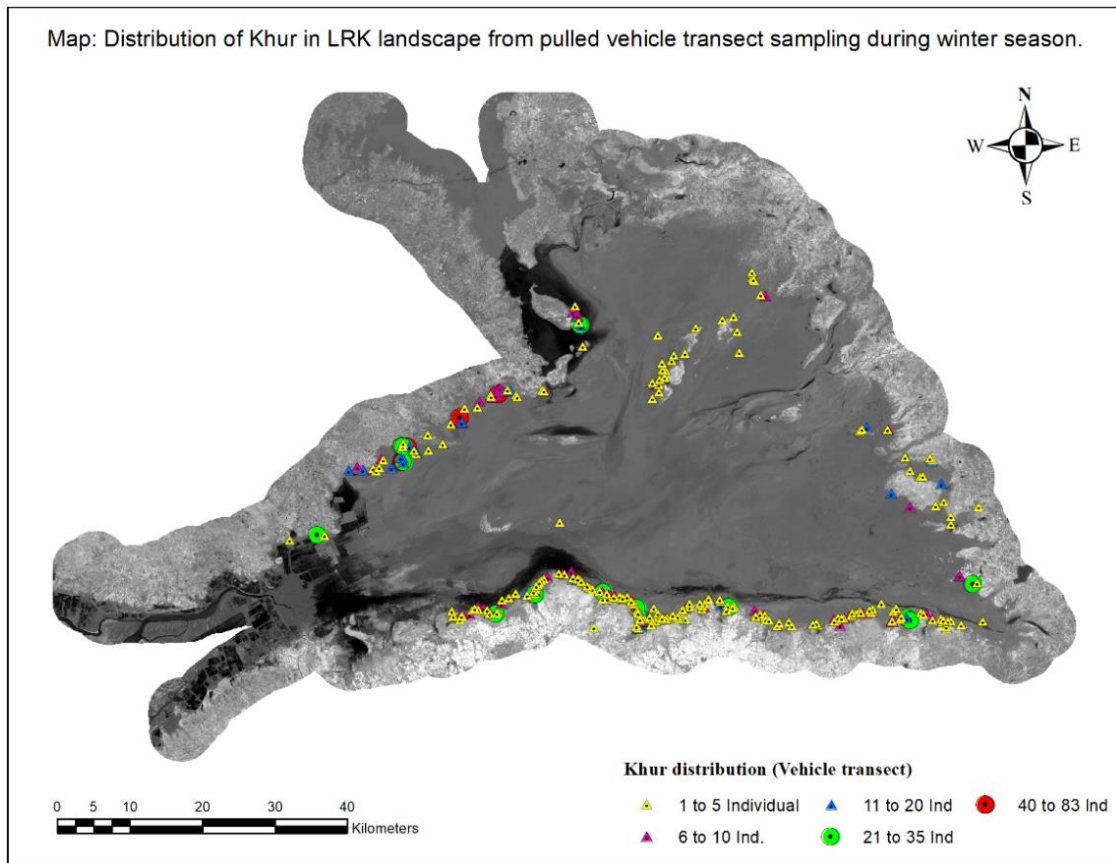


Figure 2.9: Indian wild ass (*Equus hemionus khur*) distributions of different clusters in LRK from pooled vehicle transect sampling during winter season in 2014 & 2015.

Distribution of Nilgai in Southern Fringe and the landscape

Winter distribution

Nilgai observations though very less, showed consistent presence in southern fringe in winter and summer seasons during both foot and vehicle transect sampling (Figure 2.10 to 2.12). The northern fringe and western fringe did not show presence of Nilgai during the surveys. In southern fringe, Nilgai was more evenly distributed in winter than in summer, where it was observed in few transects of southern fringe (Figure 2.10 to 2.12). The bigger cluster sizes ranging from 12 to 20 individuals were observed in both foot and vehicle transect over the same areas in southern fringe. Nilgai prefers the fringe areas only as no observations were made in major bet areas during vehicle transect surveys. Larger clusters were sighted in southern and eastern fringe only. In vehicle transect sampling as well, larger cluster of range 11 to 19 individual was recorded in the southern fringe (Figure 2.12).

Summer distribution

In summer, during foot transect sampling, cluster size was also reduced with reduced encounter rate (Table-1 & Figure 2.13). Higher group sizes with 6 to 16 individuals were

observed between Koparni and Jesada village. The number of observation was less in comparison to winter surveys. The fringe patch between Koparni and Jesada village has higher presence of Nilgai both in winter and summer.

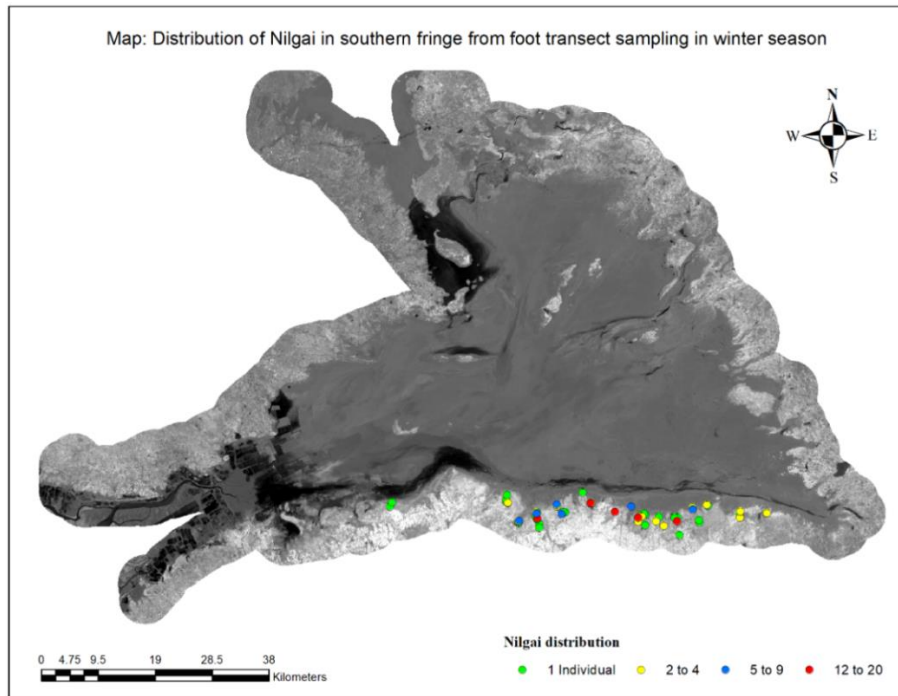


Figure 2.10: Nilgai (*Boselaphus tragocamelus*) distribution in Southern Fringes showing cluster sizes from pooled foot transect sampling of 2012-13 & 2015-16 in winter season.

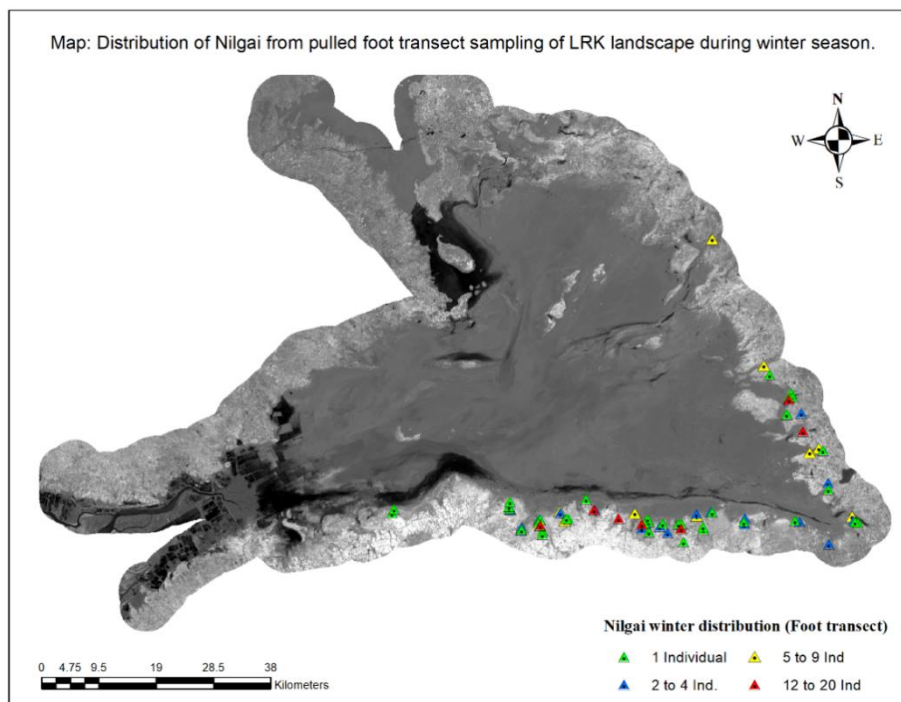


Figure 2.11: Nilgai (*Boselaphus tragocamelus*) distribution in LRK landscape showing cluster sizes from pooled foot transect sampling of 2012-13 & 2015-16 in winter season.

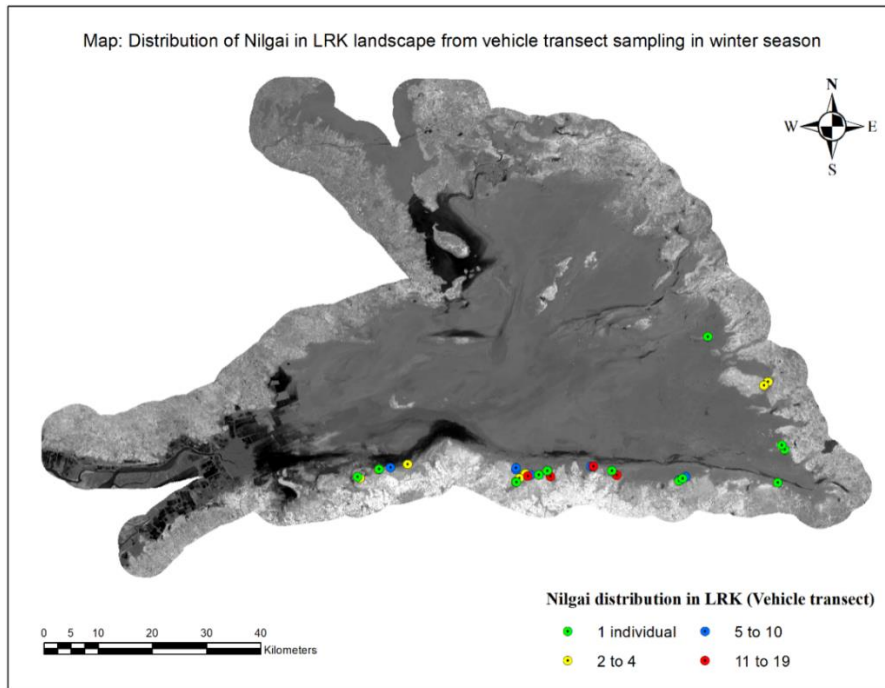


Figure 2.12: Nilgai (Boselaphus tragocamelus) distribution in LRK landscape showing cluster sizes from pooled vehicle transects sampling of 2014 & 2015 in winter season.

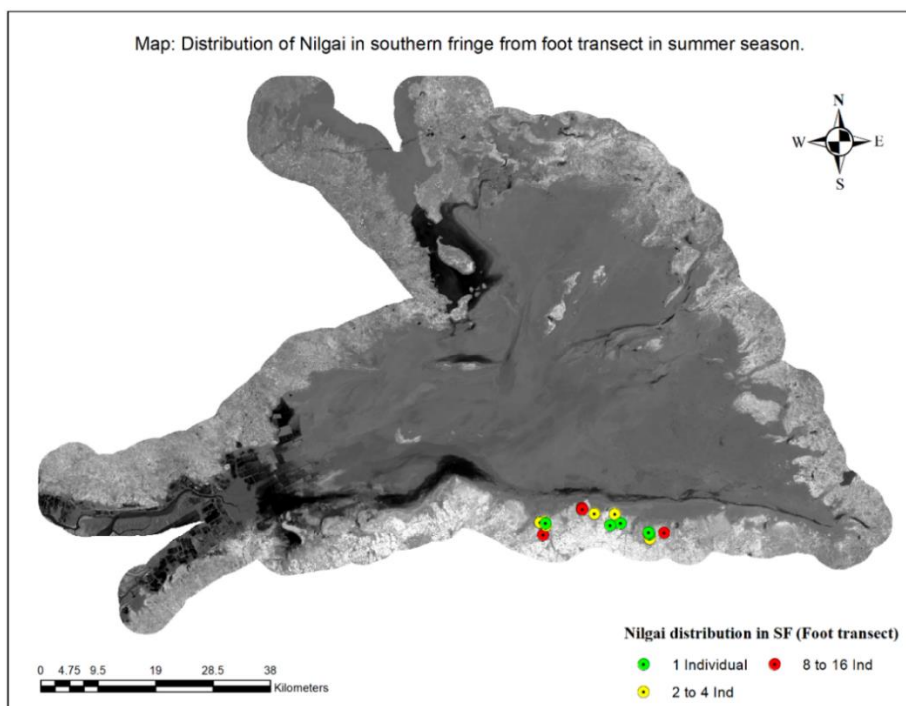


Figure 2.13: Nilgai (Boselaphus tragocamelus) distribution in Southern Fringe showing cluster sizes from foot transect sampling in summer season in 2014.

Distribution of Livestock in Southern Fringe and Landscape

Livestock was observed more in eastern and southern fringe transects. Cluster sizes were categorised as 1 to 10, 11 to 20, 21 to 30, 32 to 50, 50 to 98 and more than 100 based on the sightings recorded in foot transect sampling. In winter, clusters of more than 11 individuals

up to more than 100 individuals were observed in both the fringe areas. Northern fringe showed absence of livestock using both survey methods, whereas in the western fringe, a few observations with less than 11 individuals were recorded (Figure 2.15). In summer, the southern fringe foot transect showed livestock presence with smaller groups where the largest was 46 individuals (Figure 2.14). In vehicle transect sampling, less than 10 observations of cattle and buffalos were observed and therefore excluded from analysis.

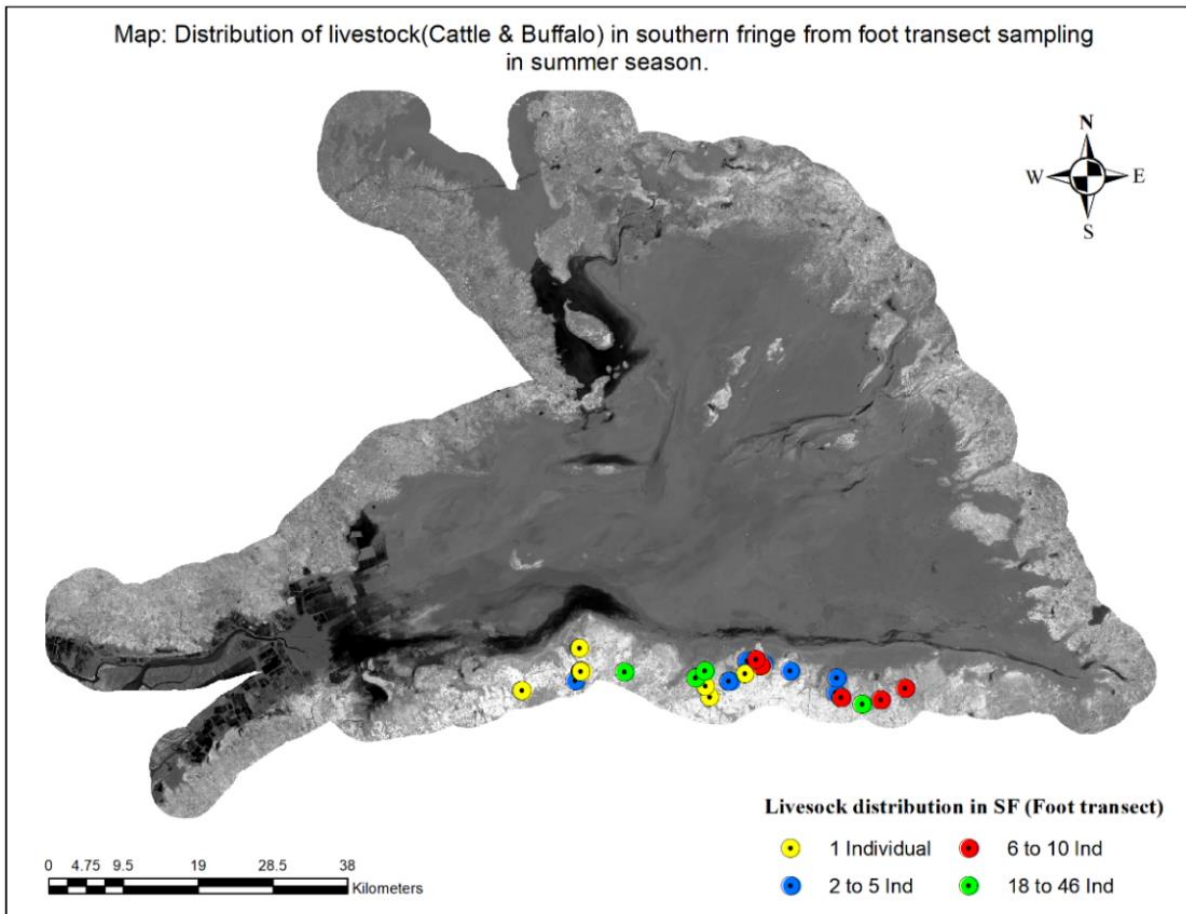


Figure 2.14: Livestock (Cattle & Buffalo) distribution in southern fringe showing cluster sizes from foot transects sampling in summer season in 2014.

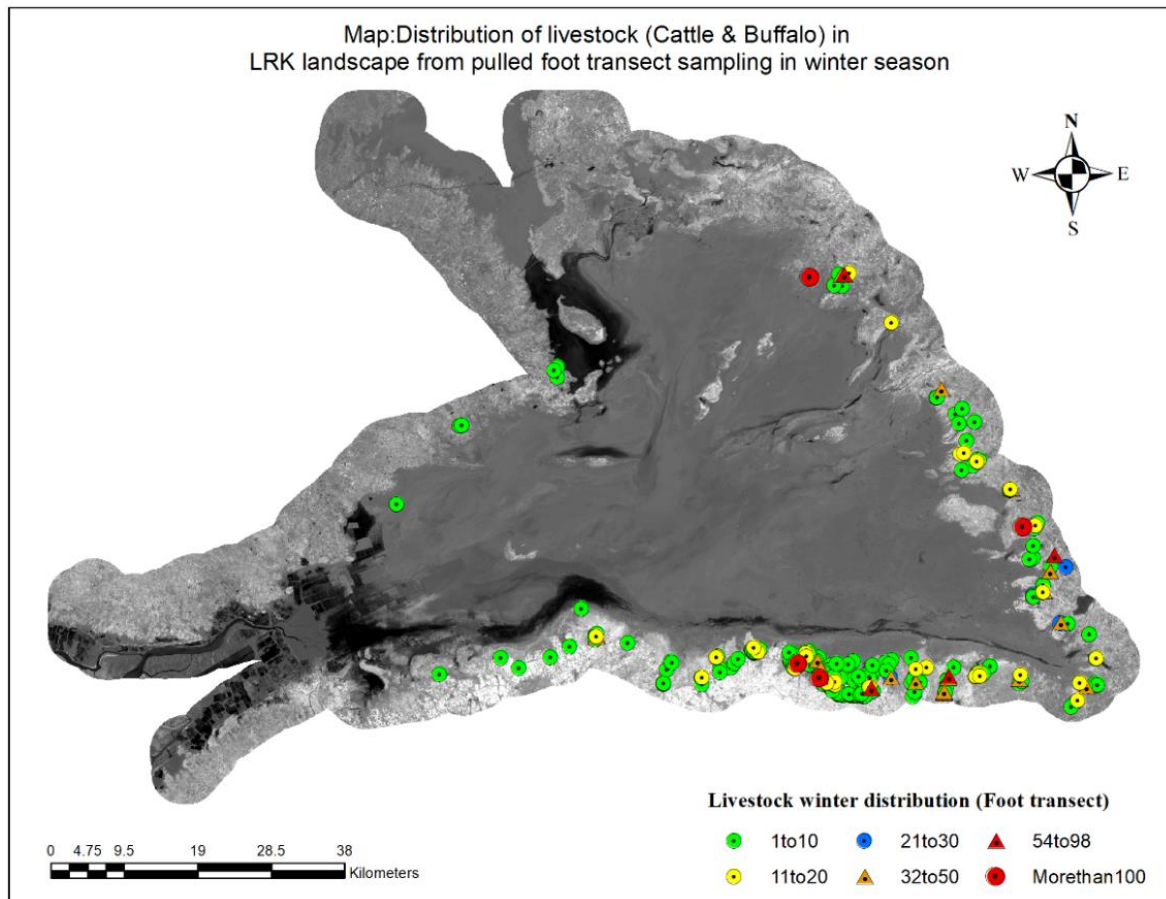


Figure 2.15: Livestock (Cattle & Buffalo) distribution in LRK landscape showing cluster sizes from pooled foot transect sampling of 2012-13 & 2015-16 in winter season.

Discussion

Population density and distribution of Indian wild ass

The large herbivore population dynamics shows regular or semi-regular population cycles owing to several density-dependent factors but that their periodicity is assumed to be so long that the oscillations in population size have not been noticed (Caughley, 1993 and Clutton-Brock et al, 1997). Following the catastrophic decline in their population during the mid-20th century, Indian wild ass abundance showed a stable population growth by reaching 2940 number in 1998 (Singh, 2000) and since then a steady growth in population has been documented (Shah, 1993; Singh, 2000; Forest department record). The south-eastern fringe area has been the resource rich area (Shah and Qureshi, 2007) where sustainable water source could be found which suggests that the distribution has been guided by the resource availability. The estimated population density of Indian wild ass in southern fringe was 3.68 per km² in 2012-13 and in 2015-16 it was 3.58 per km² (Table 2.1) from foot transect

sampling. This suggests that the density is stable over the period of 3 years and remained unchanged. In summer, the density estimate was lower, i.e., 1.74 in southern fringe.

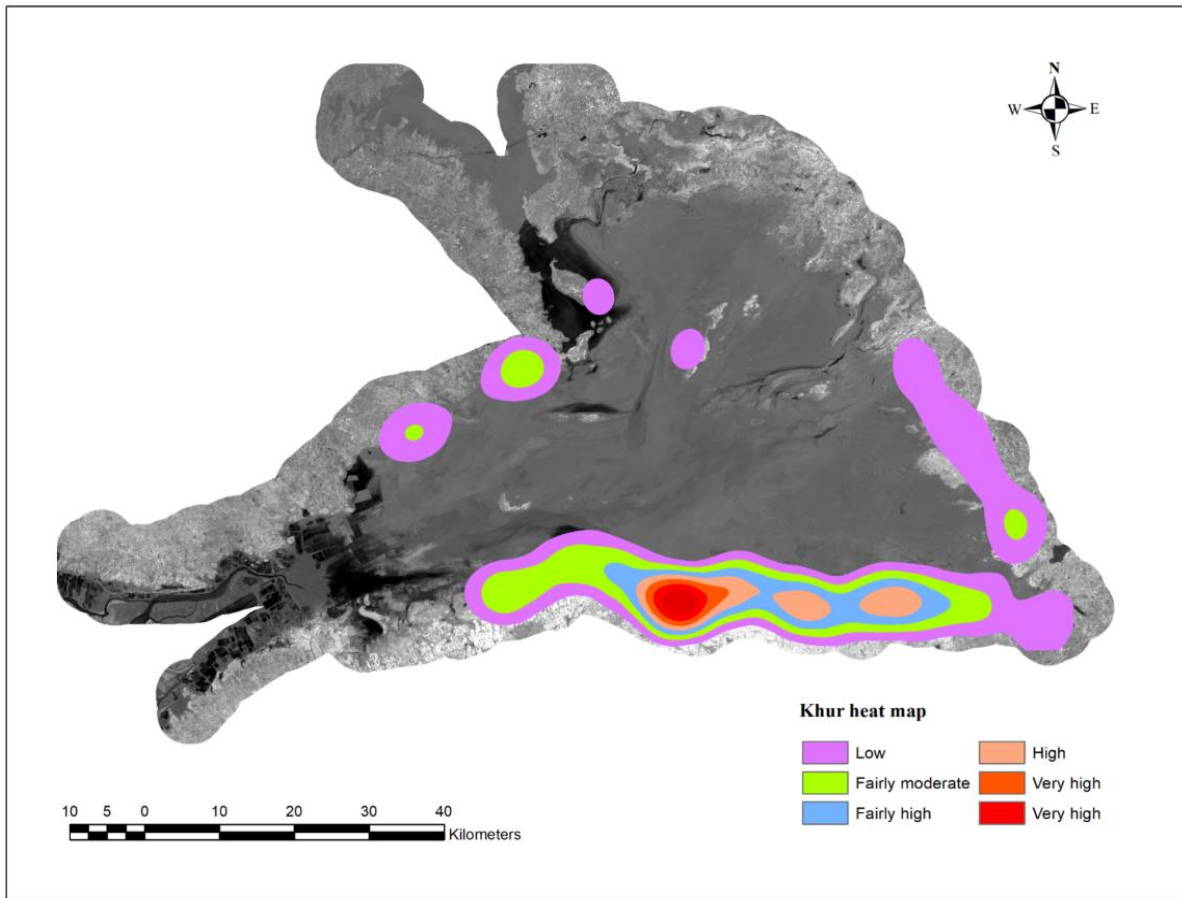


Figure 2.16: Indian wild ass (*Equus hemionus khur*) heat map in LRK landscape from pooled foot transect of 2012-13 & 2015-16 and vehicle transect of 2014 & 2015 in winter season.

The post monsoon period had been productive across the fringe areas and coupled with the better irrigation facility, the southern fringe had been remaining persistent in terms of Indian wild ass distribution. In summer, the fringe grassland dries up forcing the larger herds to divide into smaller groups and disperse along the patchy habitats of the fringe (Figure 2.16). Some groups also move out of the protected area into the wastelands. Although southern fringe is resource rich in terms of forage patch and agriculture (Shah and Qureshi, 2007), during dry season grassland patches and water sources dries up and Indian wild ass herds tend to divide into smaller groups and a few of them move outside protected area into the mainland beyond the villages resulting into lower observation during transect walk. Outside the sanctuary, large herds operate throughout the year and information on their exchange with the source population inside the sanctuary was not available. The islands were used by Indian wild ass as their breeding grounds (Shah, 1993) during monsoon when entire Rann gets

inundated with rain water. Among other major bets, only Pung bet has a resident population that accesses the north-eastern fringe areas for resource and neighbouring bets. Being largest in size (34 km²), Pung bet was more productive and livestock from nearby fringe areas visit it during the wet season. Apart from southern and eastern fringe, large herd sizes of Indian wild ass was also recorded in western fringe. The topography of the western fringe is undulating and rocky unlike other fringe areas. The distance between village and Rann is also high providing larger fringe patches with very less amount of livestock and Nilgai presence. Also, salt farming is not present in the western fringe. Since villages are quite far from the sanctuary boundary, with non-irrigated crop-lands and complete absence of salt farming have attributed towards lesser human movement in compared to other fringe areas. Therefore, the lower anthropogenic pressure and absence of grazing pressure from livestock and Nilgai allows groups of Indian wild ass to congregate into larger herds along the western fringe. On the other hand, the north-western fringe areas, the northern fringe has high disturbance level from extensive salt farming and charcoal making activities which resulted into very poor encounter of Indian wild ass during both foot and vehicle transect surveys (Figure 2.17-2.18). Also the limited encounters occurred in northern fringe areas might be because of the population from Pung bet and Dhut bet which occasionally access the north-eastern fringe areas.

The major bets are very crucial for the population and at the same time the fringe habitats were important refuge during monsoon season. In summer, the fringe grasslands get almost dry except for a few patches of saline grasslands. While in winter, immediately after the monsoon season, fringe habitat become productive with different palatable and perennial grass species to encourage congregation of groups into larger herds. The congregation and dispersal has been observed to affect the encounter rate during transect walks. During the winter transects of 2012-13 and 2015-16, encounter rates were 0.37 and 0.31 respectively while in 2014 summer, it was 0.20 in southern fringe. Similarly, while surveying the larger part of LRK covering other fringes, the encounter rates were 0.29 and 0.21 in 2012-13 and 2015-16 respectively.

The density estimate in summer season was observed to be low as the scarcity of resources attributed to the dispersal of Indian wild ass herds in smaller groups to cover more areas with better resource condition beyond protected area boundary. Although stallions in family groups defend their territories aggressively, but during the lean period they tend to adjust with neighbouring groups (Shah and Qureshi, 2007). Especially outside the protected area,

the agricultural lands were developed with better irrigation facilities and it could be assumed that Indian wild ass herds dispersed into small groups into those areas. The mean cluster size was also less in summer than in winter. Also during summer, Indian wild ass depends more on the *Prosopis* pods for necessary nutrition and during day hours they divide into smaller groups to forage inside *Prosopis* patches where visibility reduces during transect walk and contributed towards lower encounter rate. The mean cluster size was 5.07 and 4.9 in 2012-13 and 2015-16 respectively during winter which reduced to 2.78 in summer.

Population density and distribution of Nilgai

Nilgai was observed to visit crop-fields more frequently than Indian wild ass and according to farmers, they visit standing crops regularly to meet their food requirement. The low encounter of Nilgai against evident and wide spread occurrence suggests that they prefer habitats with medium to high scrub growth during the day time to feed on understory grass and browse leaves from *Acacia* species and rest most of the day time (Bayani and Watve, 2016). Although there was no observation during transect samplings, presence of Nilgai was recorded in western fringe during regular field visits. However, in terms of area preferred, both Nilgai and wildass was found to be overlapping (Figure 2.17). Near the fringe, land holding was observed to be small in size unlike eastern and southern fringe. Also, canal network was not established in western fringe villages and the farmers were depending on rain water for cultivation. Therefore, it could be assumed that majority of Nilgai groups have moved towards villages with irrigated crop-lands far from fringe villages. However, in southern and eastern fringe where Nilgai presence was observed to be good but detection was poor during transect walk. Its diurnal behaviour could be the reason as they spend most of the time resting during the day (Chauhan and Singh, 1990) under *Prosopis* cover avoiding transect trails with more human movement and left undetected during survey. Similarly, in northern fringe, agricultural activities are very less as the major livelihood of resident people was salt farming and charcoal making. During the survey and during my regular visit in northern fringe, not a single occasion of opportunistic encounter of Nilgai occurred.

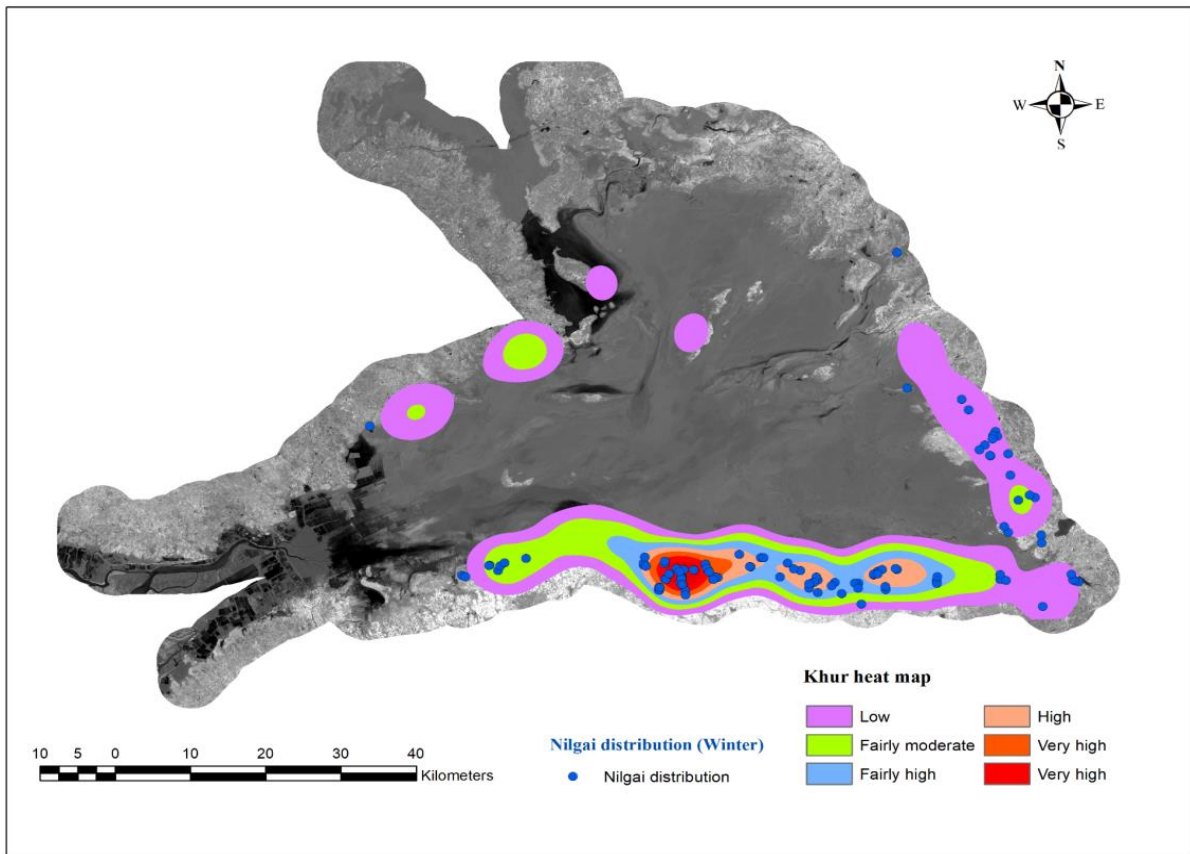


Figure 2.17: Distribution of Nilgai over Indian wild ass heat map in LRK landscape from pooled foot transect of 2012-13 & 2015-16 and vehicle transect of 2014 & 2015 in winter season.

Population density of Livestock

The competition between wild herbivores and livestock could also be an important factor affecting the distribution of Indian wild ass. Unlike other wild herbivores as suggested in many studies, Indian wild ass has been observed to have sensitive co-existence with livestock population where the distribution of Indian wild ass was dependent on the density of livestock (Kackzensky et al, 2011). The southern fringe abundance of Indian wild ass has been stable over the year's despite the higher density of livestock across the fringe habitat (Table 2.1-2.2). The traditional migration of livestock herders has been reduced over the years due to many factors like reduction in livestock holding and sudden land-use change across the fringe areas following the introduction of Narmada canal (Field observation). The density of resident population of livestock also decreased (Table 2.1- 2.2) over the years due to shortage in fodder and absence of foraging ground. In winter surveys, it was observed that the southern and eastern fringe holds larger clusters of livestock during. In addition, they were using the similar forage patches as used by Indian wild ass (Figure 2.18). The distribution of Indian wild ass, Nilgai and livestock (Figure 2.19- 2.20) showed that resource

sharing in terms of areas was nearly similar. Resource rich southern and eastern fringe observed similar congregation pattern of both wild and domestic large herbivores. During productive season, high resource overlap in terms of forage species was visible which is reflected in their distribution patterns. During summer when palatable forage for livestock was sparsely distributed they shift to the agro-pastoral patches.

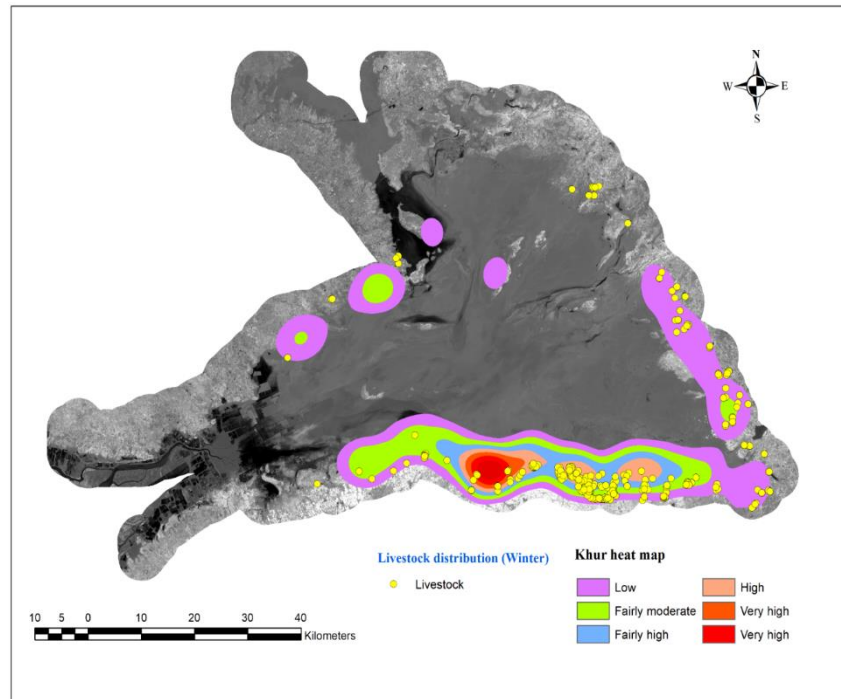


Figure 2.18: Distribution of Livestock over Indian wild ass heat map in LRK landscape from pooled foot transect of 2012-13 & 2015-16 and vehicle transect of 2014 & 2015 in winter season.

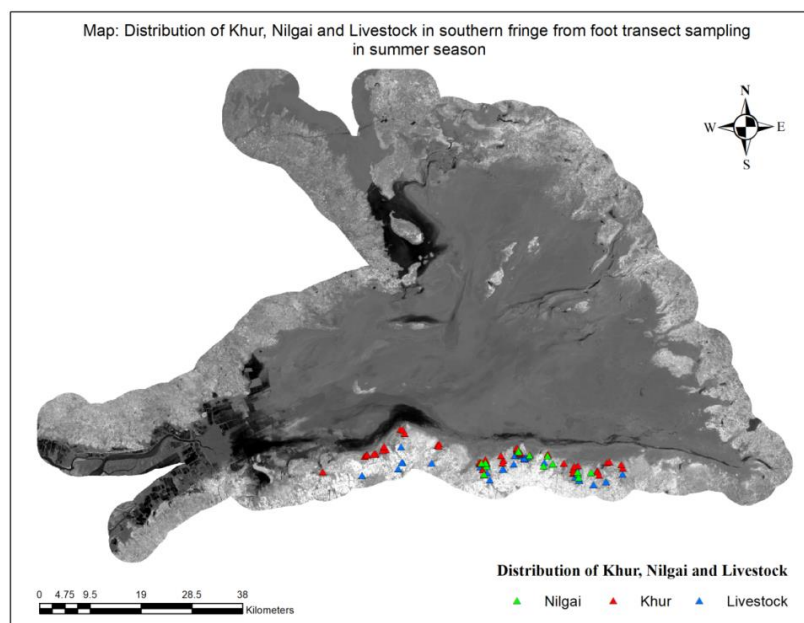


Figure 2.19: Indian wild ass, Nilgai and Livestock distribution in southern fringe of LRK landscape from foot transect sampling during summer season in 2014.

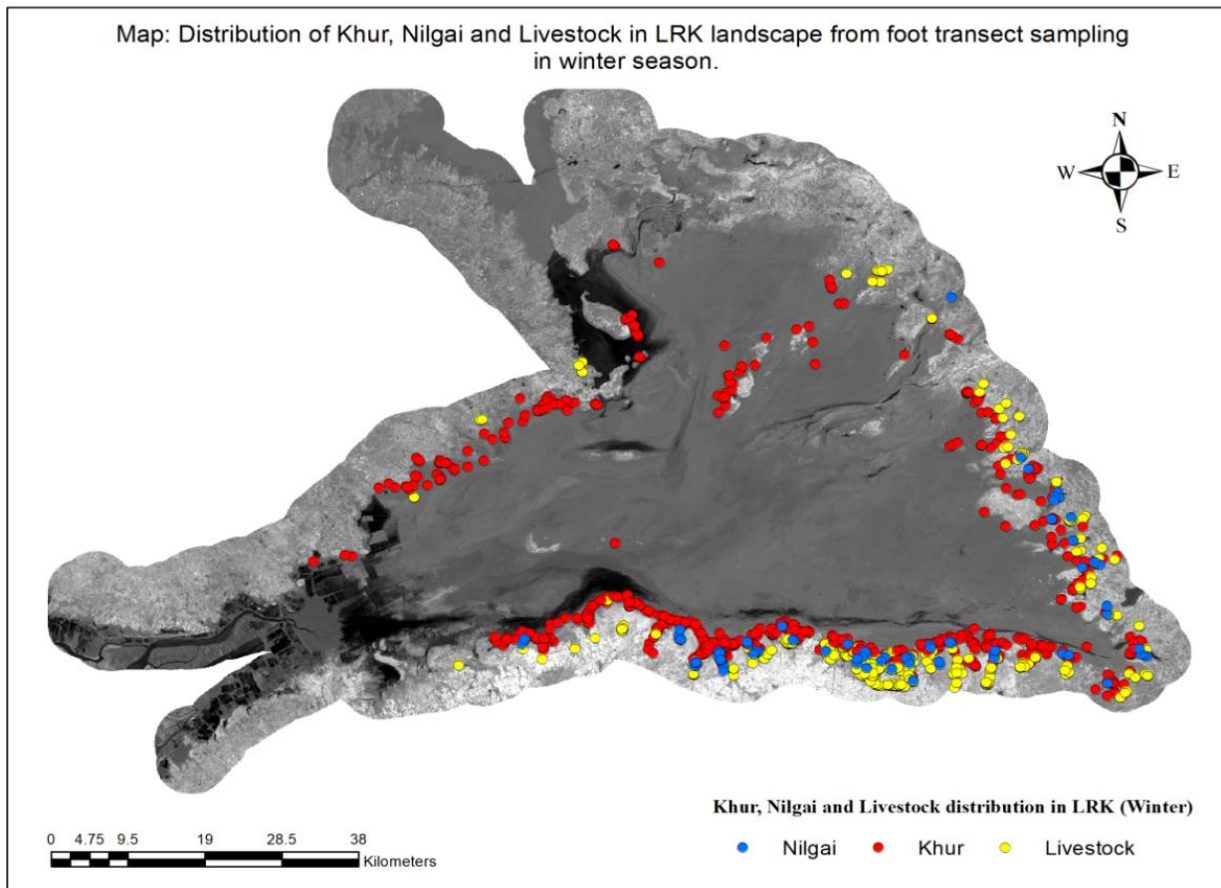


Figure 2.20: Indian wild ass, Nilgai and Livestock distribution in LRK landscape from pooled foot transect sampling during winter season in 2012-13 & 2015-16.

Also, forage species of Indian wild ass and livestock differs (see Chapter-3) where the saline grass species were avoided by cattle and buffalo during dry season. In wet season, looking into the overlap on species congregation, it could be assumed that resource rich areas were under lots of pressure. The movement of Indian wild ass outside protected areas could also be assumed as reduction in access to good forage patches due to livestock presence would compel Indian wild ass to move larger distances in search of nutrition and water (Tesfai et al, 2021).

Monitoring Indian wild ass population

Foot Transect sampling

The survey results show foot transect sampling is robust in an open landscape like LRK (Table 2.3). The winter season estimates of southern fringe and the larger LRK landscape provided estimates that are close to each other. This shows that density estimates have not changed over a period of 3 years from 2012-13 to 2015-16 as large mammal population does not change noticeably within a short span of time (Caughley and Gunn, 1993). To estimate the population density of Indian wild ass and Nilgai, it is not necessary to sample entire

landscape. Instead, a smaller area with better habitat condition could be sampled in shorter intervals.

Table 2.3: Indian wild ass population estimated by Distance sampling and total count

LULC 2014-15		Distance sampling				Total count
Study area	Area	Density	Confidence Interval	2015-16 Winter Population	Population Range	2014 Winter (Department census)
Southern fringe	213.4	3.68±0.74	2.03 - 6.32	785	433 - 1348	1145
LRK landscape	1065.48	4.13±0.87	2.74 - 6.22	5316	2919 - 6627	4451

The southern fringe of the landscape is the most convenient in terms of logistic limitations of the sanctuary. The vast sanctuary with a handful frontier forest staff is always difficult to survey regularly. Therefore, the southern fringe with better road connectivity to each and every village should be considered as the critical habitat which needs intensive monitoring. I assumed that vehicle transect would be best for continuous monitoring of the population but the lacuna in the survey design appeared to be affected the estimate. With proper survey design, vehicle transect method could be adopted for quicker sampling followed by foot transect sampling at a regular interval. The issues with vehicle transect is discussed in the following section. Forest department organises Indian wild ass population census at every 5 years covering about 15000 square kilometre area (Census report, 2014). This mammoth task involves large man-power let alone the anomalies that remain unattended in estimating the total count of animals. Since, the purpose of such census is to monitor population status and such survey method does not report the population density, we could always fail to understand if there is any change in their population structure. Also, the monetary expanses involved in implementing large scale census exercise could also be avoided by adopting scientific method. Distance sampling method is an efficient technique of sampling animal population (Buckland et al., 1993, 2001, 2008 and Anderson et al., 2013) and it appeared to be efficient in such open landscape of LRK. The estimated population density for southern fringe and entire fringe areas of LRK landscape gave us the total population of Indian wild ass in the said areas (see Table-3). However, a trained team of forest staff could walk established foot transects and monitor fringe wise Indian wild ass population. It is advisable to monitor southern fringe population regularly. The southern fringe population is stable and represents the population structure of Indian wild ass in the entire landscape.

Vehicle transect sampling

Although LRK is very vast, the flat terrain allows us to access all parts of the landscape with vehicle. It was appeared to be more efficient in surveying large areas with lesser man power. Foot transect samples were laid across the fringe starting from village to rann covering all the habitat types. Whereas in vehicle transect, the samples were along the fringe running through the vehicle trails covering mostly open rann habitat. In addition, I chose to do the sampling towards the late afternoon because after observing the animals and their movements I concluded that animal detection would be more if I start the survey during late afternoon and it should be along the fringe in open Rann area. But this survey design left major fringe habitat, i.e., the scrub-land adjoining crop-fields unattended. The transects laid over the vast plain rann to survey the bet areas were long with very poor encounter rate, since Indian wild ass is mostly absent from non-vegetative saline plain areas. Density estimates come lower than foot transect estimates. Mean cluster size and encounter rate were also lower than I observed in foot transect estimate. The summer vehicle transect in southern fringe were laid in a zig-zag manner starting from on village and ending in another neighbouring village covering all the habitat types including agricultural areas. The density estimate was found similar to the foot transect estimate. The encounter rates were also very close to each other (Table 2.4). The distribution points of Indian wild ass from southern fringe from both the survey methods during both winter and summer season shows the distribution of both foot and vehicle transects along the fringe (Figure 2.21). The summer encounters of Indian wild ass from vehicle transects showed Indian wild ass observation close to the villages where as the Indian wild ass encounters from winter vehicle transects gave only Rann observation points since the transects were laid close to Rann leaving the habitats close to village.

Table 2.4: Density estimates of Indian wild ass from foot and vehicle transect in winter and summer

Parameters	Foot_Winter		Vehicle_Winter		Foot_Summer		Vehicle_Summer	
	Estimate	%CV	Estimate	%CV	Estimate	%CV	Estimate	%CV
Density	4.45±0.61	13.82	2.05±0.59	28.72	1.74±0.52	29.95	2.48±0.76	30.46
Enc. rate	0.25		0.27		0.2		0.17	

For future monitoring, vehicle transect could be done following the summer transect design. The length of transect in summer design were also similar in comparison to winter vehicle transects where lengths were much larger. In zig-zag manner, uniform transect lengths could be maintained whereas for transects parallel to the fringe it was difficult to maintain. Also,

the distance between fringe and bets could be excluded from transect, rather transect in bet areas should be laid separately covering only the bets.

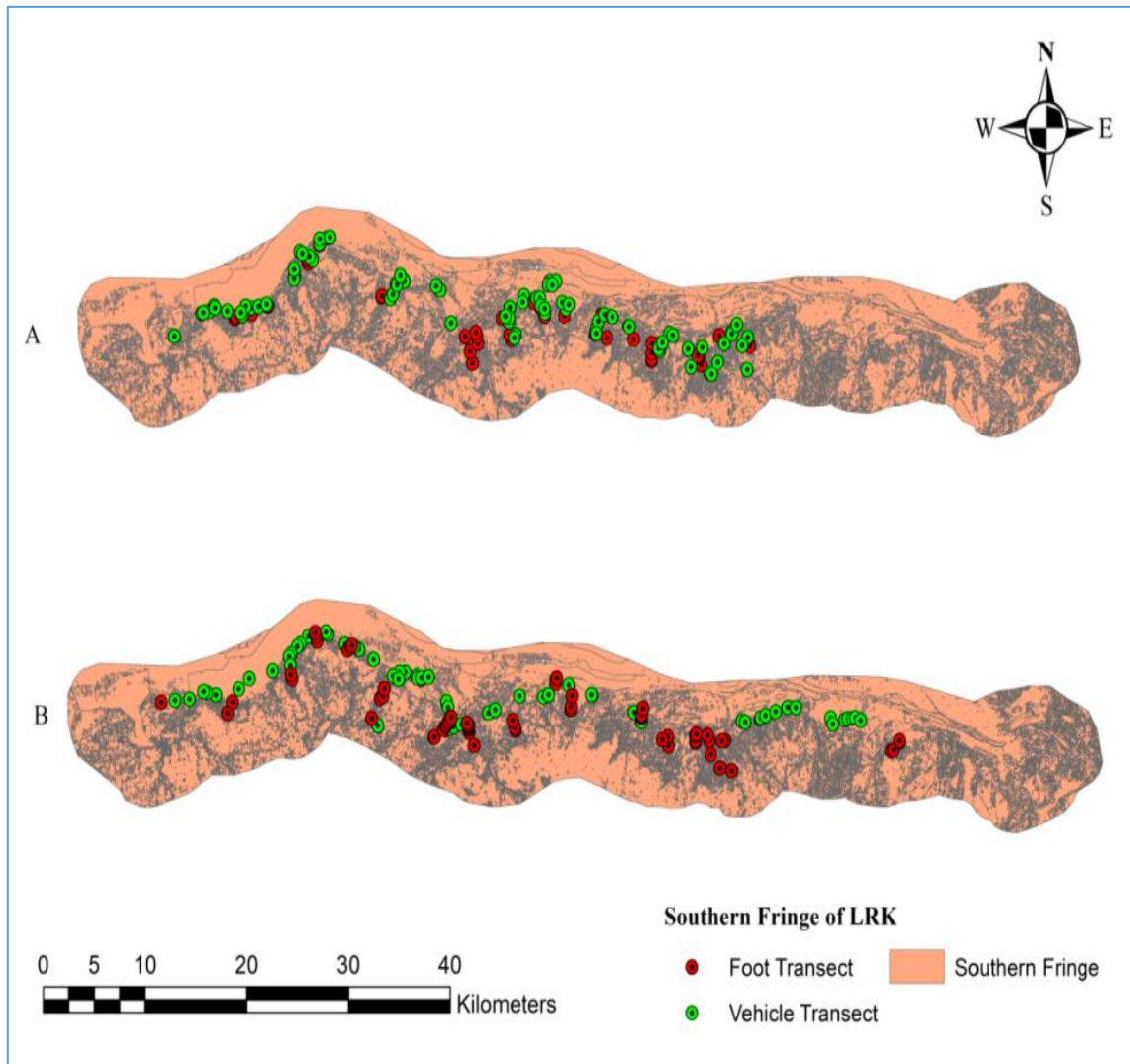


Figure 2.21: Indian wild ass distribution points from foot and vehicle transect sampling along the Southern fringe in (A) Summer and (B) Winter where distribution of animal locations varies

The vehicle transects for population estimation carried out following an appropriate design could be more useful at the landscape level. It was expected that with low man power and to cover large landscape vehicle transects on motor bike or car could be more economical. Since, more replicates of vehicle transects were not achieved during the survey, it is advisable to exercise the vehicle transect method to standardise the robust design. However, the foot transect method should be exercised regularly in the southern fringe because of the available logistic support and convenient approachable road network to each village.

Chapter 3 Habitat preference of Indian wild ass and Nilgai in Little Rann of Kachchh landscape

Introduction

Habitat is one of the most widely used in ecology which can not be used to express one certain meaning, rather it is used interchangeably to characterise biome, ecosystem, spatial entity and forage patch and all these habitat characteristics are represented by species and population of interest (Morris, 2003). Any species or animal population chooses its habitat based on resource availability, abundance of conspecific and interspecific competitors, risk of predation, parasitism and disease to maximise its population growth (Morris, 1987; Ben-shahar and Skinner, 1988). In a particular geographical region, it is important from management point of view, to know different habitat factors that influence resource selection strategies of animals; however, resource choice is a hierarchical behavioural response to environmental factors shaped by evolutionary and ecological processes (Cody 1985) and their differential use allows species-coexistence (Rosenzweig 1981).

Habitat selection by ungulates is a function of several attributes, among which forage availability, mate availability and predation risk are of major importance (Jarman, 1974). Sympatric ungulates tend to co-exist owing to the fact that their resource selection are different or non-limiting and segregation among them occurs at fine scale for some resources (Darmon et al, 2012). The habitat selection process influences the abundance and distribution of these ungulate species and largely contributed to the effective conservation and management (Van Beest et al, 2014). It is important to quantify the habitat selection pattern of sympatric ungulates occupying the same landscape to understand the mechanism of niche selection which eventually may lead to co-existence (Hutchinson, 1959). Besides, utilization of similar resources at temporal and spatial scales is opposed to co-existence therefore a species preference of one habitat over others changes in different seasons depending on the population densities of species (Van Beest et al, 2014).

Arid and semi-arid environments cover 17% of world's environment and accommodate 25% of terrestrial vertebrate species which includes many charismatic and threatened ungulate species (Cook et al, 2016). Resource scarcity and their patchy distribution are major characteristics of arid and semi-arid landscapes. Resource distribution could be unpredictable, varying not only between habitats but also in seasons (Nandintsetseg et al, 2016). Large ungulates adapted to live in such environmental conditions are either nomadic or resident.

Owing to the resource scarcity and patchy distribution of forage habitats, they tend to move longer distance or occupy available resource patches (Roshier et al, 2008). Predicting the distribution of animal population over a presumed habitat specific to that population using habitat mapping tool is widely accepted by wildlife management (Morris et al., 2016). It is important to identify various habitat categories which has been used by the species or holds potential distribution of the species of interest (Morrison, 2001; Smith et al., 2013). In addition, the spatial scale of habitat categories are dynamic to change, especially in human dominated landscapes where anthropogenic developments like agriculture, encroachment plays crucial role in affecting species decision towards resource use (Hoare, 1999; Hoare and Du Toi, 1999; Matawa et al., 2012). Several studies have indicated the use of habitat modelling with machine learning approach using spatially explicit modelling apart giving relevant and precise prediction in areas where resources are limited and unpredictable (Sander et al., 2010; Rainho and Palmeirim, 2011; Polansky et al., 2015). These modelling not only include potential habitat qualities but also species' biological information like body size, homerange, etc. to understand the utilisation pattern of available resources (Rainho and Palmeirim, 2011). In semi-arid areas during dry season, species like large herbivore tend to move larger distance to use sparsely distributed resources (Kaczensky et al., 2008; Kaczensky et al., 2010). To model habitat suitability in areas with limited resource availability, distance between environmental variable and species locations is essential in designing essential to accurately predict preferred and preferable habitat (Rainho and Palmeirim, 2011; Sappington et al., 2007; Gibbon et al., 2007).

There are seven species of wild equids, of which four live in Africa and three live in Asia in open, grass or scrub dominated landscapes of arid ecosystems (Moehlman 2000, 2002). Asiatic wild asses are primarily adapted to live in desert or semi-desert ecosystems where water is available only in the wet seasons and remaining dry during rest of the year, this necessitates them to adapt to a life-style away from water and venture forth to better exploit resources that vary with space and time (Kaczensky et al, 2008). Wild ungulates might need to widen their dietary preferences to maximize their energy intake in dry season when quality and quantity of forage decline (Shi et al, 2016). In Little Rann of Kachchh, the landscape is harsh, with unpredictable climatic conditions with a high anthropogenic pressure. Resources for ungulates are restricted to the fringe scrub-lands and patchy grasslands. The changing land-use practices might alter the resource regime of Indian wild ass and other sympatric ungulates in the landscape. Crop-fields could contribute to their resources greatly, since with

better irrigation facilities, the wastelands and fallow-lands are being increasingly converted into contiguous crop-fields. In this chapter, I have discussed the different land covers and attempted to understand the resource selection of Indian wild ass and Nilgai and their preferences. For the long term conservation management, it is necessary to identify the used and preferred resources of Indian wild ass and Nilgai.

Methods

Land cover mapping

To identify land cover categories, a supervised maximum likelihood classification of satellite images was conducted using training sites which were known from field reconnaissance (Hepner et al., 1990; Bellis et al., 2008; Razafinimaro et al., 2021). Firstly, after reviewing satellite images of LANDSAT-8 from productive season (October) in the year 2014 and corresponding dry season (May) in the year 2015 in open source USGS platform (EarthExplorer, <http://earthexplorer.usgs.gov>), the selected images were downloaded (Figure 3.1). Two scenes (images) were selected based on clarity to cover the entire LRK landscape from each year. Total four sets of images downloaded, each pair from each season, i.e. from productive season (October, 2014) and dry season (May, 2015). The LANDSAT-8 scenes are comprised of 11 bands.

In the second step, I have first processed images for October, 2014 (productive season) by layer stacking 1st to 7th bands of each image into a composite raster image in ERDAS IMAGINE 2016 software. Both the images were again stacked with the 8th band (panchromatic) of respective images to improve the spatial resolution of each image (Ahmed, 2021). The images were then merged to get one single raster image for October, 2014. This process was repeated for May, 2015 images. In the third step, Principal Component Analysis (PCA) was run on both October and May images to draw out major band components which hold all the necessary pixel information. Based on Eigen value of each component, 3 higher ranked bands from each image was selected. The selected bands from both years were stacked together and a single raster image (comprising 6 bands) with all the necessary pixel information was created. In the fourth step, unsupervised classification was done in ERDAS software by giving 250 training classes where nearest pixels were clustered together to divide entire raster into 250 sets of class (k-class) to give an unsupervised raster image. In the next step, supervised classification of the unsupervised image was done. In supervised classification, the image was analysed by providing training sample sites to those 250 classes

to represent various land cover types of the study area. The training sets specific to a land cover type were designated to different unsupervised classes based on the knowledge of the area acquired from field surveys. During this process, Google Earth image was also compared as a reference layer to cross-check the working raster with the land cover of that period to correctly categorise pixels to different land cover classes. The training sites which were then used to check the accuracy statement of classification the final thematic land cover map was generated (Prasad et al., 2015). The raster was converted into polygon in Arc Gis 10.7.1 software to calculate area of each land cover polygons (Figure 3.1). For the mapping, the Indian wild ass Sanctuary boundary polygon was used overlaying a 4 km buffer around it.

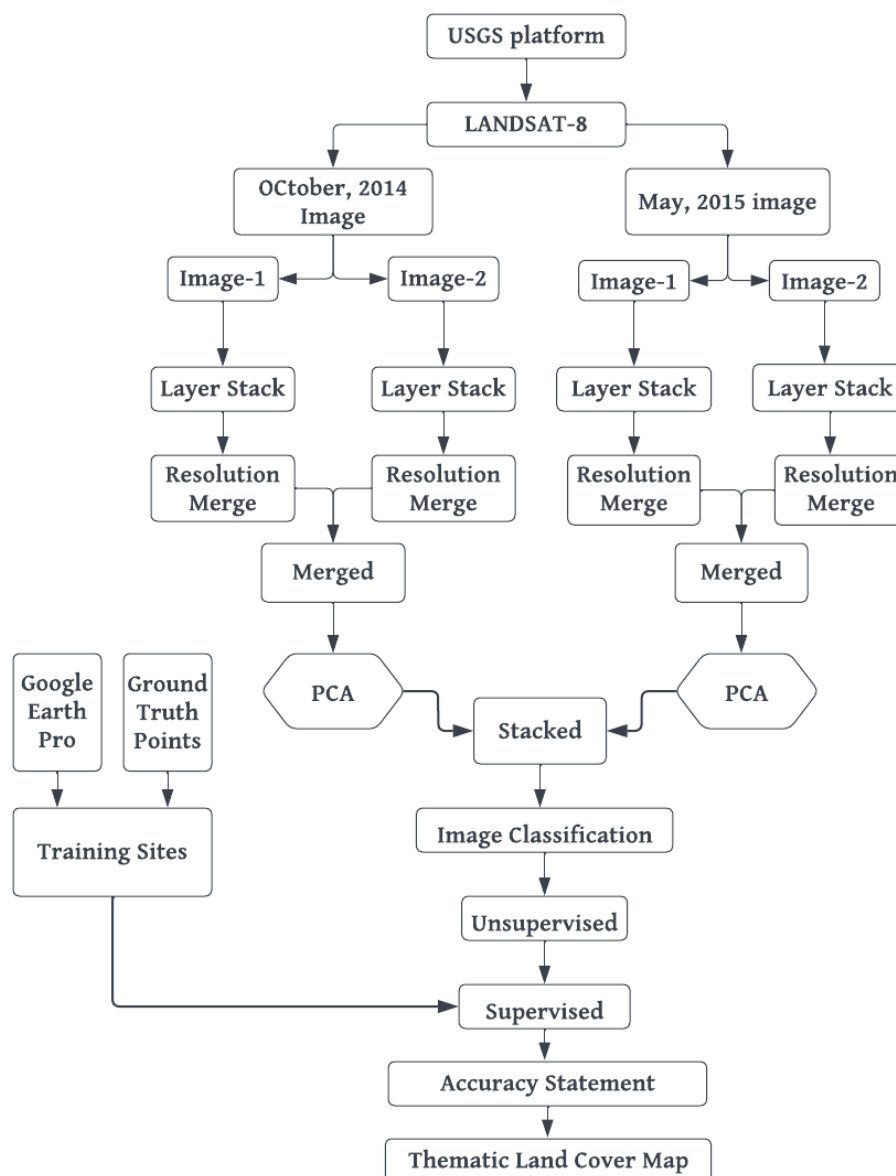


Figure 3.1: Flow chart showing the approach followed for land cover mapping

Habitat use and selection pattern

To understand the habitat use and selection pattern of Indian wild ass and Nilgai in different habitat categories, design-I of sampling design described by Thomas and Tailor (1990) was selected to evaluate use and availability of resources. The presence only location of Indian wild ass and Nilgai was used to see the proportion of species presence over respective habitat or land cover categories (Table 3.1). The habitat use was measured by the proportion of Indian wild ass and Nilgai in each habitat category. The availability of habitat category was measured as area proportion of each habitat categories in respect to the total study area, i.e., the total area of the landscape.

Table 3.1: Used and available resource data of wild ass and Nilgai used to calculate Manly's selectivity index for both winter and summer seasons in Little Rann of Kachchh landscape.

Season	Habitat type	Used	Available	Used	Available
		No. of WA	Area proportion	No. of Nilgai	Area proportion
Winter	Scrub_low	405	217.58	123	39.14
	Scrub_med	369	147.31	46	26.50
	Scrub_dense	74	171.73	50	30.89
	Barren land (Rann vegetation)	1189	1332.64	95	239.70
	Moist barren	822	509.97	174	91.73
	Agriculture	104	592.98	21	106.66
	Fallowland& Fallowland with sparsh vegetation	117	107.79	9	19.39
Summer	Scrub_low	38	44.44	15	11.52
	Scrub_med	77	30.08	31	7.80
	Scrub_dense	102	35.07	34	9.09
	Barren land (Rann vegetation)	94	272.15	24	70.53
	Rann_moist	233	104.15	39	26.99
	Agriculture	69	121.10	12	31.38
	Fallowland& Fallowland with sparsh vegetation	15	22.01	8	5.70

Crop-raiding pattern

Crop-field survey was conducted in 14 villages in the Intensive Study Area (see study area, chapter-I), i.e. in southern fringe. All types of observed crops during the study period were surveyed. All the crop-fields selected were close to the fringe scrubland or the Sanctuary boundary. The size of the crop-fields were mostly marginal (less than 1 ha or 2.47 acre) followed by small (1 to 2 ha or 2.47 to 4.94 acre) landholding (Ministry of Agriculture and Farmers Welfare, Government of India, 2019) A recky survey was conducted to gather information on type of crops and location of crop-fields. The crop types were sampled based on their abundance, i.e. crops which are practiced more or stayed longer period of time to harvest were sampled more in number followed by other crop seasonal crop types. The sampling of standing crop was done following quadrature sampling method (Kreb, 1999; Engemen and Sterner, 2002) where quadrature size was adopted based on the crop types and kept it uniform for all kind of crops (Figure 3.2). Total 5 randomly placed quadrature of 5m x 5 m size were placed where 4 quadrates were placed at each corner of rectangular crop-field at random location and 1 plot was placed at the centre. The crops were sampled based on their phenology. For all the crops, three phonological stages, namely seedling stage (after germination at 2 to 6 leaves stage), immature or intermediate stage (when branching starts) and mature or pre-harvest stage (fruiting stage in the process of maturing) were identified (Dave, 2010; Gross et al., 2018). Each phonological stage was sampled for one time in each crop type. During sample in each quadrature plot, presence of wild herbivore signs like foot print, dung dropping, browsing and trampled marks was recorded. The species responsible for visible crop damage was also recorded based on the foot print and damage time. In case of the presence of more than one herbivore sign at damaged plot, then the species responsible for the damage was not mentioned.

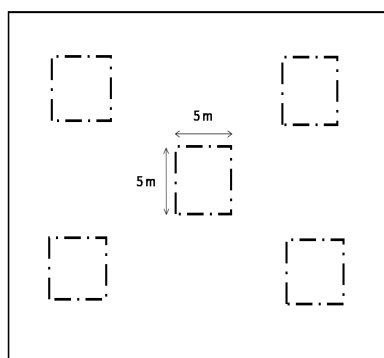


Figure 3.2: Diagrammatic representation of Quadrature Sampling design to study crop-raiding pattern

To determine the crop raiding pattern by wild herbivore during night, a pair of trap camera was installed. Due to logistic constraints and limitation of time, only one crop-field of Sorghum crop was sampled. This limited study was to see which animal visits during night and its raiding frequency.

Data analysis

Pattern of crop-raiding

To see the pattern of crop-raiding by Indian wild ass, Nilgai and wild pig, the frequency of their presence in each crop during each survey was calculated. Bar-plots are prepared to see their preference to any particular crop based on their presence.

Habitat use and selection pattern

Habitat preference

The habitat preference was calculated using Manly's standardised preference index, B_i (Manly et al., 2002). The index is based on the selection ratio $w_{i,s}$ which is the proportional use divided by the proportional availability of each habitat category or resource which could be written as,

$$w_{i,s} = o_{i,s} / \pi_i$$

Where, $o_{i,s}$ = Proportion of the number of individual of species recorded in the habitat category i .

And π_i = Proportion of habitat category i among all the habitat sampled.

The selection ratio ($w_{i,s}$) was first calculated and then the preference index was computed.

The preference index was standardised using Manly's equation,

$$B_i = \frac{w_{i,s}}{\sum_{i=1}^H w_{i,s}}$$

Where, H is the number of habitat units.

If the value of the preference index is greater than 1, the habitat is considered to be preferred by the species, and the habitat is considered to be avoided if the value is less than 1. The value around 1 suggests that habitat was used in proportion to its availability. The most preferred habitats are considered as the key habitats for the species concerned. The data were analysed in program R (R Core Team 2019) using the package 'adehabitatHS' (Calenge 2011).

Habitat suitability

Habitat suitability was assessed by modelling spatial distribution of wild ass and Nilgai in LRK landscape using maximum entropy (MaxEnt) approach (Phillips et al., 2006). MaxEnt model is accepted and practiced globally considering it as a robust and efficient model for predicting species distribution from presence only data (Matawa et al., 2012; Mopushi et al., 2016)). I execute one common model for both wild as and Nilgai based on NDVI, distance from village, distance from water, land cover and distance from salt-pans. All the fringe villages, natural and artificial water points and salt-pan areas in the landscape were digitised in Google Earth Pro and imported to ArcGis 10.7.2 software to create shape files. In ArcGis, using Euclidean distance algorithm, the distance of animal locations from the nearest village, water point and salt-pans were calculated (Muposhi et al., 2016). Based on these spatially defined variables, MaxEnt model generates an estimate of probability of presence of the species and predict spatial distribution of the species in the area of interest (Matawa et al., 2012). MaxEnt model is also considered efficient because it is known to give reliable predictions with smaller sample size because of its both statistical and machine learning approach. I have used freely available MaxEnt software, version 3.4.4. All the encounter locations from line transect surveys conducted in 2014 and 2015-16 were used. Opportunistic sightings of both the species were also used to cover maximum area of the study area and assist the model in better predicting the distribution. Total 888 and 97 presence location of wild ass and Nilgai were used. In the model for both wild ass and Nilgai, I have used 70% and 30% of the observation records to train the model and test the performance respectively for wild ass. For Nilgai, 80% observation records were used to train the model and 20% records to test the performance, since Nilgai observations were less than 100. Prior to that, a Principal Component Analysis for all the spatial variables was run to test for correlation among the variables and non-correlating variables were only used in the model (Table 3.2). The model features used for wild ass was linear, quadratic and product where as for Nilgai only linear and quadratic features were used as required in MaxEnt to model relationships between covariates and species abundance. In the model. For both wild ass and Nilgai, 100 bootstrap was run to get the best fit model for each species. Based on the mean prediction of 100 bootstraps, spatial probability map of wild ass and Nilgai distribution is produced.

Table 3.2: Correlation matrix of different environmental variables used in habitat suitability modelling for Indian wild ass and Nilgai in MaxEnt.

Environmental Variables	dist to salt pan	NDVI	Land cover	dist to water	dist to village
dist to salt pan	-0.03081	1	0.123	-0.08828	0.08198
NDVI	0.42509	0.123	1	-0.02956	-0.1718
Land cover	0.15904	-0.08828	-0.02956	1	-0.22104
dist to water	-0.2881	0.08198	-0.1718	-0.22104	1
dist to village	-0.58755	0.1503	-0.22152	-0.02242	0.0626

Results

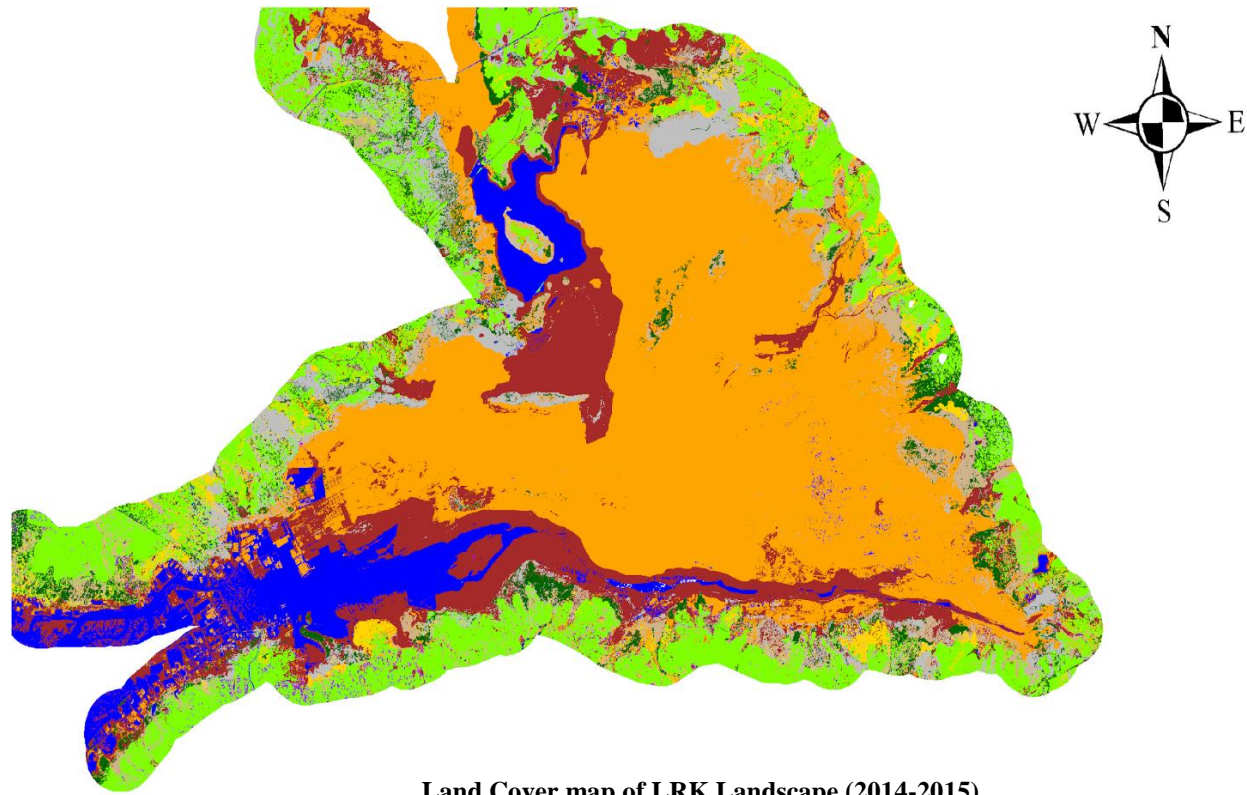
Land-cover of Little Rann of Kachchh

A total of 6668.19 square kilometre area was mapped. Different land cover types described were scrub-low, scrub-medium, scrub-dense, barren land, moist barren land, agriculture, fallow land and water (Figure 3.3). The calculated areas of each of the categories are shown in Table 3.3. Barren land occupied the highest area whereas fallow-land had the lowest area covered in the landscape. Grasslands are very important habitat which is not mapped as a separate habitat category due to their association with scrublands. Following are the classes with description:

1. Agriculture: It includes crop-lands with standing crop or without crop of both irrigated and non-irrigated crop-fields.
2. Barren land: It is the largest class with areas without vegetation. Majority of Rann mud-plain is included in this class; however, barren patches inside fringe are also included.
3. Fallow land: Crop-fields very close to scrub-lands, which were left unattended for several seasons and with very sparse vegetation like grass and scrub.
4. Moist barren land: It included the areas inside Rann and along the fringe with moist and saline soil due to prolonged water logging. Salt pans and salt encrusted areas were also included in this class.
5. Scrub-dense: This class has dense scrub growth predominantly *Prosopis juliflora* forming a dense canopy cover.
6. Scrub-medium: It includes the patches with scrub growth without forming closed canopy. Other species like *Acacia spp*, *Salvadora spp* were present in this class.
7. Scrub-low: It includes the areas where scrub growth is sparse and dominated with grassland.

Table 3.3: Land cover classes and area covered in Little Rann of Kachchh landscape

Habitat	Area (km²)
Agriculture	1177.35
Barren land	2645.95
Fallow land	214.02
Moist barren land	1012.54
Scrub-dense	340.98
Scrub-low	432.02
Scrub-med	292.48
Water	552.86
Total	6668.19



Land Cover map of LRK Landscape (2014-2015)



Figure 3.3: Land cover map of Little Rann of Kachchh landscape

Habitat use by Indian wild ass

Winter

Scrub-medium was the most used habitat type followed by scrub-low, moist barren land and fallow land were other habitat types which were favoured by Indian wild ass during the winter season. Barren land, scrub-dense and agriculture respectively were least preferred or avoided by Indian wild ass (Figure 3.4).

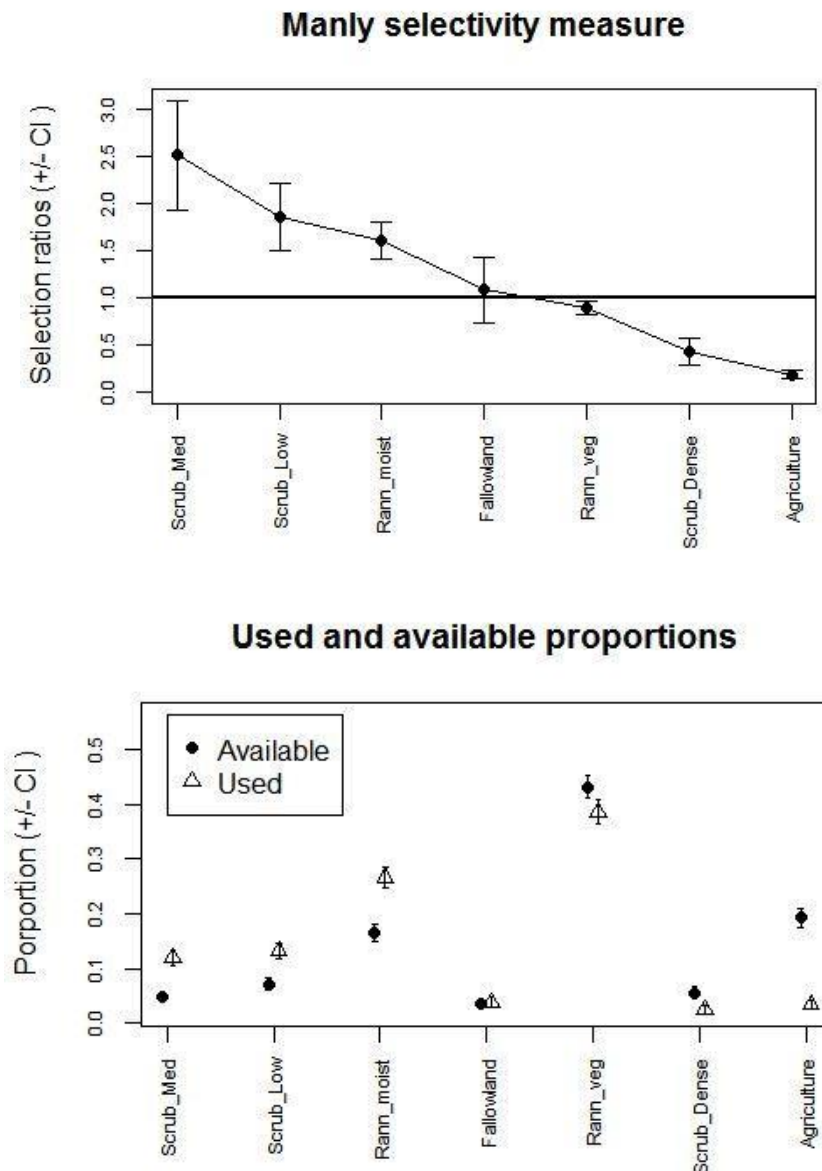


Figure 3.4: Used-availability graph of Indian wild ass in winter season in LRK.

Summer

In summer, scrub-dense habitat type was most favoured followed by scrub-medium and moist barren land was the other habitats which were used by Indian wild ass. Scrub-low, fallow land, agriculture and barren land habitat classes, respectively were not preferred (Figure 3.5).

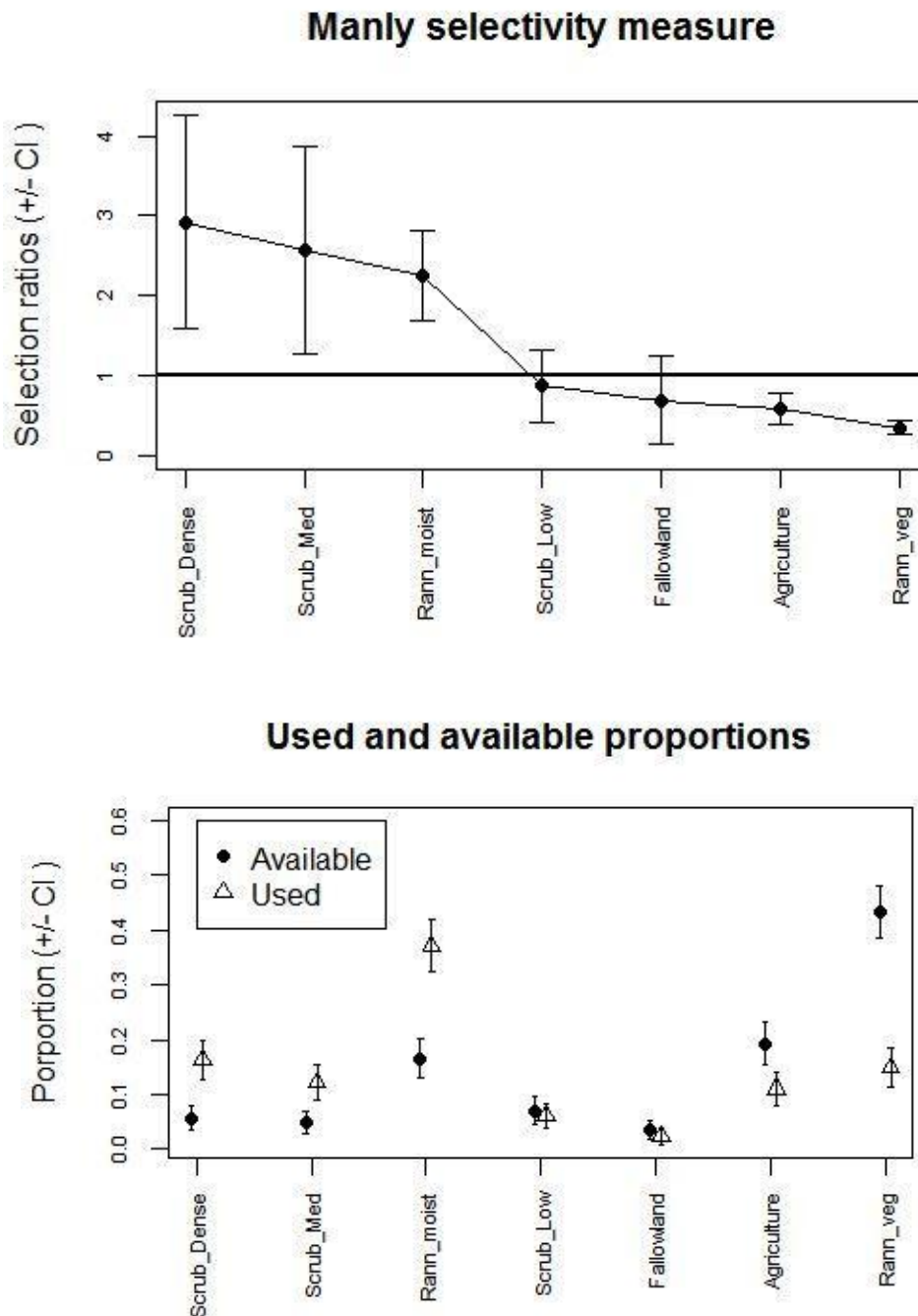


Figure 3.5: Used-availability graph of Indian wild ass in summer season in LRK.

Habitat use by Nilgai

Winter

Scrub-low, moist barren lands, scrub-medium and scrub-dense, respectively were the preferred or used habitat types by Nilgai. Fallow land, barren land and agriculture, respectively were least favoured or not used by Nilgai (Figure 3.6).

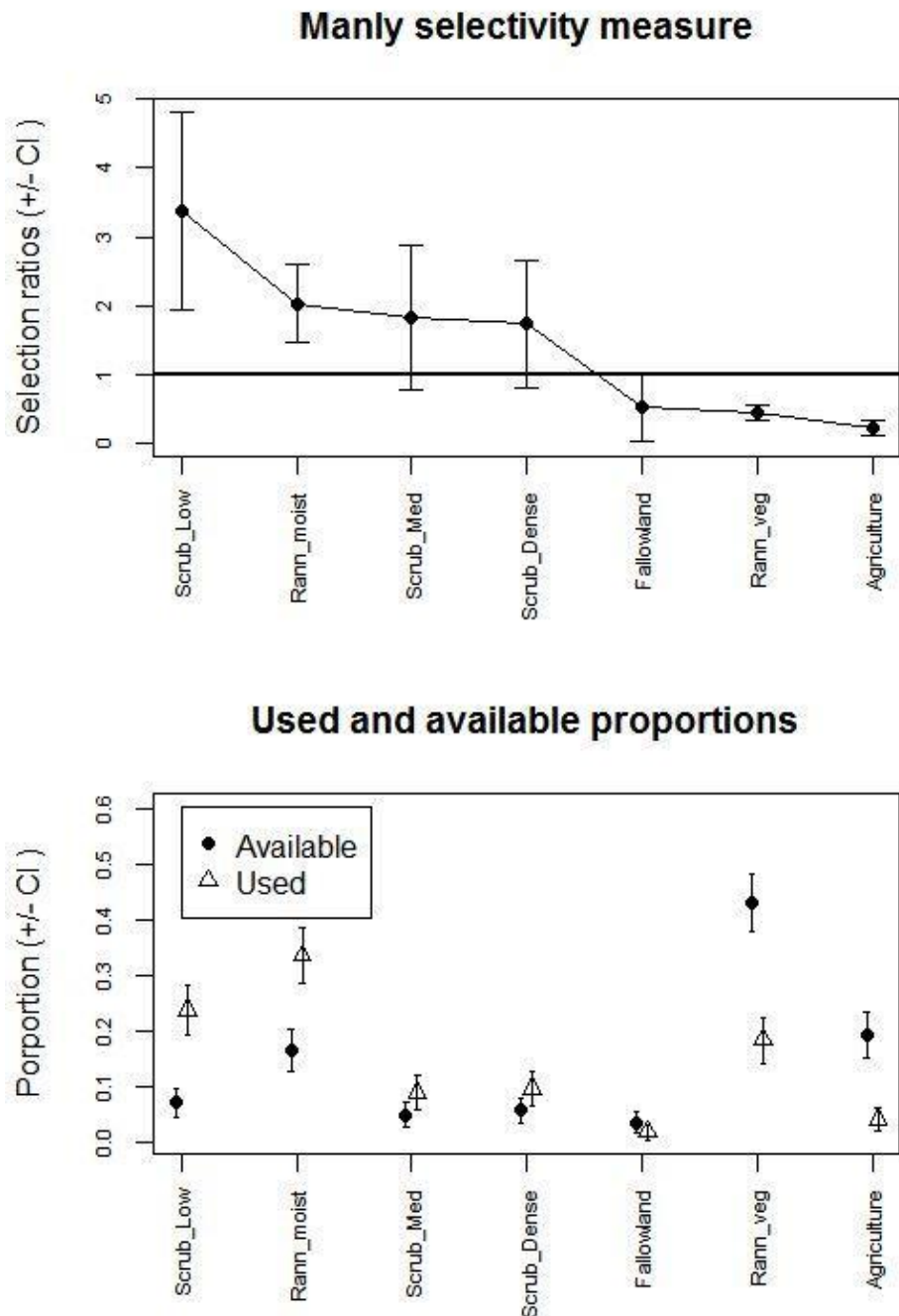


Figure 3.6: Used-availability graph of Nilgai in winter season in LRK.

Summer

Scrub-medium, scrub-dense, moist barren land, fallow land and scrub-low, respectively were preferred by Nilgai in summer. Scrub-medium was the most preferred habitat. Agriculture and barren land were not preferred by Nilgai during the day time in summer (Figure 3.7).

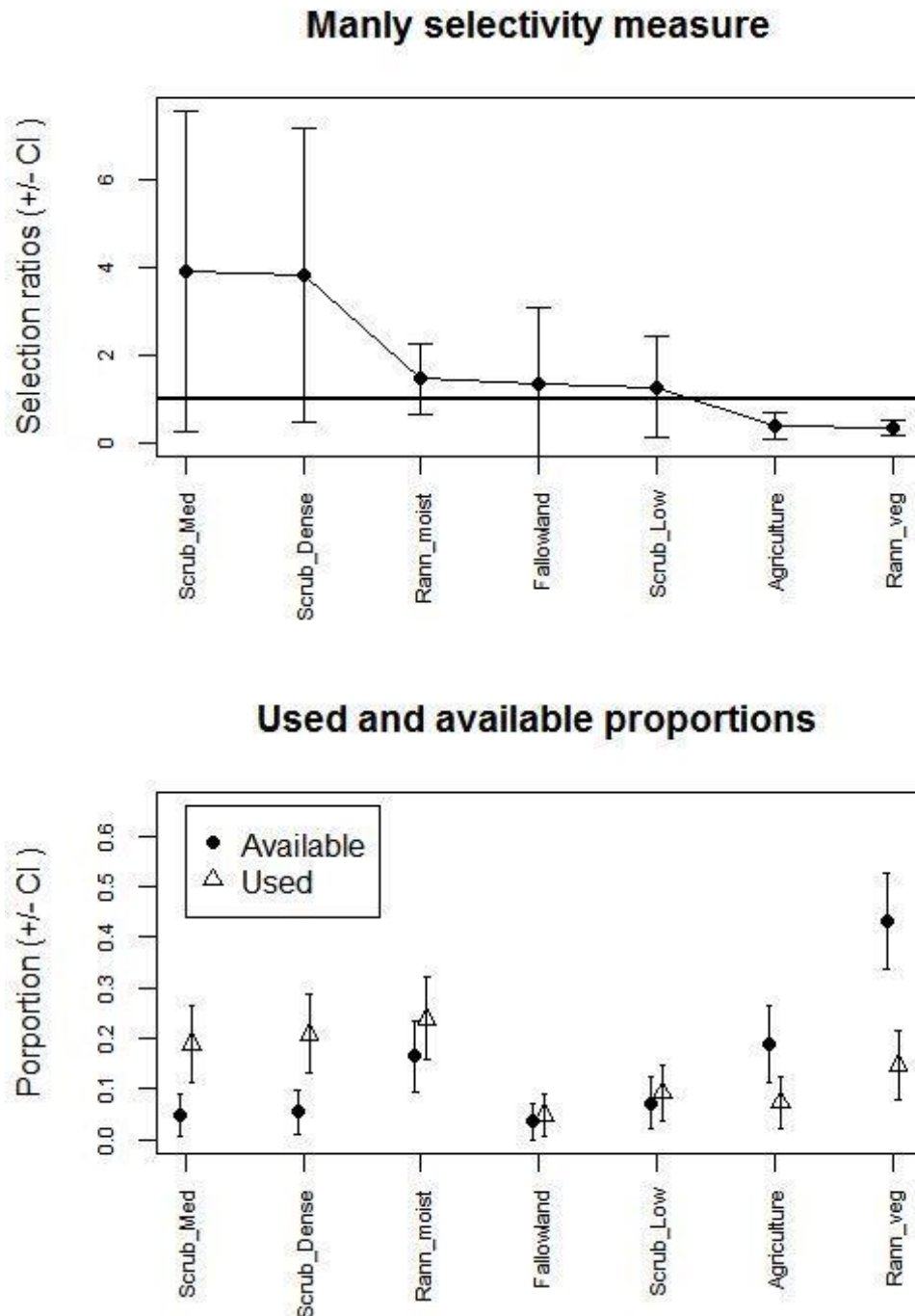


Figure 3.7: Used-availability graph of Nilgai in summer season in LRK.

Habitat suitability of Indian wild ass and Nilgai

The MaxEnt model predicted the probability distribution of wild and Nilgai in LRK landscape and showed the contribution of predictor variables towards selection of predicted resource areas. The model gave an overall prediction irrespective of season, since observation data from all the seasons were used as a combined layer.

Habitat suitability for Indian wild ass

Using 70% of observation data, MaxEnt model predicted southern fringe and south-eastern fringe as most suitable habitat for Indian wild ass. Part of western fringe and north-western fringe also showed strong prediction as suitable habitats (Figure 3.8). Fair distribution is predicted in central part of Rann in bet (island) areas as well.

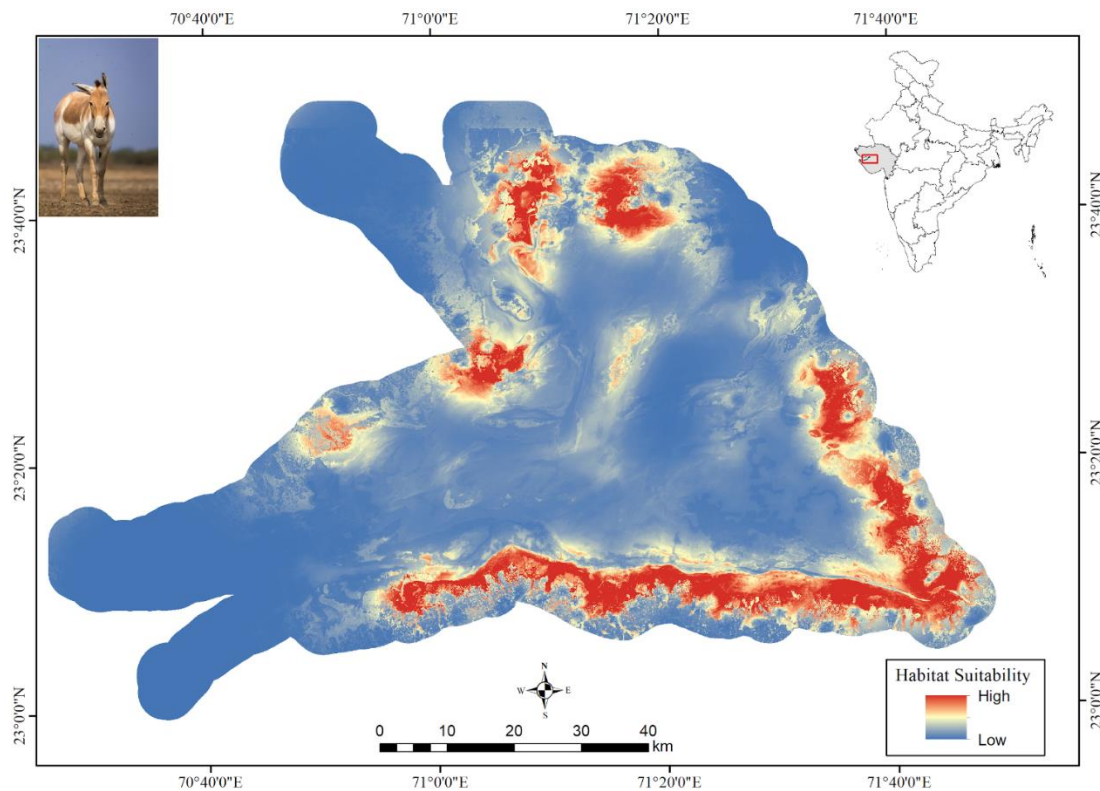


Figure 3.8: Indian wild ass distribution map of habitat suitability in LRK landscape

For Indian wild ass, the prediction of model fitness showed significantly better performance of the model than random ($p < 0.05$, see figure 3.8). The mean AUC from both training and test data is 0.890. The model prediction for both suitable and unsuitable habitat for Indian wild ass is much higher as the area under training (red) and test (blue) curve are much greater than that of the random prediction line shown by black diagonal line (Figure 3.9).



Figure 3.9: Receiver Operating Characteristic (ROC) curve showing training (red) as well as test (blue) data for Indian wild ass distribution prediction.

Maximum contribution to Indian wild ass habitat model was given by distance to village (55.2%). Indian wild ass distribution was further explained by distance to salt-pan (22.7). Other variable like NDVI and distance to water contributed less (Table 3.4). The model explained the unique contribution of all the variable showing their relationships with Indian wild ass distribution (Figure 3.10).

Table 3.4: Percent contribution of different variables towards Indian wild ass distribution

Variable	Percent contribution
Distance to village	55.2
Distance to salt pan	22.7
Land cover	12
NDVI	5.2
Distance to water	5

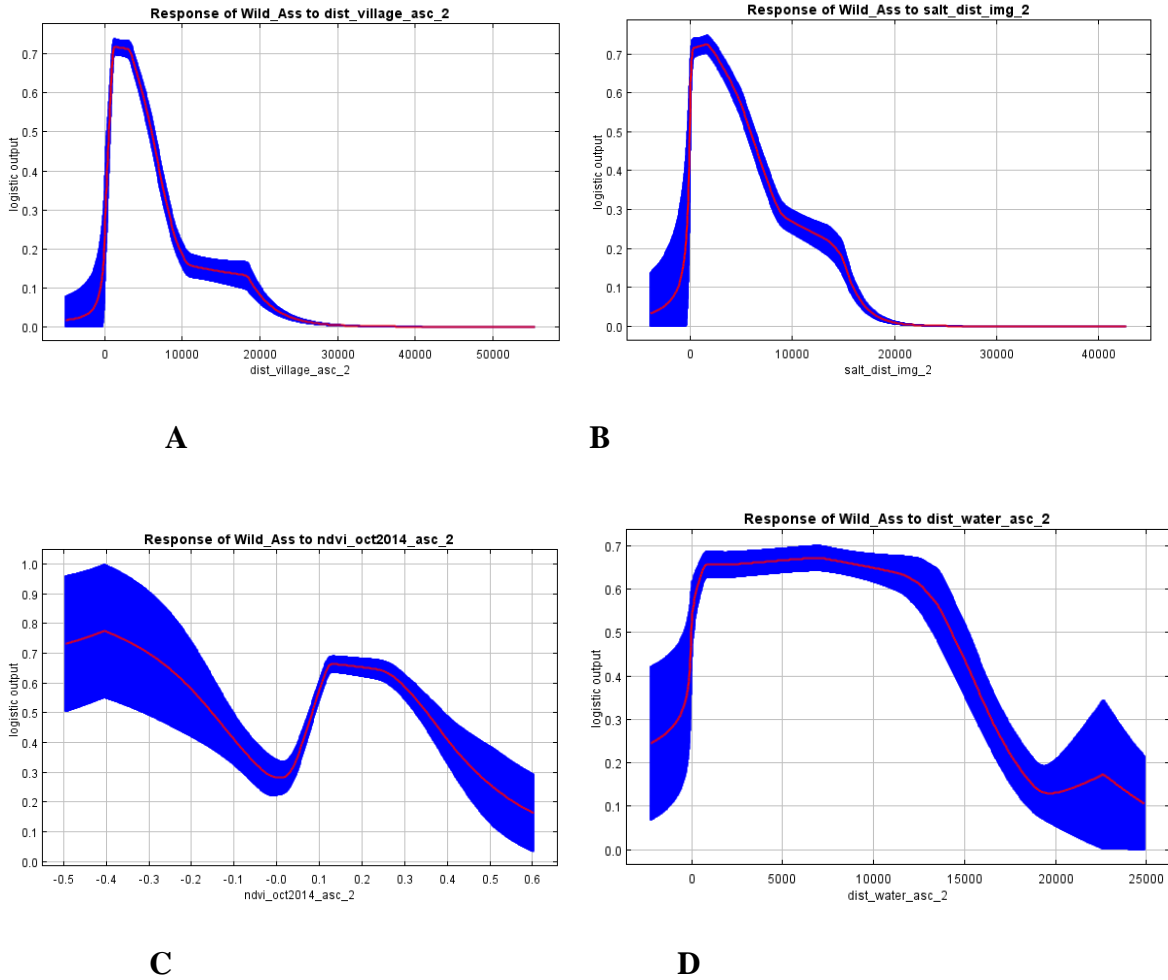


Figure 3.10: Relationship of Indian wild ass with different spatial variable, A. distance to village, B. distance to salt pan, C. response to NDVI and D. distance to water

Jack-knife of variable importance analysis (Phillips et al., 2006) is another illustrator that demonstrated the importance of all the spatial variable in predicting Indian wild ass distribution. It is observed that distance to village showed highest influence in predicting distribution of Indian wild ass (Figure 3.11).

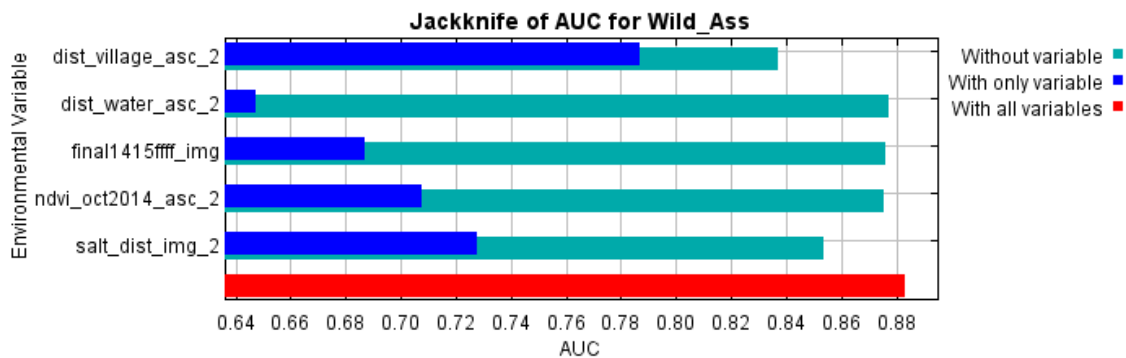


Figure 3.11: Jack-knife test showing the importance of variable in Indian wild ass distribution

Habitat suitability for Nilgai

For Nilgai, after using 80% observation data, the model predicted south, south-eastern, northern and north-western fringe as most suitable habitats. Their presence is completely absent from the bets and other parts of the landscape (Figure 3.12).

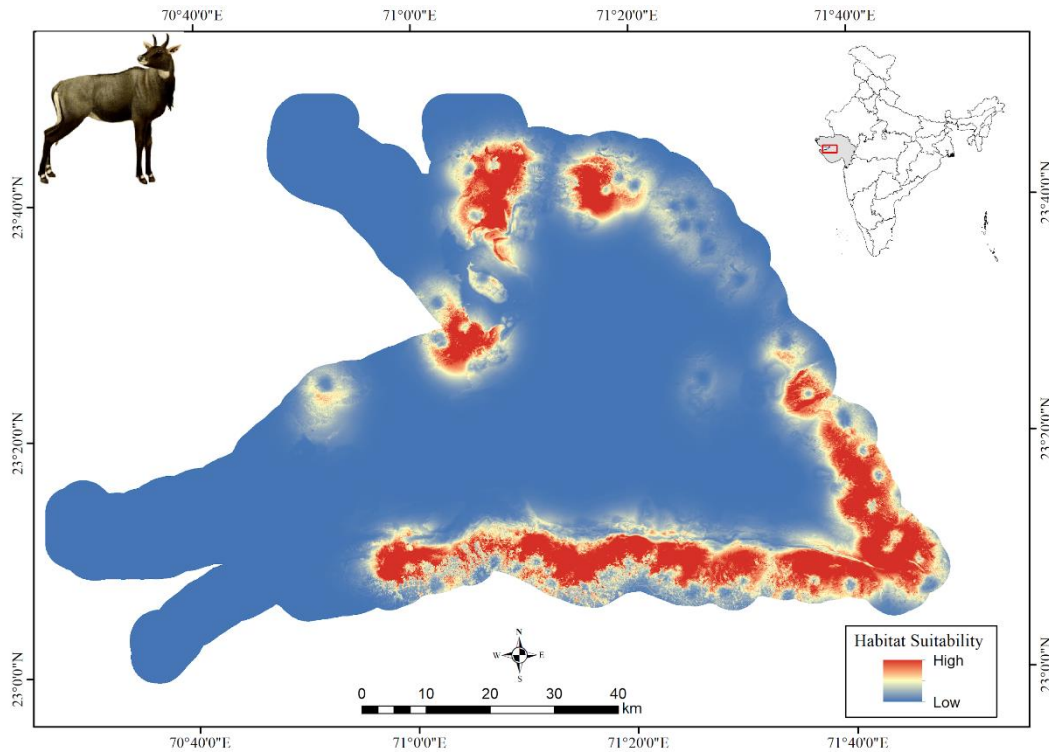


Figure 3.12: Nilgai distribution map of habitat suitability in LRK landscape

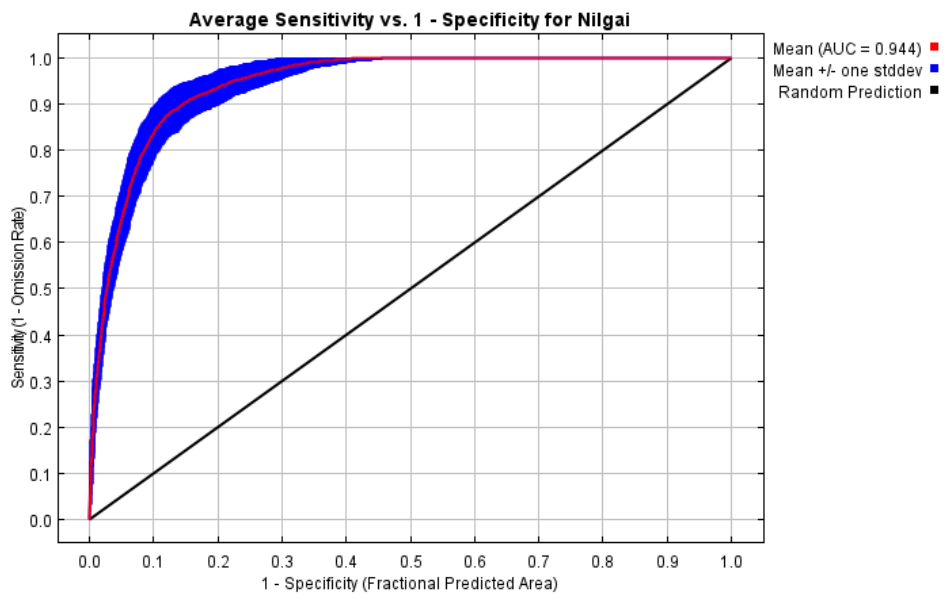


Figure 3.13: Receiver Operating Characteristic (ROC) curve showing training (red) as well as test (blue) data for Indian wild ass distribution prediction.

The model prediction showed much higher performance with AUC 0.94 (Figure 3.13).

Maximum contribution to Nilgai habitat suitability model was given by distance to village (60.9%) followed by distance to salt pan (18.1). Distance to water showed better contribution than response to and cover and NDVI (Table 3.4). The relationships of different variables with Nilgai distribution is explained by the model (Figure 3.14).

Table 3.5: Percent contribution of different variables towards Nilgai distribution

Variable	Percent contribution
Distance to village	60.9
Distance to salt pan	18.1
Distance to water	9.4
Land cover	8.4
NDVI	3.2

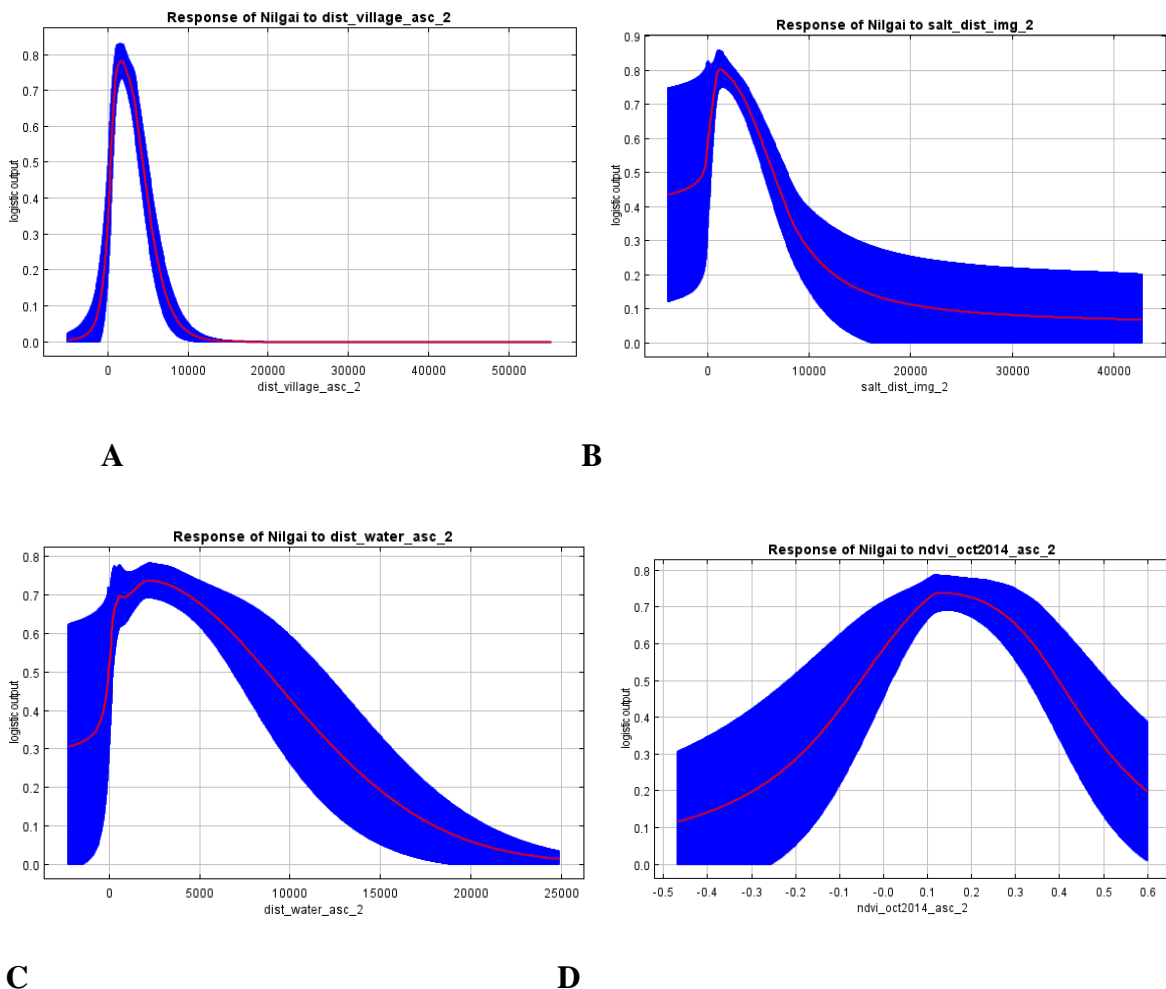


Figure 3.14: Relationship of Nilgai with different spatial variable, A. distance to village, B. distance to salt pan, C. distance to water and D. response to NDVI

In jack-knife illustration, it was observed that distance to village alone contributed to 0.85 AUC and reduced to below 0.65 when distance to village was removed from modelling (Figure 3.15).

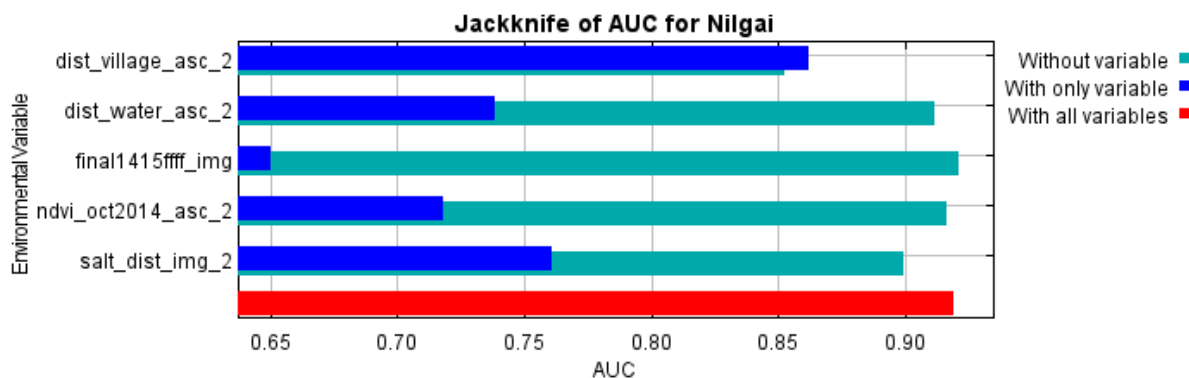


Figure 3.15: Jack-knife test showing the importance of variable in Indian wild ass distribution

Crop pattern

Total 17 types of crop and total 44 crop-fields were surveyed during study (Table 3.6). The southern fringe farmers farm their lands throughout the year as Narmada Canal supplies enough water for irrigation during both winter and summer. Majority of crops were cash crops. BT-cotton (*BT-Gossypium herbaceum*) and cotton (*Gossypium herbaceum*) crops stay for longer period of time. These are sowed in late summer in the month of May-July and last till February. Castor (*Ricinuscommunis*), cumin (*Cuminum cyminum*), coriander (*Coriandrum sativum*), fennel (*Foeniculum vulgare*), cluster beans (*Cyamopsis tetragonoloba*), sesame (*Sesamum indicum*) and mustard (*Brassica nigra*) are the other cash crops. Peanut (*Arachis hypogaea*) and corn (*Zea mays*) are not cultivated regularly. Wheat, mung bean and math bean are food grains regularly cultivated. BT-cotton and cotton are major cash crops. They are cultivated in large scale. Cumin, coriander and fennel are also cultivated regularly as profitable cash crops. BT-cotton is cultivated in irrigated crop-fields only. Indigenous cotton crops are cultivated in non-irrigated crop-fields.

Table 3.6: Different types of crop sampled

Sl. No.	Crop	No of crops	No of plots	Season
1	BT-Cotton (<i>BT-Gossypium sp</i>)	10	50	Monsoon-winter
2	Cotton (<i>Gossypium herbaceum</i>)	5	25	Monsoon-winter
3	Castor (<i>Ricinuscommunis</i>)	3	15	Monsoon & winter
4	Bajra or Pearl millet (<i>Pennisetum glaucum</i>)	3	15	Summer

5	Sesame (<i>Sesamum indicum</i>)	4	20	Monsoon & winter & summer
6	Cumin (<i>Cuminum cyminum</i>)	3	15	Winter
7	Cluster Bean or Guar (<i>Cyamopsis tetragonoloba</i>)	3	15	Monsoon
8	Sesame-cluster bean mix	1	5	Monsoon
9	Jowar (<i>Sorghum bicolor</i>)	3	15	Summer & monsoon
10	Wheat or Gehu (<i>Triticum aestivum</i>)	2	10	Winter
11	Fennel or saunf (<i>Foeniculum vulgare</i>)	1	5	Winter
12	Coriander or Dhaniya (<i>Coriandrum sativum</i>)	1	5	Winter
13	Peanut (<i>Arachis hypogaea</i>)	1	5	Monsoon
14	Maize or corn (<i>Zea mays</i>)	1	5	Winter
15	Math (<i>Vigna aconitifolia</i>)	1	5	Monsoon-Winter
16	Mustard (<i>Brassica nigra</i>)	1	5	Winter
17	Tobacco (<i>Nicotiana tabacum</i>)	1	5	Wintet

Pattern of crop-depredation

Indian wild ass

Indian wild ass raided cotton crop in higher frequency during all phenological stages than other crops. Other than cotton, BT-cotton, sesame and math bean crops were raided by Indian wild ass. Indirect signs of Indian wild ass was not observed in majority of crops (Figure 3.16 a).

Nilgai

Nilgai was observed in all types of crops irrespective of the crop phenology. Sorghum, sesame, pearl millet, castor, cotton and BT-cotton are mostly raided by Nilgai. During seedling and immature stages, Nilgai presence was observed more in these crops (Figure 3.16 b).

Wild pig

Like Nilgai, wild pig also raided all types of crop and during all three phenological stages. Math, maize, clustered beans, pearl millet, cotton and BT-cotton crops were observed to be raided more when crop is mature and fruits present in crop plants (Figure 3.16 c).

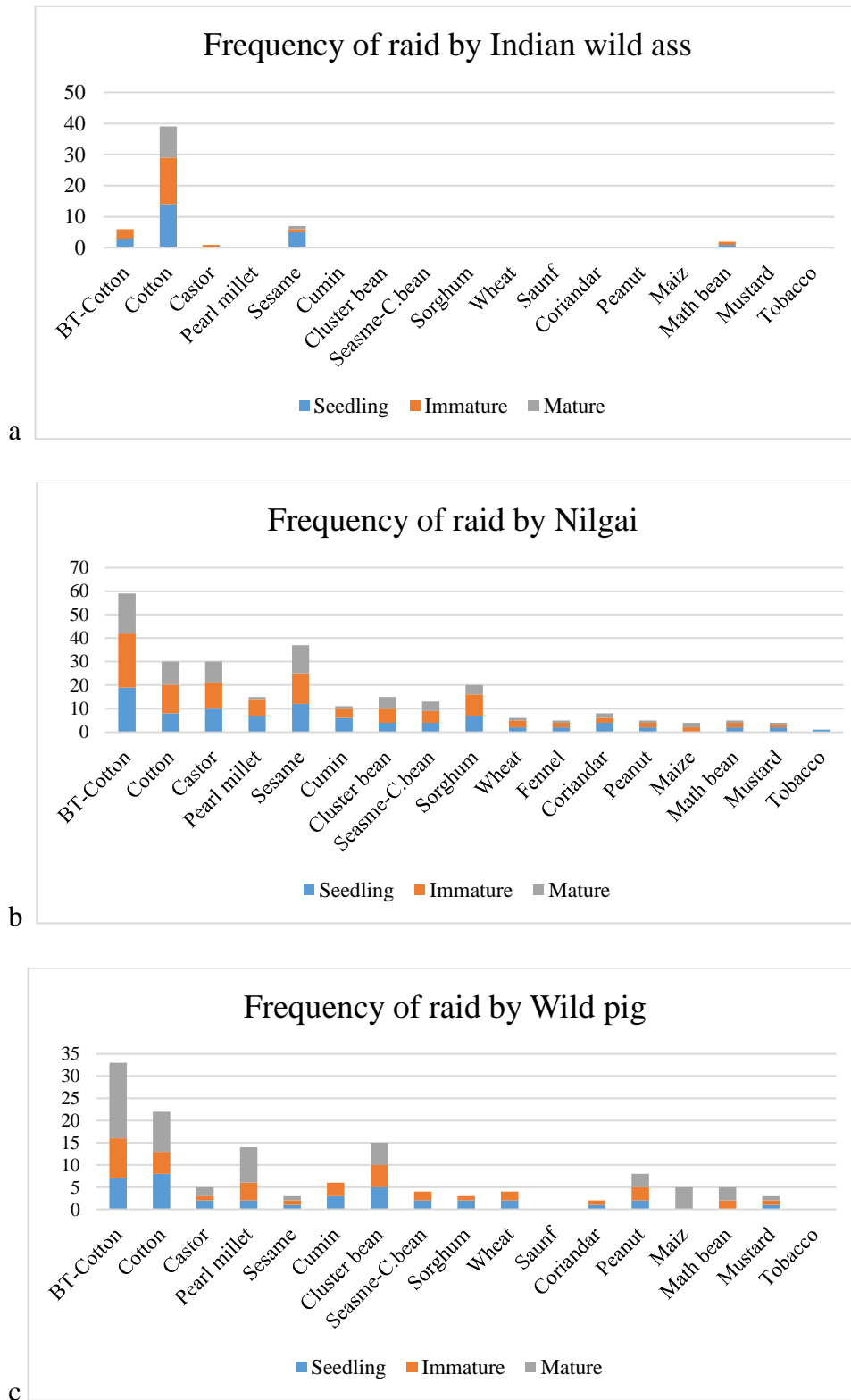


Figure 3.16: Frequency of raid by a) Indian wild ass, b) Nilgai and c) Wild Pig in different crop-types during different phenological state

Monitoring crop-raid at night

Total 16 sessions of camera trapping was conducted at a shorghum crop-field adjacent to the fringe scrub-land. The raiding events were captured on 4 occasions where only Nilgai was captured. No evidence of other animal was observed in the camera trap effort. According to the farmer of that crop-field, Nilgai had visited his crop every night of which they were captured only on 4 nights. The captured events were occurred between 22:24 to 07:10 hours. Captured images revealed that all the individuals were male suggesting bachelor bands of Nilgai was responsible for raiding and damage. Nilgai broke or damaged his electric fence regularly but Indian wild ass was not reported by the farmer as having damaged the fence (see chapter-IV on farmer's perception on crop-raiding by Indian wild ass and Nilgai).

Discussion

Habitat map is essential to understand the structure of the landscape by relating it to the real features on the ground. Arid and semi-arid landscapes are represented by extreme climatic conditions limiting resource availability that govern the distribution of species population (Holmgren et al., 2006; Pontifes et al., 2018; Pumo et al., 2019). Little Rann of Kachchh landscape has very high evapotranspiration rate (Shah, 1993; Shah and Qureshi, 2007) coupled with limited rainfall largely reduces the availability of palatable water resource (Rubenstein et al., 2007; Khandelwal et al., 2012) for animal population. Mapping water resource in the landscape is therefore of utmost importance to understand the distribution pattern of Indian wild ass and Nilgai. Agricultural upliftment in the region due to extensive canal irrigation resulted into rapid land cover change. Encroachment into newer landform or converting abundant wasteland into agricultural land is quite common in the region with large population of marginal farmer. In a previous study by GEER Foundation, Gujarat (1999), the land-use land-cover (LULC) map was prepared which largely classified scrubland into a single category. In this study, scrubland is categorised into three different habitat classes based scrub abundance, i.e., scrub low (432 Km²), scrub medium (292.48 Km²) and scrub dense (340.97Km²). This has helped in addressing Indian wild ass and Nilgai distribution in all the three habitat categories. It is also important to see if there is any seasonal variation in use and availability of these resources. Vast majority of the landscape is barren (2645.9Km²) without any vegetation, which largely provides shelter to Indian wild ass population as observed from surveys. Moreover, accuracy statement for land cover mapping is crucial, especially it become a challenge to achieve accuracy above 80% in semi-arid landscapes

where accuracy tend to remain low (Ref). The grassland patches and sparse scrublands matches with the barren land reflectance and resulted into misclassification. Sufficient field data from all the habitat categories is important apart from Google Earth image and following rigorous recoding, a desirable accuracy is achieved.

Habitat use by Indian wild ass in LRK

In LRK, the fringe productivity gradually starts declining towards the winter but Indian wild ass could utilise the scrub-land with medium and low scrub growth to forage on available grass species (Shah, 1993). During the study, Indian wild ass population demonstrated seasonal variability in habitat preference. During the study, Shah (1993) observed that Indian wild ass uses scrub-low patches throughout the year. Excessive irrigation in fringe crop-fields, releases large quantity of water towards Rann. Especially in southern fringe, due to excessive seepage of canal water, portion of Rann habitat have increased in moisture content supported growth of wetland grass patches including greening of saline grass patches. It was observed that, where water logging remained for longer duration after monsoon, grass species like *Typha* grows which also presumed to attract Indian wild ass and Nilgai.

Summer habitat preference

In summer, Indian wild ass showed preference towards medium and dense scrub areas. Moist area of Rann adjoining fringe areas gets dried up completely during peak summer. The grassland patches predominantly *Aeluropus* species remains green in late winter as well and Indian wild ass forages on these grassland patches (Shah, 1993). Manly's selectivity index showed that in summer, scrub low habitats are least likely preferred by Indian wild ass in comparison to scrub-medium and dense areas (Figure 3.5). In fringe scrubland, livestock forages on open and scrub-low areas and due to overgrazing, seasonal grasses are consumed quickly by the end of productive season. In summer, annual grass species gets completely degraded and remaining perennial grasses whether grazed or non-grazed also dries. These remaining dry grasses are very low in nutrition and avoided by livestock but preferred by Indian wild ass population as they favour roughage and in large quantity (Kaczensky et al., 2008; Schulz and Kaiser, 2012). Besides, Indian wild ass forages over dried *Prosopis* pods (Shah, 1993) to meet required nutrition in absence of favourable grass species.

Winter habitat preference

In winter, scrub dense areas are least preferred by Indian wild ass in comparison to scrub medium and scrub low (Figure 3.4). Most preferred habitat category was scrub medium

according to Manly's selectivity index. In monsoon, the livestock population of both migratory and surrounding villages, graze over the fringe grassland (Shah and Qureshi, 2007) and scrub-low areas are mostly grazed towards the end of productive season. Transect surveys of southern fringe (Intensive Study Site) from post productive season (September-October), showed large congregation of livestock over the preferred habitat patches of Indian wild ass (see figure 2.22 in chapter II).

Habitat suitability for Indian wild ass in LRK

MaxEnt model predicted strong suitability of habitat along the southern fringe followed by south-east fringe where no fragmentation in preferred habitat was observed (Figure 3.8). The western, northern and north-western fringes were showing higher suitability in small fragmented patches. The distribution prediction was largely contributed by the distance to village variable (Figure 3.10 A). Since the fringe habitats are resource rich in terms of both natural and crop resources due to the close association with the agricultural patches followed by the villages, it has become a determinant factor for habitat suitability (Owen-Smith, 2003). Habitat suitability studies on Kiang (*Equus hemionus kiang*) suggested that suitability probability increases with increasing distance from human settlements (Sharma et al., 2004) which is observed to be least likely situation in case of Indian wild ass. The distance to salt pan played crucial role in predicting suitable habitat near salt pans in northern fringe (Figure 3.10 B) suggesting Indian wild ass distribution in LRK is not affected by the presence of human. On the other hand, similar study on African wild ass (*Equus africanus*) showed that due to political unrest and human disturbance, Indian wild ass habitats were predicted away from human presence (Kebede et al., 2014).

Availability of water assumed to be a limiting factor whereas it had least contribution towards habitat suitability prediction. Habitat suitability prediction for Kiang also showed similar prediction where Kiang was observed to move larger distance away from permanent water sources (Sharma et al., 2004). Similarly, in a recent study on Persian wild ass (*Equus hemionus onager*) in the Bahram-e-Goor protected area, it demonstrated higher affinity towards moderate rangelands and slopes than water source (Almasieh et al., 2020). Barren habitats, away from fringe also showed some degree of preference which may be due to the presence location mostly collected during the breeding season which continues till winter starting from monsoon. Study on Kiang and African wild ass also showed partial preference in selective seasons (Sharma et al., 2004; Kebede et al., 2014). Kaczensky et al., (2008, 2010)

in their study on Asiatic wild ass and other sympatric ungulate in the Mongolian Gobi come up with fascinating findings that Asiatic wild ass drink water every alternate during the hot season and drink less frequently during spring and in comparison with other sympatric wild equids, Asiatic wild ass moves far away from water to make use of pasture.

The model also predicted higher variability in Indian wild ass distribution in sparse vegetation, i.e., away from denser scrub patches (Figure 3. 10 C). A seasonal variation might be there as suggested by Manly's index for scrub abundance during winter and summer (Figure 3.4 and 3.5). The overall prediction in the MaxEnt model suggested that variability in Indian wild ass abundance decreases with increasing NDVI value (Figure 3.10D).

Habitat suitability for Nilgai in LRK

Similar to the prediction in Indian wild ass, distance to village and salt pan contributed largely towards distribution of Nilgai (Table 3.4). The habitat suitability map showed that Nilgai prefers to stay close to the fringe and least likely deterred by salt farming activities (Figure 3.12). Unlike Indian wild ass, distance to water contributed more towards Nilgai distribution. Studies also suggested that Nilgai prefer habitats with contiguous forest (Habib et al., 2010; Niyogi et al., 2021) and watershed areas (Jha and Udgaonkar, 2010; Kumar et al., 2013). Response to NDVI showed variation which was moderate and showed preference towards denser patches as well (Figure 3.14 D). Similarly, land cover had fairly good contribution towards ecologically reliable prediction.

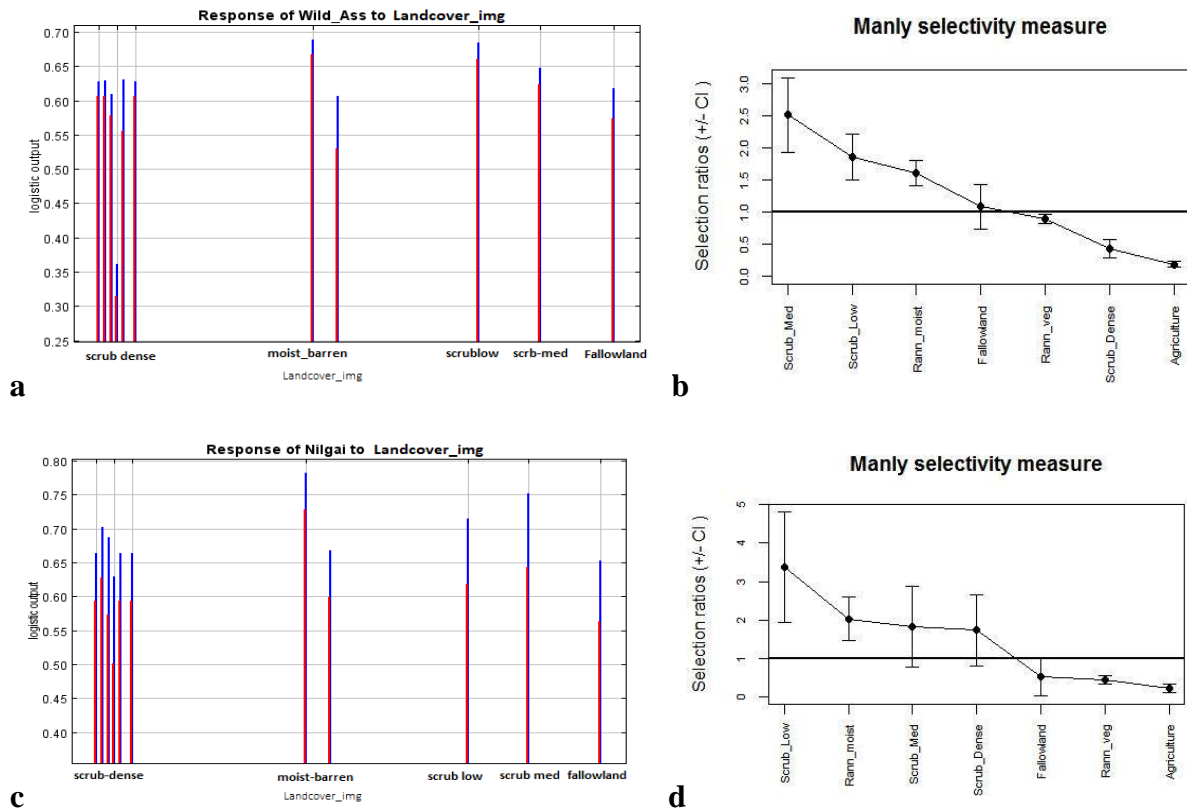


Figure 3.17: Comparing overall habitat preference suggested by MaxEnt modelling and Manly's selection index in winter season for Indian wild ass (a,b) and Nilgai(c,d) respectively in LRK landscape

Nilgai showed overall higher preference towards moist barren land followed by denser scrub patch suggested by both MaxEnt modelling and Manly's selection index in winter season (Figure 3.17 c-d).

Pattern of crop-depredation by Indian wild ass

The monsoon crops like pearl millet (*Pennisetum glaucum*), mung bean (*Vigna sp*), math bean (*Vigna sp*), wheat (*Triticum aestivum*) and cotton (*Gossypium sp*) which are harvested in winter were observed to compose parts of Indian wild ass dung (Shah, 1993). During this study, presence of Indian wild ass was found in math bean (*Vigna sp*), sesame (*Sesamum indicum*), cotton (*Gossypium sp*) and BT-cotton crops (*BT-Gossypium sp*) where majority crop-fields were either open or thorn fenced (see figure 4.11 in chapter IV). All the sampled crop-fields of cotton were open and Indian wild ass preferred raiding in all three phenological stages (Figure 3.15a). Indian wild ass tend to avoid crop-fields with proper fencing besides they prefer multiple kind of crops whenever they get chance to enter. However, farmers have reported crop raiding and damage caused by Indian wild ass and attested to the fact that

Indian wild ass rarely crosses wire or solar fence but if left unattended, Indian wild ass would greatly damage their crop (see chapter-IV discussion). The wire and solar fence has become largely popular among farmers in southern fringe in recent years and it greatly reduces the raiding frequency of Indian wild ass by not allowing them to enter which was evident from the lack of Indian wild ass presence in many crop-fields during the survey.

Pattern of crop-depredation by Nilgai

Nilgai is browsing species and mostly browses on scrub-twigs with tender leaves (Mathur, 1991). Nilgai are mostly observed in scrub thickets with medium and dense scrub growth. During the day time, they spend majority of time inside scrub thicket (Chopra and Rai, 2009; Bajwa and Chauhan, 2019). In winter, i.e., post-productive season, Nilgai was observed in scrub-low and moist fringe areas where palatable food species are present. In water logged areas of fringe scrubland, *Typha spp.* grows and Nilgai was seen foraging on *Typha* leaves. In many occasions, Nilgai forages on *Typha* species available alongside drains near village or moist areas inside sanctuary. In summer, there hardly any green grass present in scrub-low and open areas except the moist part where mostly saline grass grows dominated by *Aeluropus spp.* and *Cressa critica*. Nilgai tend to avoid scrub-low areas in summer (Figure 3.7). Scrub-dense and medium areas have more resource in the form of browsing plants like *Prosopis juliflora*, *Acacia tortilis*, *A. nilotica*, etc. whose leaves and tender twigs are eaten by Nilgai (Chauhan and Singh, 1990; Field observation).

Nilgai is naturally nocturnal and it forages mostly during evening and night (Chauhan and Singh, 1990). Its most favoured resource is crop and throughout the night it depredates on standing crop. BT-cotton was the most affected crop from regular raids by Nilgai (Figure 3.16 b), however in other studies it was reported that Nilgai does not damage cotton crop by eating but uses as refuge (Chopra and Rai, 2009). BT-cotton crop is the longest standing crop and after the improvement in irrigation facility, BT-cotton was widely adopted by the southern fringe farmers for better yield compared to indigenous cotton. In a mosaic of BT-cotton crop, Nilgai have used this crop for their daily movement. In Haryana, a study reported Nilgai to show affinity towards wheat (*Triticum aestivum*), rice (*Oryza sativa*) and pearl millet (*Pennisetum glaucum*). However, castor, sesame, pearl millet, cotton and sorghum were also preferred by Nilgai (Figure 3.16 b) in southern fringe area.

Chapter 4 Attitude and perception of people towards crop-depredation and Indian wild ass conservation

Introduction

Human and wildlife interaction is evident from the beginning of the history of mankind and with time due to increasing human population at the cost of shrinking wildlife habitat, it has become one of the most extensive and obdurate issue (Dickman, 2010 and Nyhus, 2016). The issues contained in it, the interface of diverse situations and a wide variety of animal taxa like grain eating rats to man-eating tigers make the conflict situation more difficult to deal with (Medden, 2004; Distefano, 2005; Seoraj and Pillai, 2016; Manral et al., 2016). The people in India and other developing countries living close to the forest are poor and their struggle to meet their daily needs compels them to extract resources at the cost of the wellbeing of wildlife though they may be well aware of the harm caused (Thirgood, 2005; Ogra, 2008; Ogra and Badola, 2008; Ogra, 2009; Barua, 2013). Conover (2002) had defined human-wildlife conflict as the situation which arises when an action by human or wildlife has an adverse effect on each other. Land use in the form of converting wasteland to croplands, encroachment into forested areas or grasslands compels wildlife whose habitat is degraded or shrunk into finding ways to adjust with their altered habitat (Shemwetta, 2000; Mekonen, 2020). The trend of human population growth shows that in near future the demand for land would increase and this would give rise to more conflict with wild animals (Naughton-Treves, 1997; Matson, 2006).

In developing countries like India, the conflict situation is more intense where majority of people are poor and suffers higher loss (Distefano, 2005). The western part of India, where rainfall is less and seasonal, rain dependent resources are scanty and life forms struggle to sustain themselves during the dry-season (Mehta, 2001; Kuchimanchi et al., 2019) resulting into seasonal migration of livestock herders along with their livestock. The pastoralists along with their livestock from far western villages migrates towards east to greener areas with better irrigation facilities (Bharwada and Mahajan, 2002; Gowane et al., 2018; Mehta and Srivastava, 2019; Srivastava et al., 2021). Similarly, Indian wild ass and Nilgai populations also tend to move into resource rich greener agricultural areas during the dry season (Mohammadi, 2021; Barman et al., 2022) and raid crops to meet their dietary requirements (Shah, 1993).

The better irrigation facility to the farmlands provided by the Narmada Canal Network has enabled farmers to cultivate during the dry season (Amte, 1990; Goyal et al., 1999; Sangvai, 2020). In the presence of standing crop during the lean period when natural resources dry out, it is obvious that Indian wild ass, Nilgai and Wild Pig population will always look for the opportunities to raid crops. In LRK as well, majority of rain-fed agricultural lands were converted into irrigated lands resulting in a much higher yield per year than that previously obtained. Moreover, to ensure better household income from the growing agriculture market, farmer community tends to cultivate more cash crops than food grains (Nadkarni and Vedini, 1996). In India, apart from moderately wealthy farmers with larger land holding, the farmers with marginal land holding have been prioritizing cash crop as an alternative cropping pattern (Kennedy and King, 2014). In such a scenario, farmers' attitude towards crop-raiding by wild herbivore could be impacted negatively as damage of cash crops directly affects their income (Hockings and Sausa, 2012), although the socio-cultural perspective of the people of LRK landscape representing the Indian tradition holds a positive outlook towards life forms (Sukumar, 1995; Dave, 2010). However, tolerance level of people might not remain stable when food security and better living condition is affected by the crop-raiding incidents from Indian wild ass, Nilgai and wild pig. The hardship of people in finding the way to uplift their living conditions compels them to think less about wildlife and more towards protecting their crops from any form of loss (Ogra and Badola, 2008; Liu et al., 2011). Moreover, struggle to protect crops from crop-raiding animals, affects peoples' mindset negatively towards wildlife conservation (Kaltenborn et al., 1999; Hill, 2000; George et al., 2016). Therefore, integrating peoples' attitude into decision making process is a growing concern among the resource managers (Decker and Brown, 1982; Andreas et al., 2010) to achieve long term conservation goal.

The ethnic communities, i.e., Thakor, Bharwad, Darbar, Patel, Scheduled Cast and Muslim (See chapter-I) are predominant in fringe villages. Therefore, looking into their interaction with the fringe and associated wildlife would be important. The southern fringe is rich in both natural and crop resource and Indian wild ass abundance (See chapter-II). In this chapter, I tried to understand the perception and attitude of people from southern villages who were practicing agricultural farming during the study towards crop raiding activities by Indian wild ass and other herbivore.

Methods

To understand the attitude of the farmer towards Indian wild ass and their perception regarding conservation, questionnaire-based interviews were conducted (Figure 4.1). As I did not had a woman team member and due to ethnic customs and social norms in local communities, where women were not comfortable talking to men other than their own community members,, I could not interview women, hence, only men farmers were interviewed (Vissandjée et al., 2002). A semi-structured questionnaire was developed and interviews were conducted in 14 villages of southern fringe. As only farmers were targeted snowball sampling (Goodman, 1961; Parker et al., 2019) approach was used to identify the households and respondents were selected on the basis of their willingness to participate and experience (Dobriyal et al., 2022). The farmers were approached at their houses, farmlands and resting places in villages. The purpose of the study was thoroughly explained to them and their verbal consent was taken before starting the interview.

The questionnaire had both close and open ended questions. Information on age, educational qualification, ethnicity and occupation was recorded. Questions related to their perception were asked and validated through cross questioning. The landholding and source of irrigation were asked. The answers were recorded keeping in mind the variations in their replies and questions focusing on their attitude and perception were asked. Communities interviewed were Thakor, Bharwad, Darbar, Patel and Muslim. Thakor community had majority representation in sampled villages followed by Bharwad community. Darbar and Patel communities were not uniformly distributed as in some villages their representation was very less and in some were higher than Thakor and Bharwad communities. Muslim community was present in three sampled villages where majority of them were not farmers and engaged in alternate livelihood. Very few were having owned or shared crop field. Likewise, very few Bharwad community members were observed to practice farming apart from livestock rearing. Following snowball approach, practicing farmers from these communities were approached and interviewed.

The data was analysed using non-parametric analysis. Chi-square test is conducted to see the significance level between dependent and independent variables. Age group, educational qualification, landholding and ethnicity are the four independent variables which were tested.

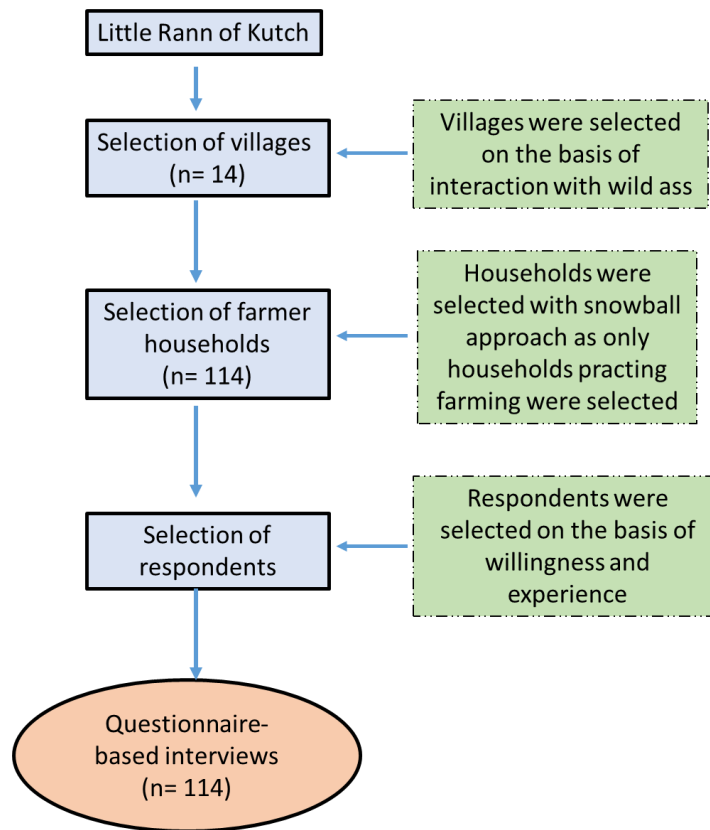


Figure 4.1: Approach used to assess the attitude and perception of farmers towards Indian wild ass and its conservation

Results

Profile of respondents

All the interviews were conducted in the southern fringe villages. A total of 14 villages were sampled and total respondents were 114. The ethnic groups recorded were Thakor, Patel, Maldhari, Darbar and Muslims with 62, 30, 7, 13 and 2 respondents. Muslims were a minority and are settled in two villages in southern fringe. Majority of people are from Thakor community in the sampled villages.

Age structure of respondents

The youngest group of farmers was categorised within 20-30 years of age where as the oldest group falls within 61-70 years of age category (Figure 4.2). The highest percentage of respondents belonged to the 51-60 years of age category which was 35.08 % of the total respondents (Figure 4.2).

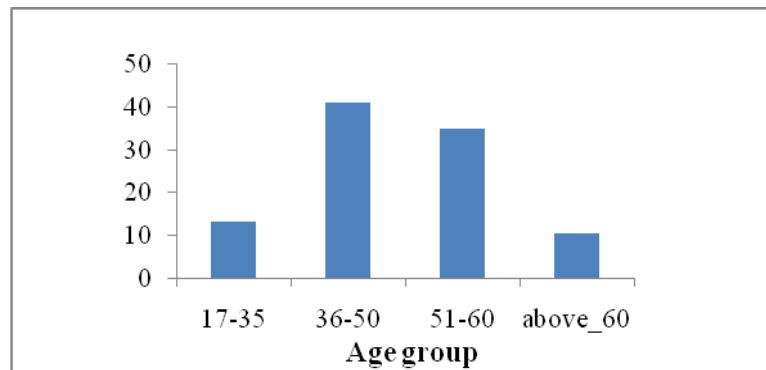


Figure 4.2: Percentage of respondents from different age group (n=114)

Educational Qualification

Majority of the respondents (64.91%) were illiterate (Figure 4.3). The primary education starting from 1st to 4th standard was received by 18% respondents. About 17.09% of respondents were observed to have received education between 5th to 9th standard (middle and high school, Figure 4.3).

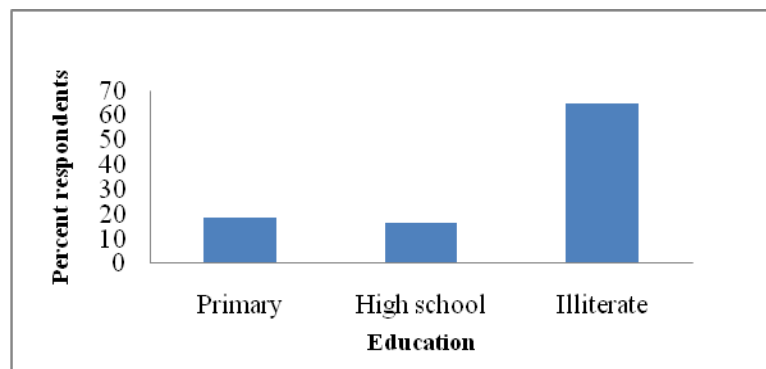


Figure 4.3: Respondents' educational qualification (n=114)

Land holding pattern

Different land holding categories were identified as marginal (less than 1 hr), small (1-2 hr), semi-medium (2-4 hr) and medium (4-10 hr) following Agriculture Census, 2015-16 report, Government of India (2019). Majority of land holding among respondents were marginal (Figure 4.5). Thakor community has majority of marginal and small land holding followed by Patel community with majority of semi-medium land holding (Figure 4.4). However, Patel community holds maximum land holding area (43%, in hectare) followed by Thakor community (40%) among the respondents (Figure 4.4).

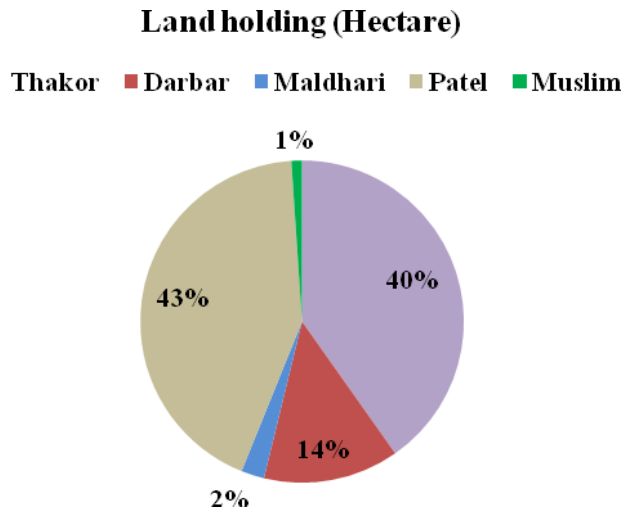


Figure 4.4: Percentage of land holding areas of respondents (n=114)

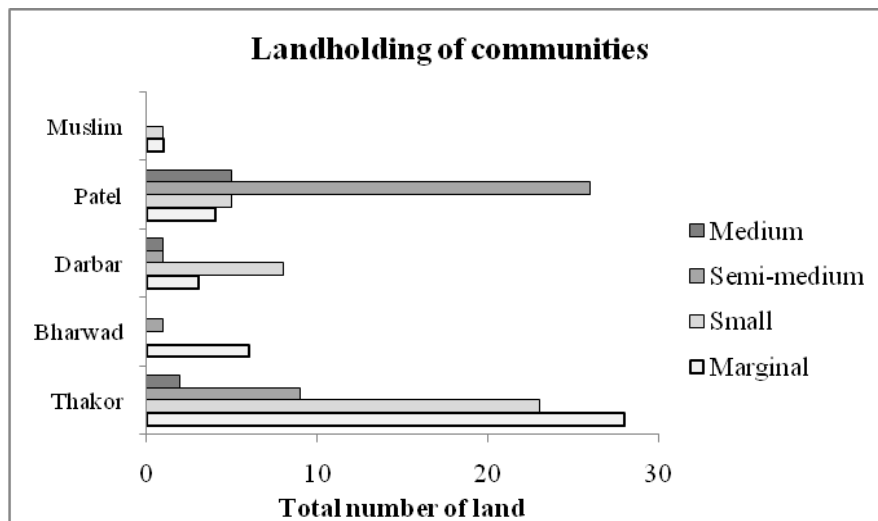


Figure 4.5: Land holding of different categories by the respondent communities (n=114)

Dependency on Rann

The Rann was used by the villagers for various reasons which include fodder collection, fuel wood collection and movement towards other fringe villages. Total 78% respondents reported to be dependent on the Rann for resources whereas 22% respondents did not have any dependency on Rann (Figure 4.6). Majority of respondents had fuel wood dependency (69.29%) and 38.6% respondents had both fuel wood and fodder dependency on fringe and Rann. All the respondents from Bharwad and Muslim communities had fuel wood and fodder dependency. Respondents from Darbar community reported least dependency for fuel wood (38%) and fodder (23%) out of total Patel community members sampled. Thakor community

respondents reported higher dependency for fuel wood (76%) than fodder (34%). Higher percentage of respondents from all the communities reported to have access to Rann.

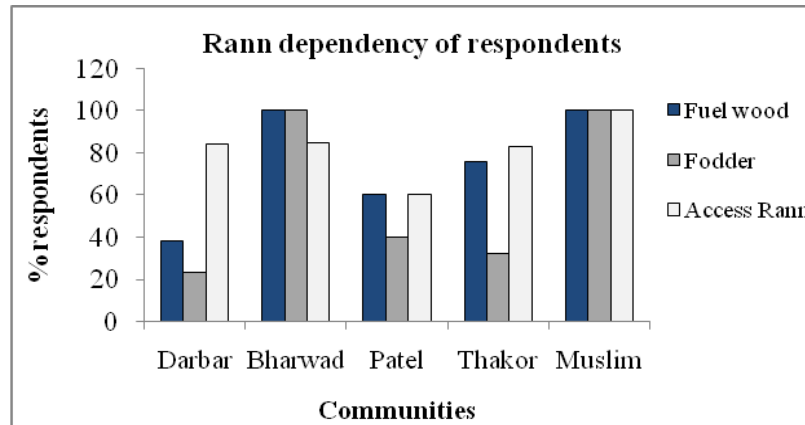


Figure 4.6: Rann and fringe dependency of different communities (n=114)

Irrigation

After the Narmada Canal Project was implemented in this region, agriculture activities escalated. About 78% respondents reported to have irrigated land where as 17% reported to have non-irrigated farm lands. Looking at the period of farming practices of individual respondents, it could be assumed that water supply through Canal has encouraged them to cultivate throughout the year.

Livestock holding

Cattle and buffalo are the major livestock and majority of respondents were having them. The respondents from Bharwad community were observed to have more livestock and apart from cattle and buffalo, they had sheep and goat (Figure 4.7).

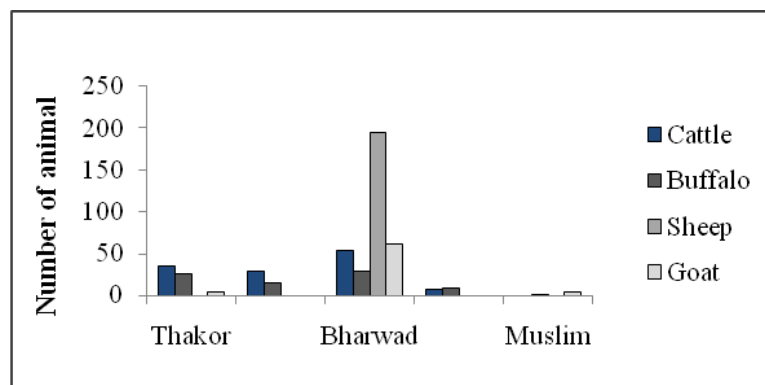


Figure 4.7: Holding of livestock by different communities in southern fringe

Attitude and perception of people towards crop-raiding by Indian wild ass and other herbivore

Majority of respondents (mention value as percentage of respondents here) reported Nilgai and wild pig as the most frequent crop-raiders followed by Indian wild ass and livestock. The farmers have confirmed damage to their crops from crop-raiding incidents. Majority of respondents said about 10-15 percent crop loss was suffered due to crop-raiding (Figure 4.8). However, the farmers have also reported that they suffer 25-30 percent crop-loss due to weather related causes (Figure 4.9).

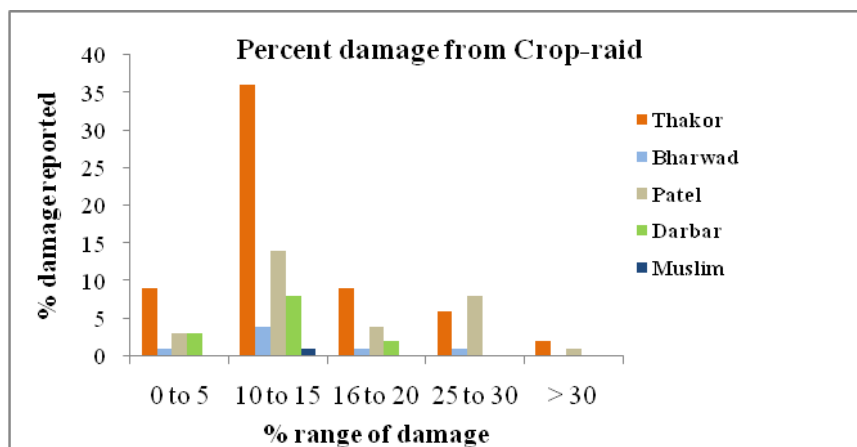


Figure 4.8: Response on respondents' on crop-damage from crop-raid

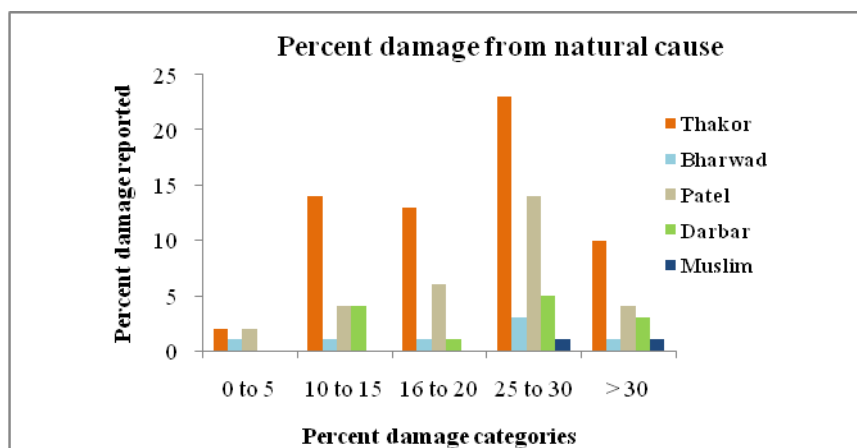


Figure 4.9: Response of respondents' on crop-damage from natural cause

The respondents of age group 17-35 had confirmed that Nilgai is the most responsible animal to raid their crops but Indian wild ass causes more damage to crops. Respondents between 36-50 age group pointed Indian wild ass, Nilgai and wild pig equally responsible to damage their crops whereas they believed Nilgai as the most frequent visitor followed by wild pig and

Indian wild ass (Figure 4.10). The farmers of 51-60 age group believed that Nilgai and wild pig are most frequent visitors to their crops than Indian wild ass but argued that Indian wild ass causes more damage followed by Nilgai and wild pig (Figure 4.11).

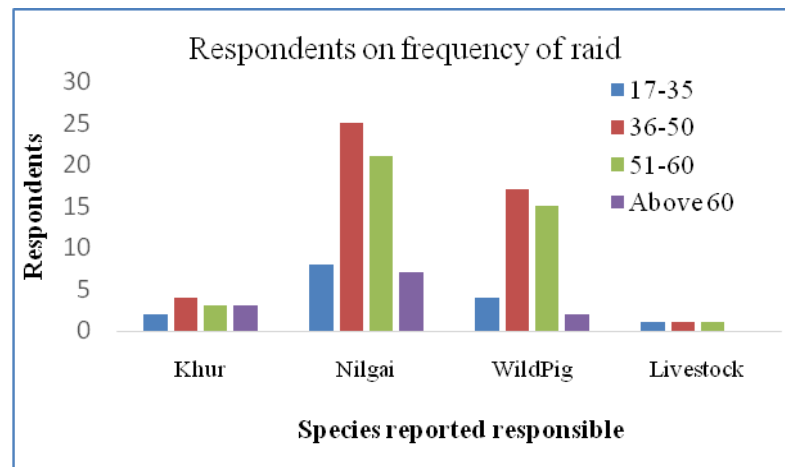


Figure 4.10: Response of respondents of different age group on the frequency of crop-raid by wild herbivore and livestock

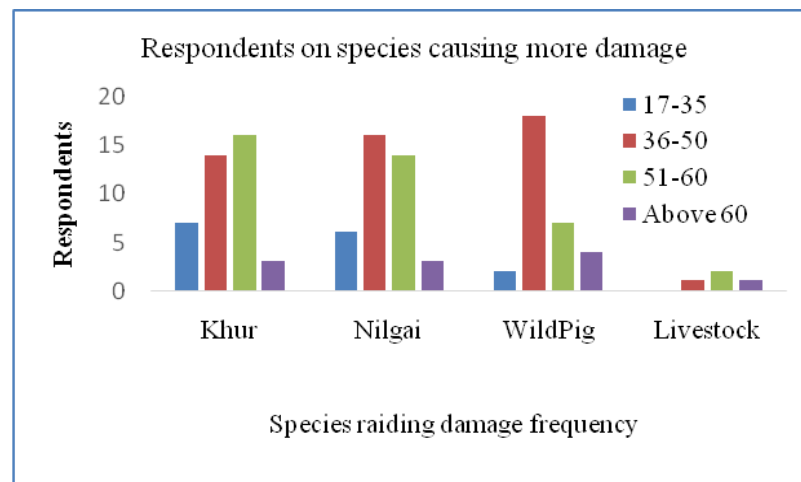


Figure 4.11: Response of respondents of different age group on the species responsible for crop-damage

Table 4.1: Results of chi-square significance test run for Indian wild ass and Nilgai between “age group” and dependent variables as “most frequent visitor” and “most responsible animal”

Most frequent visitor			Most responsible animal		
<i>p</i> value	X^2 value	Critical value	<i>p</i> value	X^2 value	Critical value
0.749	5.9	16.9	0.487	8.48	16.9

There was no significant difference observed between age group and other two dependent variables (Table 4.1) suggesting perception of people towards crop-raid by Indian wild ass and Nilgai was independent of their age.

On perception about population status of Indian wild ass and Nilgai, 43.85% and 40.35% respondents respectively reported their population has increased. About 21.05% and 18.42% respondents feels that population of Indian wild ass and Nilgai has not changed.

Attitude and perception of people towards Rann

Uniqueness of Rann

The respondents were asked their opinion about the uniqueness of Rann. A very large proportion (92.98%) agreed with the concept of Rann being a unique place. The remaining (7.02%) had no idea about the concept (Figure 4.12).

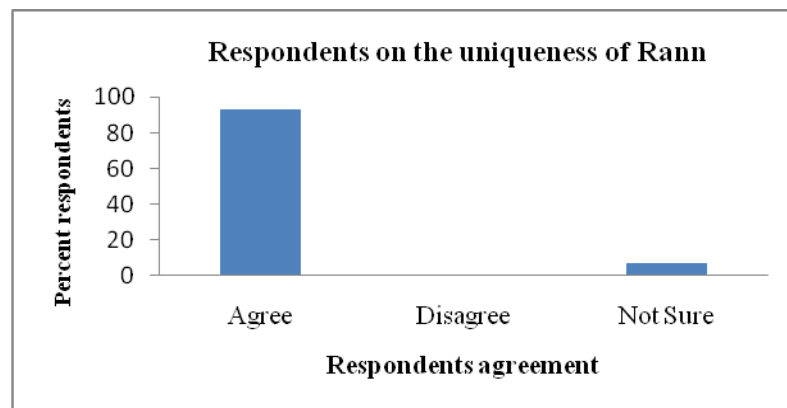


Figure 4.12: Response of respondents on uniqueness of Rann

Need to conserve Rann

The respondents showed a mixed response towards the conservation need of the Rann habitat. Total 60% respondents believed that Rann should be conserved whereas 22% respondent did not have idea whether to conserve Rann or not. About 18% respondents disagreed that it is important to conserve Rann (Figure 4.13).

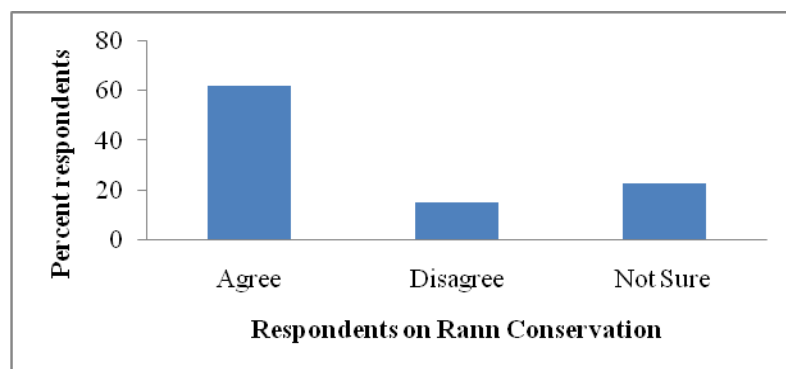


Figure 4.13: Response of respondents on conservation of Rann

Attitude of people towards Indian wild ass conservation and crop-depredation

Having a protected area near village is good

Majority of respondents disagree to this statement (56.10%) and 21.1% respondents showed their strong disagreement (Figure 4.13 a). Although a smaller section of them (10.50%) showed agreement but no one had showed strong agreement here.

Indian wild ass should be protected

Total 51.80% (n=59) respondents agreed that Indian wild ass should be protected, while 20.20% (n=23) respondents did not agree. A very small section (n=7) of respondents strongly believed that Indian wild ass is important and should be protected besides 0.90% (n=1) showed strong disagreement towards Indian wild ass conservation (Figure 4.13 b).

Indian wild ass is responsible for crop-damage

Majority of respondents (51.80%) agreed that Indian wild ass is responsible for damage to their crops with 24.60% (n=28) respondents showed strong agreement. However, 18.40% respondents were of the opinion that Indian wild ass does not damage their crop, besides, 5.30% respondents were not sure whether to agree or disagree (Figure 4.13 c).

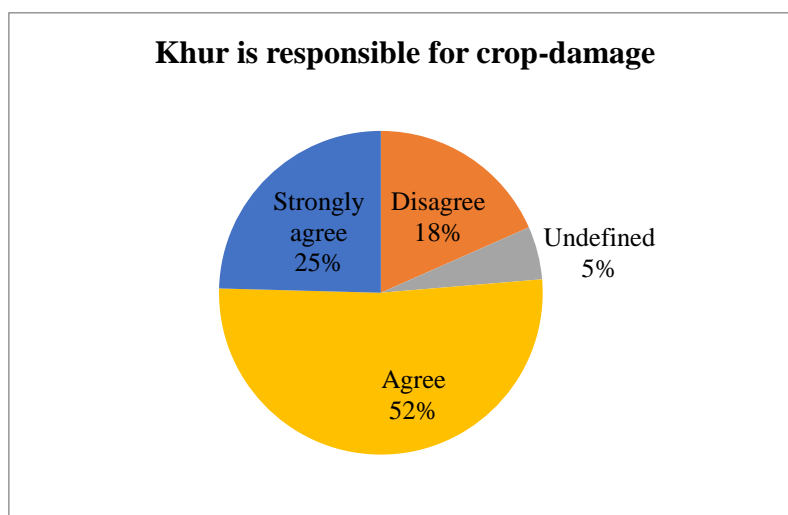
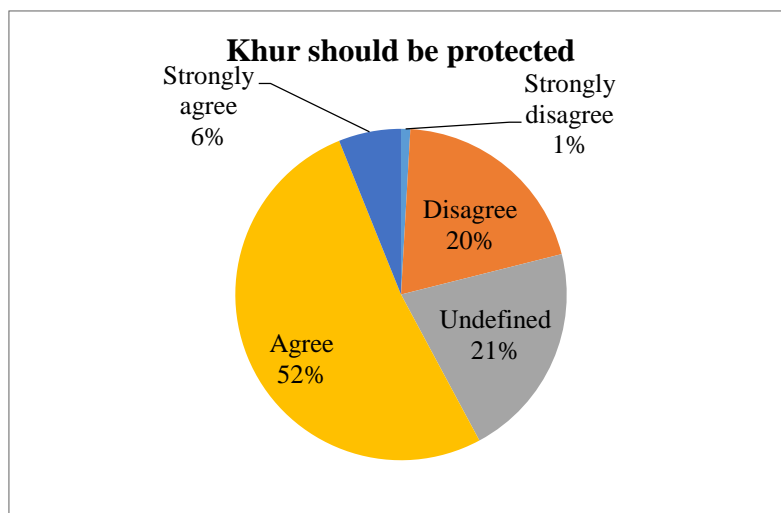
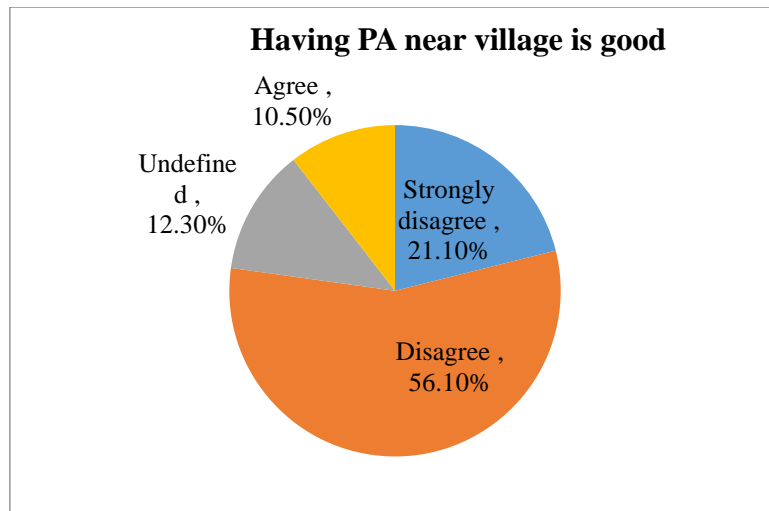


Figure 4.14: Responses made by the respondents on statements showing their attitude towards Indian wild ass conservation and crop-depredation

Discussion

Growing population settling near or in wildlife habitat has been a major factor for human-wildlife conflict (Naughton-Treves, 1997). A major portion of human population lives in arid and semi-arid regions of the world with primary source of household income being derived from agriculture (Qader et al., 2021). In LRK, majority of people are dependent on agropastoralism (Desai et al., 2021). Farming in this region, like any other semi-arid region in the world has been a challenge due to its characteristic climatic condition (Shaer, 2006; Todmal, 2019). Water has been the main resource for sustainable agriculture. The landholding is marginal like other semi-arid regions in the world where insecurity towards crop-loss by wild animal assumed to be higher (Ogra and Badola, 2008; Barua et al., 2013; Seoraj and Pillai, 2016). In the southern fringe of LRK, Thakor and Patel communities were holding majority of land but their land holding were quite marginal ranging from 2 to 6 acre in size. Majority of them (78%) were having irrigated croplands and non-food crops were cultivated extensively. In rural India, illiteracy is also a concern in terms of providing benefits through existing government schemes. In the study, majority of respondents were illiterate, whereas education plays a crucial role in developing cognitive ability in farmers (Gaurav and Singh, 2012) contributing towards community participation in wildlife conservation (Bhatta and Joshi, 2021; Mayele and Woja, 2022).

Human population living in and around forest are highly dependent on forest for subsistence and livelihood (Sekhar, 2003; Naughton-Treves et al., 2005; Lepetu et al., 2009; McElwee, 2010; Rasal et al., 2021). Total 78% of respondents were reported to have dependency on Rann and fringe habitat. All the communities observed to have livestock where cattle and buffalo were the key animals and for fodder, their livestock graze along the fringe scrubland and grasslands. Thakor community showed higher dependency towards fuel wood collection and being dominant community in terms of population would face protection measures by management more often as their movement in the scrubland areas supposed to be more. Access to Rann was also reported by almost all the respondents. During dry season when Rann is completely accessible, people from villages use Rann tracks to access other fringe villages instead of using main road to cut down on travel time and fuel expenses. Also, for salt farming activity, people from fringe villages stay for about 8 months inside the sanctuary (Johnson, 2012; Gupta, 2020) and move to and fro. Prior to the establishment of Indian wild ass Sanctuary in 1972, the Rann habitat was supposed to be free ranging area. Following the protection measures, the extraction of natural resources in terms of fodder and fuel wood has

been under regulation. The respondents, who were above 50 years of age, have seen and experienced the transformation of a free ranging area into a protected land and controlled by the sanctuary managers. Such experience assumed to have affect on their perception and attitude towards wildlife conservation and its habitat (Newmark, 1993; Mishra, 1985) and could influence younger generation, however, perception of respondents towards crop-raiding by Indian wild ass and Nilgai was observed to be independent of their age group (Table 4.1), ethnicity and educational qualification.

In the southern fringe, majority of respondents have reported that Nilgai and wild pig raid their crops in higher frequency. All the respondents have informed that frequency of raid by Indian wild ass is low. Lower frequency of crop-raiding is also reported for Onager (*Equus hemionus onager*) in a study where it was observed that Onager raided those crops which were following traditional protection measures like scare-crow, guard dog, etc. and not fenced (Mohammadi et al., 2021).

Damage to the crops by Indian wild ass and Nilgai was observed to have equal magnitude according to the respondents (see figure 3.6). Indian wild ass raided cotton crop with higher frequency than any other crops (see figure 3.6 in chapter III), since cotton crops were not-fenced and completely open. Damage by Indian wild ass was reported by respondents from all the sampled villages but cotton was cultivated in two sampled villages only, namely Pipli and Bajana (field observation). Since, Indian wild ass did not raid crops with proper fence (continuous and without any passage or damaged) and studies on other sub-species (Mohammadi et al., 2021) also reported the same, it could be assumed that farmers might have perceived the incidents of damage caused by Indian wild ass than actually have experienced. Based on indirect signs, it was difficult to identify the responsible species as Indian wild ass, Nilgai or wild pig except in case of selected crops like peanut (*Arachis hypogaea*), castor (*Ricinus communis*) and pearl millet (*Pennisetum glaucum*) where wild pig presence was more with visible damage as ploughing in peanut crop and eaten fruits with plants broken to the ground in pearl millet crop. Likewise, castor crop had more signs of Nilgai presence with visible damage of empty twigs without fruits and leaves Also, *Sorghum* crop damage by Nilgai was documented and photo-captured in several occasions during camera trap study where the affected farmer also confirmed that Nilgai breaks or damages fence while crossing. In all the above mention crops, Indian wild ass presence was negligible.

Studies have suggested that local farmers exaggerate crop-damage (Hazell, 1992; Naughton-Treves, 1997; Naughton et al., 1999; Tonah, 2002; DeMotts and Hoon, 2012; Mwamfupe, 2015) which was reflected in farmer's claim on Indian wild ass to cause equal damage to variety of crops other than cotton crop where signs of Indian wild ass presence were not found in majority crops. Also, crop-fields without fence is susceptible to damage from free-ranging livestock which was observed in BT-crop where only livestock signs were present and Indian wild ass and Nilgai were completely absent. Studies have also suggested that herbivores are unfairly blamed for crop-damage, rather actual damages caused by rodents and invertebrates are much higher (Seoraj and Pillai, 2016). From informal discussions with the respondents, it was observed that Indian wild ass is believed to be the flag bearer of all the problems caused by wild herbivore, resulted into exaggerated blames towards Indian wild ass. Since Indian wild ass represented the establishment of the sanctuary and associated restrictions imposed by the management in peoples' eyes, it seemed obvious for the respondents to accuse Indian wild ass for any inconvenience they may see fit to come from the sanctuary. Besides, majority of respondents were marginal farmers and more susceptible to loss either from crop-raiding or natural causes and less likely to tolerate any risk coming from wild herbivores, our results are in agreement with those reported by Naughton-Treves, (1997) in his study on people around Kibale National Park in Uganda. Also, the magnitude of loss caused by natural causes could not be determined during the study. Apart from harsh climatic limitations, many studies suggested that increased water availability from large scale canal irrigation also carries the threat of soil salinisation from water logging due to excessive seepage of water into the ground (Singh et al., 2010). This would definitely impact the crop productivity in future and decrease crop yield

Local people especially the farmers are most unlikely to support existence of protected area if they have a negative attitude towards the management (Alkan et al., 2009; Htun et al., 2012). It could be compensated with the increase in household prosperity and with the respondent's level of educational qualification which tend to bring positive attitude (Infield, 1988). In this study, 56% respondents showed disagreement to have a protected area close to their village and 21% showed strong disagreement. Being marginal and small scale farmers, it is obvious that majority of them showed dissatisfaction from protected area as either their crop yield was not satisfactory or they have issues with the management authorities who often impose strict regulations that restricts local people from natural resource collection which is most likely perceived as an imposed burden over them by the management (Scott, 1976; Hough, 1988).

Interestingly, 51.80% of respondents had desired to have Indian wild ass protected and conserved while 20.20% of respondents desired the opposite. The respondents largely of the opinion that animals come to their crop fields out of hunger in dry season when there is nothing left in the scrubland for them to eat other than crops. This suffices the conflict situation as majority of people have a positive attitude towards the wellbeing of any life form establishing a conservationist outlook in general. Similarly, majority of respondents (92.98%) believed that Rann habitat is unique and 62% desired to conserve Rann. However, the responses of respondents should not be considered on face value, rather it should be viewed as speculative. Besides, in face-to-face surveys respondent's perceived understanding towards the interviewer should also be considered as a potential factor to influence their responses (Williams, 1964; Kuhne, 2020). Their responses were believed to be affected by their perception towards usefulness of such kind of survey and their prolonged experience with management authorities. Therefore, the desire to protect wildlife and its habitat shall not remain positive if it negatively gets tempered by the reality of economic constraints (Infield, 1988). For long term conservation and to build sustainable relationship between farmers and management, the household wealth of farmers must improve and they must be involved in policy making in an inclusive manner reducing the gap between people and management authority.

Chapter 5 Synthesis and Recommendations

Studies regarding wild ass in The Little Rann of Kachchh (LRK) landscape was largely focused on counting Indian wild ass population with traditional total count method which has been implemented mainly by the management. After the decline in Indian wild ass population in late 60's, the population of Indian wild ass is consecutive increasing. However, the ecological importance of Indian wild ass and how the ecological parameters significantly inter-connected with the landscape were only understood after the intensive work on wild ass ecology by Shah (1993) that broadly shaped the management approach in prioritising efforts. One of the remarkable initiatives by the sanctuary management was to enrich the understanding on LRK by conducting large scale study on Rann ecology and all the associated flora and fauna.

Although we have the ecological information on Indian wild ass and its habitat, we do not have the information on population density of wild ass which is largely depend on environmental, ecological and anthropogenic factors owing to the limitations of semi-arid ecosystem. Also, Nilgai is another sympatric ungulate sharing habitat with wild ass. Apart from wild herbivore population, large numbers of livestock from surrounding villages graze along the fringe habitat. These bring us the question that what is the status of their population density and how they are distributed across the landscape.

In my study, I have sampled the entire sanctuary using widely accepted line transect method. The resource rich southern fringe was considered as intensive study site and seasonal replicates of line transect samples using both foot and vehicle transect method to see the change in abundance. The foot transect method was observed to be robust with nearly accurate population estimation which is reflected by both southern fringe and LRK landscape estimates respectively. Vehicle transect had issues with sampling design and attempt was made during the study to correct it. It is observed that sampling all the habitat categories while doing transect is crucial to sample wild ass and Nilgai population which use its resources based on its availability that varies with space and time.

LRK landscape is also experiencing visible land use changes influenced by the growing agricultural activities which is largely contributed by shifting rain fed agriculture to irrigated agriculture. Apart from agriculture, anthropogenic activities like salt farming and pastoralism putting multiple pressure on available resources shared by wild ass and Nilgai. The study also highlighted the importance in identifying significant habitat categories used by wild ass and Nilgai population by generating land cover map and area contributed by each category. This would definitely help the management to formulate better management strategies to improve the habitat condition for wild ass conservation.

Based on the identified habitat categories, the pattern of habitat use against habitat availability during both winter and summer season is established during the study. Apart from habitat preference and its selectivity, it is imperative to explain the factors which contribute towards species decision in selecting their habitat. In this study, I have modelled the wild ass and Nilgai distribution with selected variables which were believed to be the governing force in shaping and changing land use and land cover in the landscape. It has become a remarkable outcome from the study to predict suitable habitats in the sanctuary in the form of map that could be effectively used to prioritise efforts to improve and restore available wild ass habitat.

To ensure long term conservation of Indian wild ass, apart from gaining understanding on natural resource selection, it is equally important to understand the pattern of crop-depredation by both wild ass and Nilgai. In this study, I tried to understand whether the crop-depredation is prevalent in this particular region and how the main wild herbivores, i.e., wild ass, Nilgai and wild pig are using crop-fields as a potential resource along the southern fringe which is rich in both natural and crop resource. I have explored the present pattern of cropping practice by farmers and based on indirect evidence, I have reported the raiding frequency of wild herbivores and their preference towards different phenological stages of different crop types.

Moreover, it was important to understand the perception and attitude of people towards their interaction with wild ass and Nilgai with reference to the crop-raiding activities observed during the study. Since majority of farmers are marginal, it was assumed that their perception and attitude towards wild ass conservation would be influenced by crop-raiding incidents. The findings from this study would critically help the management to intervene the human-wildlife conflict situation from becoming more complex and keep the conservationist outlook of farmers intact.

Recommendations

Based on the findings from my study, I would like to put forward certain recommendation which would help the management authority to carry forward their conservation initiatives effectively.

1. The population estimation of wild ass should be done using line transect method, which would help in effective monitoring of the population at lower cost than traditional total count method. The southern fringe should be considered as intensive monitoring site. Following the scientific census method the management should monitor the southern fringe population every year during dry season.
2. Looking at the changes in land use and land cover happening in the landscape, it is recommended to estimate wild ass and Nilgai population every **three** year instead of five years both inside and outside the protected area boundary.
3. The land cover map should be revised every five year to ensure close monitoring of the changes happening in wild ass habitat.

4. In every village, foraging ground for livestock needs to be ensured which could maintain and managed by the village communities with the support from the management. Also, the pastoralist community should be actively involved as a major stakeholder and awareness building among them towards sustainable animal husbandry should be ensured by effectively engaging specialist organisations to reduce grazing pressure on major wild ass habitats.
5. The northern fringe habitat of wild ass should be given importance. Post-canal irrigation implementation, the region which was earlier regarded to have poor resource for wild ass, have shown strong suitability for both wild ass and Nilgai.
6. Also, the bottle neck between LRK and GRK (Greater Rann of Kachchh) should be developed into a strategic corridor for the wild ass population of northern, western and north-eastern fringe to move towards GRK. This will largely ensure long term conservation for wild ass.
7. It is important to know that more than water, scrubland and associated grassland is influencing the distribution of wild ass. However, certain fixed and strategic sites could be selected to construct ponds and they should be maintained and managed every year after each monsoon. Also, the canal water released by the farmers should be managed and effectively used as permanent water source for wildlife by stopping it to spread along the fringe and into the Rann.
8. The management should focus on *Prosopis* eradication at crucial habitat sites and manage them as fringe grasslands. Also, while selecting *Prosopis* patch, it should be properly studied for other mammals like fox, hyena, porcupine who largely uses dense scrub.
9. Although, salt pans did not observed to impact wild ass and Nilgai distribution, the recommendations made by GEER Foundation to create specific salt-farming zones and to regulate vehicular movement should be implemented.
10. The management should ensure community participation by engaging village stakeholders in drafting management policies regarding above mentioned approaches. Compensation scheme for crop-loss due to crop-depredation should be implemented with proper consultation of with the farmers. A monitoring mechanism of crop-loss should be formulated.
11. Perception and attitude of Women section of the village society should be studied and equally involve them in participatory conservation efforts. Active awareness building initiatives taken among fringe villages should continue.

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Student Conference on Conservation Science - Bengaluru 2018

This is to certify that **Bidyut Barman** volunteered/attended/presented a poster/talk at the Student Conference on Conservation Science, Bengaluru, India between 27th and 30th September 2018.

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SCCS is strengthening the career of young conservation scientists around the world through events in Bengaluru, Brisbane, Beijing, Cambridge, New York and Tihany.





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This is to certify that

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has attended the Student Conference on Conservation Science, 26-28 March 2019,

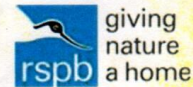
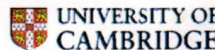
at the University of Cambridge, Downing Street, Cambridge, UK

and presented a poster entitled

“Indian wild ass distribution”

Administrator..... *SPGreen*

Date: 28 March 2019



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