Status of the Indian Leopard and Other Mammals in Asola Bhatti Wildlife Sanctuary, Delhi

A report by

Bombay Natural History Society (BNHS)

&

Department of Forests & Wildlife, Government of National Capital Territory (GNCT) of Delhi

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2022, Department of Forests & Wildlife, GNCT of Delhi

First published: 2022

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ABSTRACT

Asola Bhatti Wildlife Sanctuary (ABWS), located in the South district of Delhi is home to many mammals such as nilgai (*Boselaphus tragocamelus*), golden jackal (*Canis aureus*), Indian crested porcupine (*Hystrix indica*), black naped hare (*Lepus nigricollis*), spotted deer (*Axis axis*), black buck (*Antilope cervicapra*), Asian palm civet (*Paradoxurus hermaphroditus*) and Indian grey mongoose (*Urva edwardsii*). The presence and abundance of a large carnivore like the leopard (*Panthera pardus*) has been heavily contested over the years. Thus, this yearlong study (June 2021 to June 2022) was conducted to verify the presence of the leopard and other mammals in ABWS.

Data collection was carried out primarily through camera-traps since they are a non-invasive tool best-suited to detect elusive and nocturnal species such as the leopard. Grid-based stratified sampling method was used after a six-month long ground survey. The sanctuary was divided into 3 blocks with 7 grids in each block of 1 km^2. Camera trap stations were set up in each grid with two cameras facing each other so that both flanks of an animal could be captured. The sampling duration for each block was 28 days, with a total of 84 days over the year.

More than 14,000 stills of different mammals were captured. Eight unique leopards were identified. Leopard density was estimated at 4.5 ± 0.019 animals/100 km^2. Spatial distribution maps were prepared for each mammal species. ABWS has always been affected by anthropogenic pressures from nearby settlements and roads. Despite this, leopards and other mammals are still thriving inside this forest which is a positive indicator for the health of the ABWS ecosystem. The findings from this study will play an important role in designing management and conservation plans for ABWS, keeping the leopard and other vulnerable species in mind.

1. INTRODUCTION

1.1 Background

The Indian subcontinent is among the most biodiverse regions of the world. It is home to many mighty creatures, including five species from the big cat family, *Felidae*: lion (*Panthera leo*), tiger (*Panthera tigris*), clouded leopard (*Neofelis nebulosa*), snow leopard (*Panthera uncia*) and Indian leopard (*Panthera pardus fusca*). Of these, the Indian leopard is the most widely distributed. It is one of the nine sub-species of leopards which have been identified through genetic testing (Miththapala, Seidensticker & O'Brien, 1996), and this sub-species is found only in the Indian subcontinent. They are the smallest member in the family of big cats.

With the exception of arid deserts and beyond the tree line in the Himalayas, the Indian leopard can be found across forested habitats of India (Prater, 1980). Whether it is Rajaji National Park in Uttarakhand (Mondal, 2006; Harihar, Pandav & Goyal, 2009) or Mudumalayi Tiger Reserve in the far south, the leopard has left its pugmarks across varied terrains (Ramesh et al., 2012b). The leopard population in India has declined in recent decades due to habitat loss and fragmentation (Nowel and Jackson, 1996). As a result, it has been categorized under "Vulnerable" category in Red List of Threatened species by the International Union for Conservation of Nature (IUCN). In India, the leopard is also protected under Schedule I of the Wildlife (Protection) Act of 1972.

Leopards can be both diurnal and nocturnal depending on factors such as prey base, presence of large carnivores and human domination (Sunquist and Sunquist, 2002). In regions with strong human presence, or in forests with other large carnivores, the leopard may act as a nocturnal animal. However, in the absence of big carnivores it can show a diurnal living cycle (Sunquist and Sunquist, 2002). Leopards have been observed to coexist with tigers in Mudumalayi Tiger Reserve (Ramesh et al., 2012a). This might be possible because of their wide selection of prey. They can survive not just only on bigger ungulates like deer and antelopes but also on smaller mammals like monkeys, hares and rats. This ability to survive upon a small prey base is what allows them to live near human settlements where they predate on feral dogs, pigs and even scavenge occasionally. This adaptability could also be the reason why the colonial records such as the *Gazetteer of Delhi* included leopards even until the 1940s (Dwivedi et.al, 2018; Sati and Khanna, 2003). A study of leopards from Sanjay Gandhi National Park in Mumbai by (Surve et al., 2022) highlights the story of leopards coexisting with humans

within the limits of a megacity like Mumbai.

ABWS is the southern part of the Delhi Ridge, the northernmost stretch of the ancient Aravalli range, which begins in Gujarat and extends across Rajasthan and Haryana entering Delhi at Gurgaon. ABWS is also part of the Sariska-Delhi Wildlife Corridor, which runs from the Sariska Tiger Reserve in Rajasthan to the Delhi Ridge. Leopard movements from Rajasthan to Delhi have been traced on this corridor. This movement has led to several cases of roadkill on Gurugram-Faridabad highway as well on the Eastern-Peripheral Expressway. There is a need for improved conservation measures on these roadways, since they lie outside of the protected areas.

In 2019, the Delhi Forest Department recorded fresh sightings of leopard pug marks and scats in ABWS. ABWS had earlier supported wolves and chinkaras as well (Khanna and Sati, 2003). Due to increased anthropogenic pressure and habitat degradation, their numbers fell. It was exciting to find leopards still surviving in this urban forest, and their presence stimulated further questions about how these animals were surviving despite disturbances.

ABWS is also home to other associated mammals such as nilgai (*Boselaphus tragocamelus*), golden jackal (*Canis aureus*), Indian crested porcupine (*Hystrix indica*), black naped hare (*Lepus nigricollis*), spotted deer (*Axis axis*), black buck (*Antilope cervicapra*), Asian palm civet (*Paradoxurus hermaphroditus*) and Indian grey mongoose (*Urva edwardsii*). The abundance of mammals has not been documented in a systemic study previously. Hence, the present study aims to investigate and validate the presence of various mammalian fauna with a focus on Indian leopard as the top predator of this landscape.

The data for this study was collected using infra-red stealth camera traps. These camera traps are non-invasive and equipped with motion sensors making them well suited for studying the presence and ranges of nocturnal animals (Gil-Sanchez et al., 2011). Camera trapping has been proven to be a more effective technique than mark-recapture technique for mammals with unique markings, such as tigers which have stripes (Karanth and Nichols, 1998; Karanth et al., 2004) and leopards which have rosettes (Mondal, 2006; Harihar et al., 2009).

1.2 Research Objectives

The objectives of this study are:

1. To understand the spatial distribution and abundance of the Indian Leopard (*Panthera pardus fusca*) in the Asola Bhatti Wildlife Sanctuary, Delhi.
2. To map the spatial distribution of other associated mammalian fauna in the study area.

2. METHODOLOGY

2.1 Study Area

2.1.1 Location and Geography

Asola Bhatti Wildlife Sanctuary (28° 28’34” N and 77° 13’ 48” E) stretches across 32.71 square kilometers in the south-eastern part of the Delhi Ridge which is part of the Aravalli range, one of the oldest mountain systems in the world. Biogeographically, it has been classified as a northern tropical desert thorny forest (Champion and Seth, 1968). It is bounded by the states of Delhi and Haryana, with Sangam Vihar in the North, Chhatarpur, Bandhwari, Fatehpur Beri in the West and Gurugram-Faridabad Highway in South. Sanjay Colony, a high-density human settlement lies entirely within the sanctuary boundaries.

2.1.2 History

In 1986, under the Wildlife (Protection) Act of 1972, Asola Wildlife Sanctuary was carved out from three villages: Asola, Shurpur and Maidangarhi. Bhatti was added in 1991, leading to the new name, Asola Bhatti Wildlife Sanctuary. Before 1990, ABWS was a prominent quartzite mining site which yielded high quality silica commonly known as *bajri* or Badarpur sand. Due to mining, the sanctuary became heavily fragmented. Mining was banned in 1990 and left many empty pits, some of which later turned into perennial water bodies (Khanna and Sati, 2003).

2.1.3 Climate and Precipitation

The climate of Delhi is a cross between humid subtropical and semi-arid, there is high variation in temperatures. The summers which begin in April and peak in June are hot and dry in Delhi (average temperature 38 °C). Summers are followed by monsoons in July, August and September which are humid with precipitation about 797.3 mm and temperature averaging at 29°C. The weather begins to cool in late September and by the end of October temperature slides from 29°C to 21°C. The winters last from November to February peaking in January. They are cold (average temperature 14 °C) and dry. Late February, March and April have pleasant weather. Extreme temperatures have ranged from −2.2 to 49.2 °C. The climate of Delhi is influenced by the Gangetic plains in the east and the Thar desert in the west. The monsoon is important for the flora and fauna of the sanctuary. The rainfall is also responsible for filling the abandoned pits with water and transforming them into seasonal water sources for wildlife. With time, few pits have become perennial source of water such as the Blue Lake (Neeli Jheel).

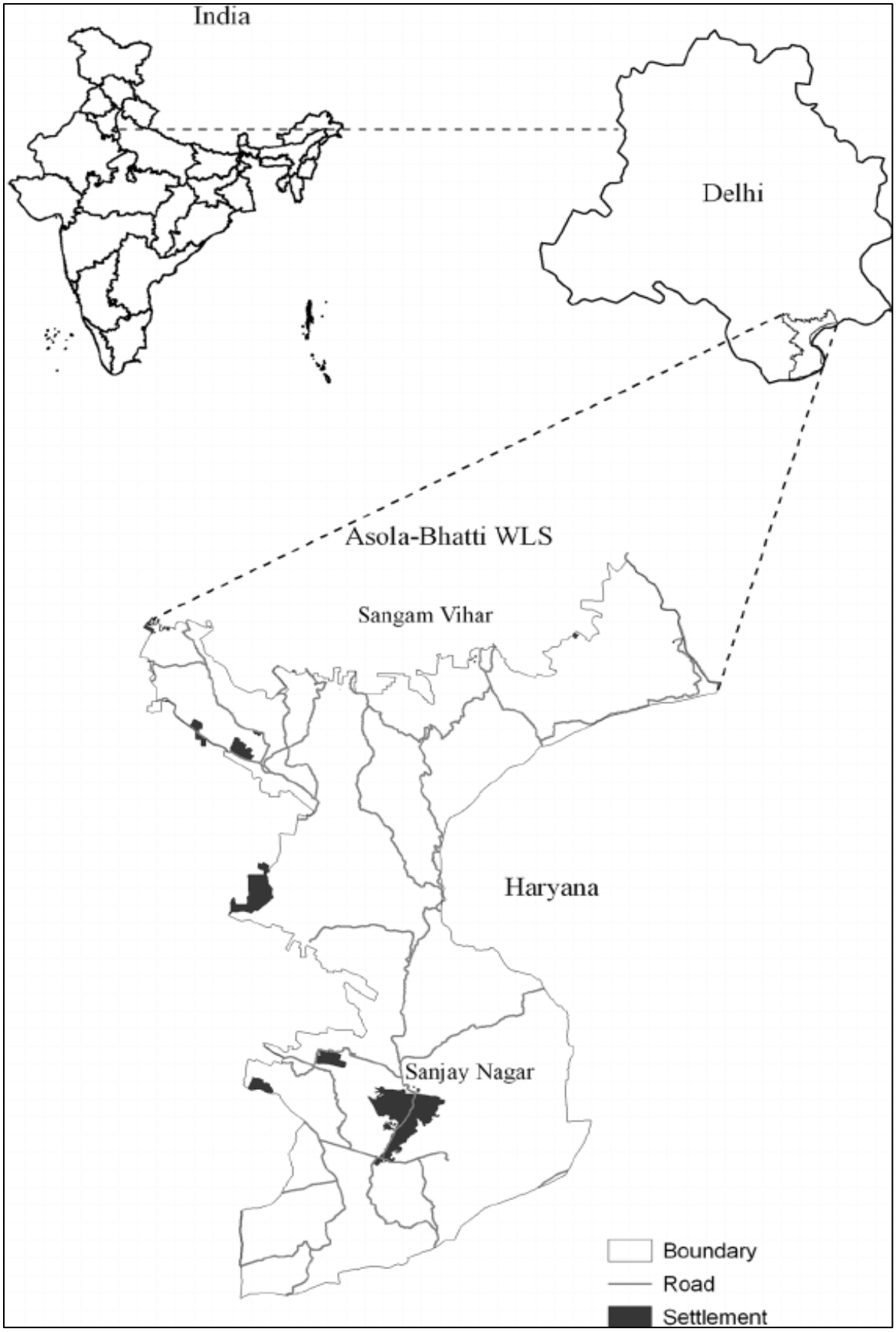


Figure 2.1: Location of Asola Bhatti Wildlife Sanctuary. Source: Kushwaha, Nandy and Gupta.

2.1.4 Vegetation

The vegetation type of ABWS is semi-arid thorny scrub (Maheshwari, 1963). The perennial species have xerophytic adaptations to withstand the water scarcity and extreme climate. The most prominent thorny trees are *Senegalia catechu* (khair), *Vachellia leucophloea* (ronjh), *Vachellia nilotica* (babool), *Senegalia modesta* (phulai), *Senegalia senegal* (kumttha). Non-thorny trees such as *Anogeissus pendula* (dhau), *Butea monosperma* (palash), *Cassia fistula* (amaltas), Phoenix sylvestris (khajoor) and *Salvadora persica* (peelu) are also found in patches. Large portions of the sanctuary are covered by an invasive tree species, *Prosopis juliflora.*

Shrubs include *Capparis separia* (heens), *Capparis decidua* (karil), *Carissa spinarum* (karonda), *Croton sparaijlorus, Justicia adhatoda* (adusa), *Grewia tenax* (gangeti), *Tephrocia purpurea, Tribulus terrestris,* and *Zizyphus sp.* (Ber). The common herbs are *Achyranthes aspera, Aerva scandens, Alycicarpus vaginalis, Calotropis procera* (aak), *Euphorbia hierta, Peristrophe bicalyculata, Pupalia lappacea, Tridax procumbens, Withania somnifera* (ashwagandha).

2.2 Study Design

The total area covered by ABWS is 32.71 km^2, it was divided into 35 grids of 1x1 km^2 each (Fig. X). Since, the area of sanctuary is uneven, we included squares with 70 to 80 percent area inside the boundary of the sanctuary. Grid based stratified sampling was followed, so centroids were marked on map using ArcMap. Due to limited number of camera traps, sampling was not possible in all 35 grids at once, thus 21 grids were chosen.

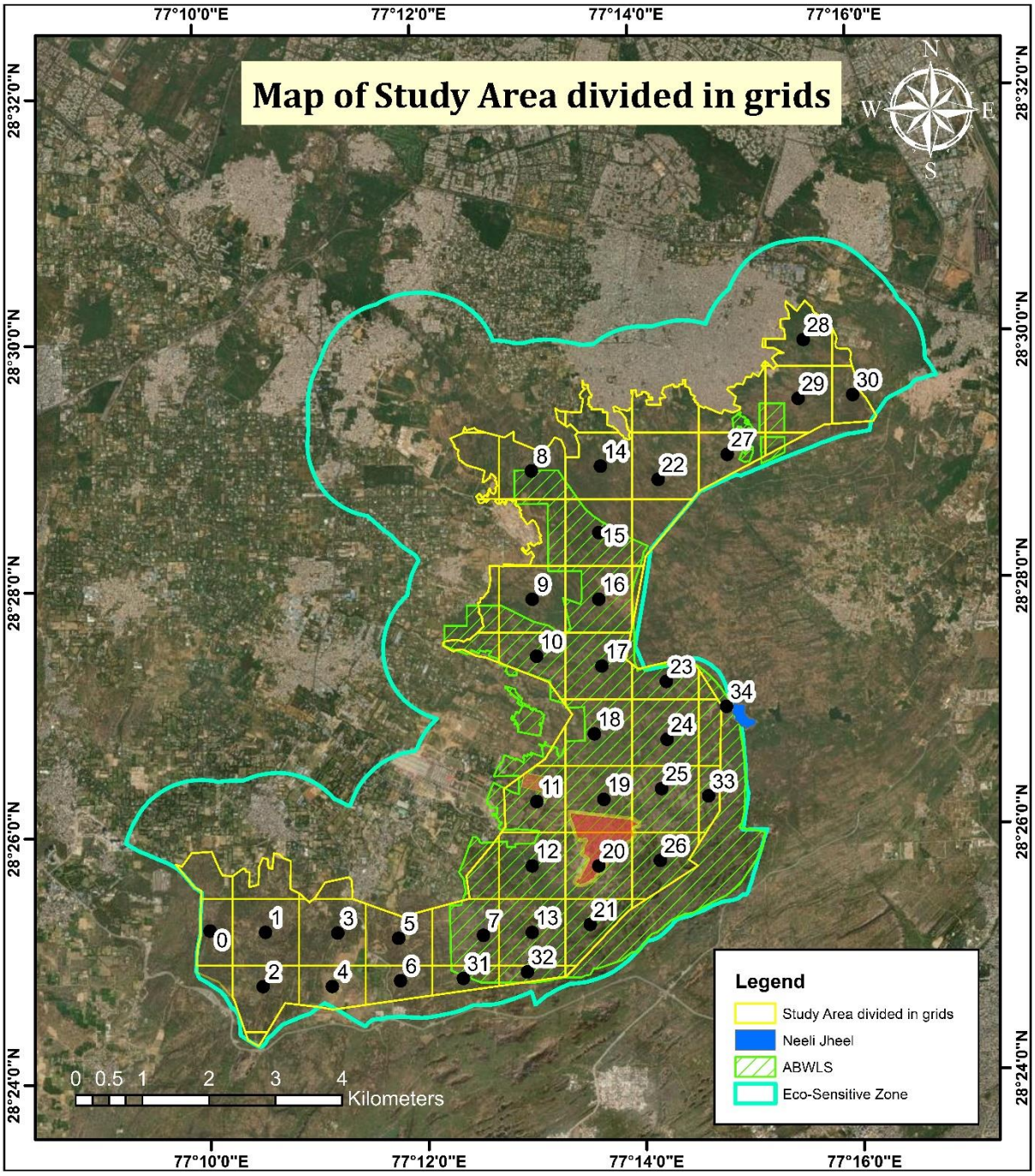


Figure 2.2: Map of study area divided into grids.

2.3 Data Collection

14 Cuddeback Digital model H-1453^{TM} camera traps were used for data collection. The sanctuary was divided into 3 consecutive blocks of equal areas with 7 grids each (Fig. 2.3). In each grid, a camera trap station having two cameras placed in front of each other was set up, to capture both flanks of the same individual. A total of 21 stations having two cameras at each station was set up. Each block was sampled for 28 days before shifting the cameras into next block. This overall gave 84 days of camera trapping. No baits were used while doing camera trap surveys.

We used a Garmin manufactured GPS device and Locus Map (Android mobile app) to reach the desired location (centroids) inside forest. The cameras were set up over trails, near water source on the basis of animal signs such as scats, scrape marks, pug marks and tracks etc. to maximize the probability to captures target animals. Checking of camera for data collection and any other potential damage was done once in a week. The cameras remained active all 24 hours, seven days a week for 84 days for sampling duration. Since this study also aimed to find the record of other small and medium sized mammals, an inter-trap distance of 1 km^2 was selected. This would allow small mammals to have an equal probability of being captured as they prefer small home ranges.

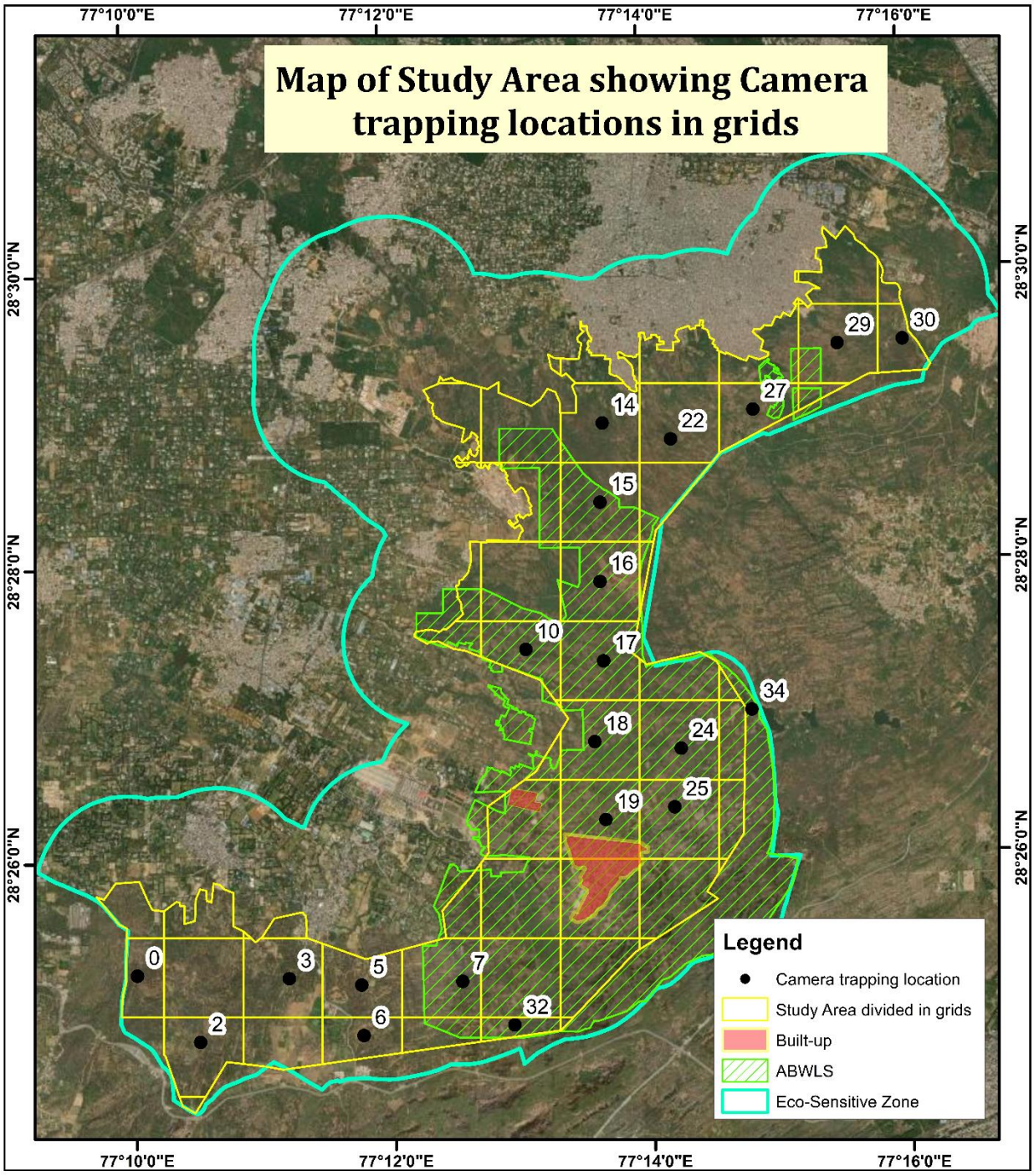


Figure 2.3: Map of study area with camera trap locations.

2.4 Analytical Methods

2.4.1 Identification of Leopards

The maximum number of clear captures of leopard was from the left flank. So, left flank was used to identify leopard on the basis of their unique rosette patterns (see Annexure A). The difference in rosette patterns was carefully analyzed from limbs, tail, head and forequarter. The identified leopard were given names such as L_1,$L_{2,...}L_N$.

2.4.2 Leopard Population Density

Programme Density 5.0 was used for investigating the population density. Two text files were created:

i. Trap file with details of the camera trap, it's ID and UTM projections (Fig. 2.6).
ii. Capture file with details of captures such as session, leopard ID, occasions of capture (day) and trap id (Fig. 2.5).

Density was calculated using Maximum Likelihood Spatially Explicit Capture Recapture (ML-SECR) model with single live detector type. Poisson distribution model was used with a buffer area of 10 km around trapping stations so that no leopard gets captured beyond the buffer zone (drawn from Singh et al., 2014).

```
#Session ID Occasion Detector
Leopard 2 18 22
Leopard 1 20 30
Leopard 2 20 14
Leopard 3 32 10
Leopard 3 32 10
Leopard 4 35 10
Leopard 4 35 34
Leopard 2 36 34
Leopard 3 39 34
```

Figure 2.4: Capture History File (.txt)

#Trap ID	X	Y
0	712284	3145736
2	713062	3144863
3	714180	3145666
5	715093	3145587
6	715121	3144950
7	716367	3145632
10	716956	3149572
14	718368	3152527
15	718096	3151771
16	718372	3151006

Figure 2.5 Trap History File (.txt)

SECR results are based on three parameters:

i. Derived density
ii. g0 - parameter which gives probability of detection at centre of home range.
iii. σ - Scale of animal movements from home range centre (Efford *et al.* 2009).

2.4.3 MaxEnt modeling of Leopard

MaxEnt (Maximum entropy) modeling software was used to predict animal occupancy. It works on the principle of entropy. In a given presence geographic data set of a species it works by searching the maximum distribution based on environment variables (Elith et al., 2011). MaxEnt requires one sample file in .csv format which includes sighting location of animal in degree decimal manner. The second object it required was environmental layers file which was downloaded in the form of bioclimatic variables from www.Worldclim.org and then clipped, resampled and converted to ASCII file format according to the study area.

2.4.4 Spatial Distribution of Leopard and other Mammals

Distribution of mammals throughout ABWS was investigated by spatial interpolation mapping. With the help of interpolation one can estimate values at unknown points from available known values. It was done by a spatial analyst tool, Inverse Distance Weighted (IDW). Maps of all the mammals recorded was prepared based on frequency data from Camera Trap photographs.

3. RESULTS

3.1 Sampling Effort

The cameras remained active all 24 hours, seven days a week which culminated in 588 trap nights. More than 14,000 high resolution digital photos of various mammals were captured by the cameras. These photographs were sorted manually based on species, and categorized into separate folders for further analysis.

3.2 Population and Distribution of Leopard

Leopard was captured in 11 stations out of 21 stations in entire sanctuary area. The cameras gave us 111 photographs of Leopard including both flanks. Photos from left flank were used for analysis as the rosette patterns on the left side were better visible. The blurred photographs were removed from identification process. The presence of leopard was also confirmed by collecting scats and pug marks which act as an important sign for territorial marking. A total of 8 leopards were identified unique and probably found home within sanctuary either on a permanent or temporary basis. The name tags L_1, L_2, L_3, L_4, L_5, L_6, L_7 and L_8 was given to leopards.

The recaptured frequency varied from one individual to another. L_1 was captured 4 times, L_2 came 11 times in front of cameras, L_3 made its appearance 15 times, L_4 was observed 10 times, L_5 came only 3 times, L_6 and L_7 were seen only once and L_8 was observed roaming 5 times in the study period.

3.2.1 Population Closure Test

CAPTURE 2.1 was used for testing whether population was closed during the study period. z value was -3.178 with a probability of smaller value *i.e.* $p = 0.0007$. The test result satisfies the earlier assumption of population closure during study period. An encounter history file (inp) was devised to do the above task (Fig. 3.1). An encounter file was made by using binary number system where 1 (one) used to denote presence of individual and 0 (Zero) used to indicate absence of particular individual on each sampling occasion (days of trapping). Considering the first row from below data, leopard was encountered on 2nd, 11th and 23rd day of sampling (Annexure C).

```
010000000010100000000100000 1 0;
110010010101000001000000000 1 0;
001001101010110010011001000 1 0;
000100100001000101000100010 1 0;
000000000000011010000000000 1 0;
000000000000000000000010000 1 0;
000000000000000000000001000 1 0;
000000000000000000000000100 1 0;
```

Figure 3.1: Encounter history file of Leopard in inp file format

3.2.2 Population size

Closed population was estimated by using Null estimator E(0) in DENSITY 5.0 software which showed that leopard were captured ($N_{Capture}$) 38 times and recaptured(N_{Recapt}) 30 times with 8 unique(N_{Animal}) species of individuals of Leopard. The capture probability of leopard (P-hat) is 0.0517 whereas population size (N-hat ± SE) at 95% CI was estimated at 8.0 ± 0.3 (8.0 - 8.9). Alternatively, M_h Jackknife estimator gave a population size of 9.0 ± 1.5 with a capture probability (P-hat) of 0.0509(Annexure C).

3.2.3 Density of Leopard

Leopard population density was estimated as per distribution model-Poisson in Maximum Likelihood SECR mode. The detection and distribution model used were Half-normal and Poisson model respectively.

Leopard Population Density = 4.5 ± 0.019 animals/100 km^2

g(0) = Detection probability of leopard at the centre of home range.

g(0) = 0.017 (SE = 0.004)

σ = Scale of individuals movement from home range.

σ = 2.01 km^2(Annexure C)

3.2.4 MaxEnt Model of Leopard

MaxEnt model helps in the prediction of suitable habitat for individuals. In the map (Fig. 3.2), white dot depicts the location of leopards captured on camera trap during the study period. The color has been ranked from 0 to 1, the warmer colors such as red, orange and yellow showing the most suitable habitat conditions for leopard. The cooler colors such as blue indicate least favorable conditions for leopard (Fig. 3.2). The map indicates that region near to blue lake and Gate 10 are most preferred by leopards. These regions have moderate canopy cover to medium dense forest. This probably aids the leopard in predation.

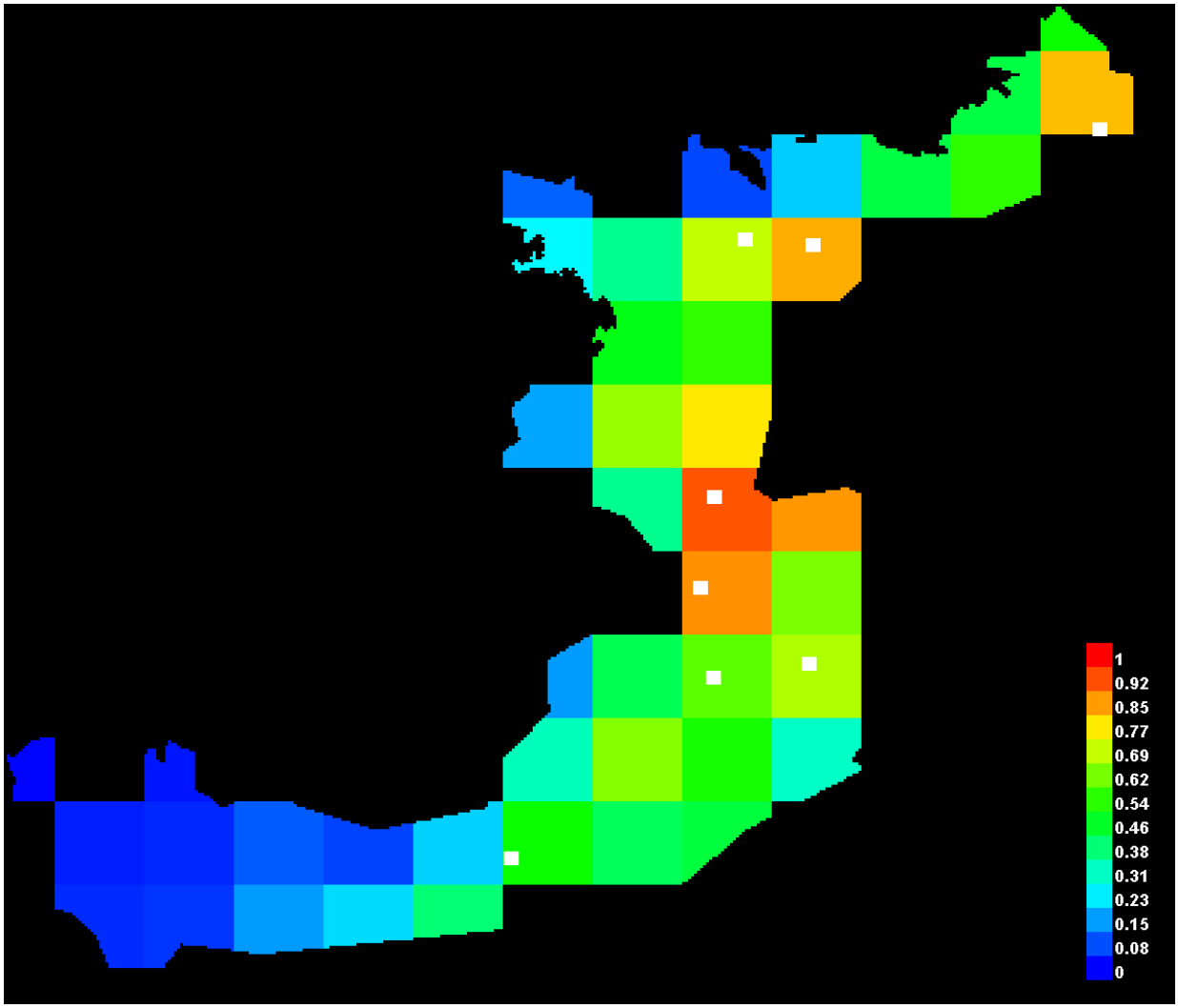


Figure 3.2: MaxEnt model of Leopard Habitat

3.2.5 Spatial Distribution of Leopard

Leopard was spotted in all the three blocks at 11 stations out of 21. The maximum presence of leopard was recorded in block 2 at station 10 which is located at the edge of grid 10. Sanjay Colony is highly human dominated area, despite this leopard were seen visiting the area from time to time. Area of sanctuary touching to Chhatarpur region followed by *Neeli Jheel* has witnessed maximum sightings of Leopard which indicates that leopard has been adapted well along with humans. Station no. 10, 34 and 32 are the most frequent spots where leopard visited most.

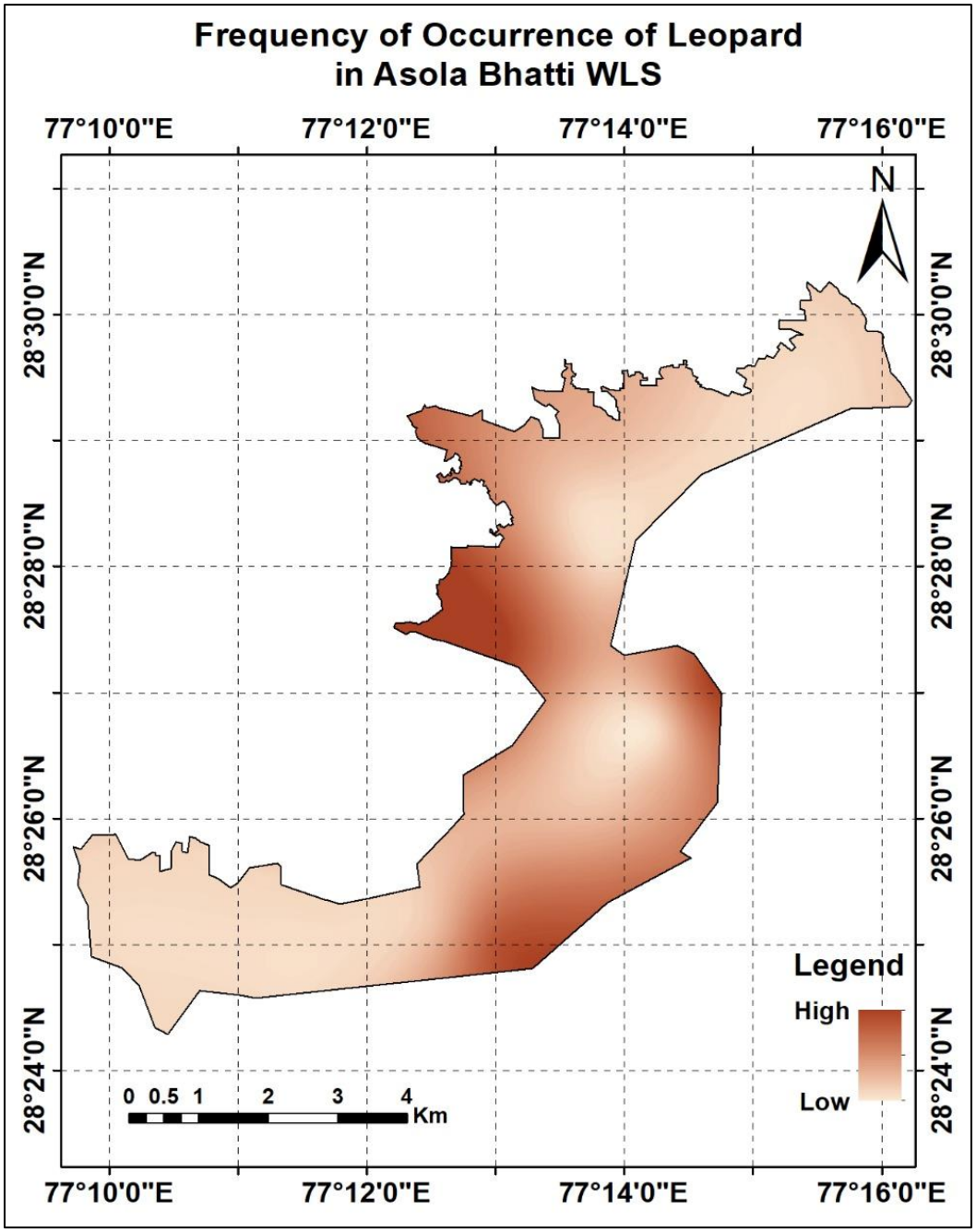


Figure. 3.3 Distribution of Leopard in ABWS

3.3 Distribution of Other Associated Mammals

Apart from leopard, the other mammals that made it in the list were striped hyaena (*Hyaena hyaena*), jungle cat (*Felis chaus*), golden jackal (*Canis aureus*), Indian hare (*Lepus nigricollis*), Indian boar (*Sus scrofa cristatus*), nilgai (*Boselaphus tragocamelus*), black buck (*Antilope cervicapra*), sambar deer (*Rusa unicolor*), spotted deer (*Axis axis*), hog deer (*Axis porcinus*), rhesus macaque (*Macaca mulatta*), Indian crested porcupine (*Hystrix indica*), two species of civet which are small Indian civet (*Viverricula indica*), Asian palm civet (*Paradoxurus hermaphroditus*), three species of mongoose including ruddy mongoose (*Herpestes smithii*), small Indian mongoose (*Herpestes auropunctatus*), Indian gray mongoose (*Herpestes edwardsii*), dog (*Canis lupus familiaris*), domestic cat (*Felis catus*), cow (*Bos taurus*), buffalo (*Bubalus bubalis*) and goat (*Capra aegagrus hircus*). Striped hyena, the scavengers responsible for cleaning of the carcasses are probably 2-4 in number. Due to lack of clear photographs, the individual identification of hyenas was not possible.

The most abundant mammals were cattle (including cow and buffalo). They were seen moving in deepest of the forest patches where hardly any animals visit. The next most abundant were nilgai which were also observed throughout the sanctuary, followed by dogs, golden jackal, Indian hare, porcupine, spotted deer, mongoose and civets. Striped hyena was found to be localized in few grids. The least abundant species were black buck and sambar deer as they are centered in a single grid. Rhesus macaques also have a enormous population inside ABWS. Feeding points have been made so that the monkeys won't escape the sanctuary boundary and enter the city. Humans from nearby areas also have their own share of photographs. Almost all camera trap stations have witnessed human presence at least once in a month. Cattle along with dogs had maximum presence near areas of human settlement such as Sanjay Colony.

Distribution of each mammal along with Human and cattle presence is shown below with the help of interpolation method.

3.3.1 Striped Hyaena (*Hyaena hyaena*)

IUCN Category: Near threatened

Striped hyaena is the only hyaena species that has been recorded in Indian subcontinent. They are mostly nocturnal and live a solitary life. They play a major role as a top scavenger within forests (Singh 2008). Like leopards, they are also known to survive in areas near human settlements. In ABWS, hyaenas have its maximum presence in third block which is closest to the Gurugram-Faridabad Highway. Micro-habitat of *Butea monosperma*, *Diospyros montana*, and *Holoptelea integrifolia* was common across sites where hyaena was spotted with an average canopy cover of 50 percent.

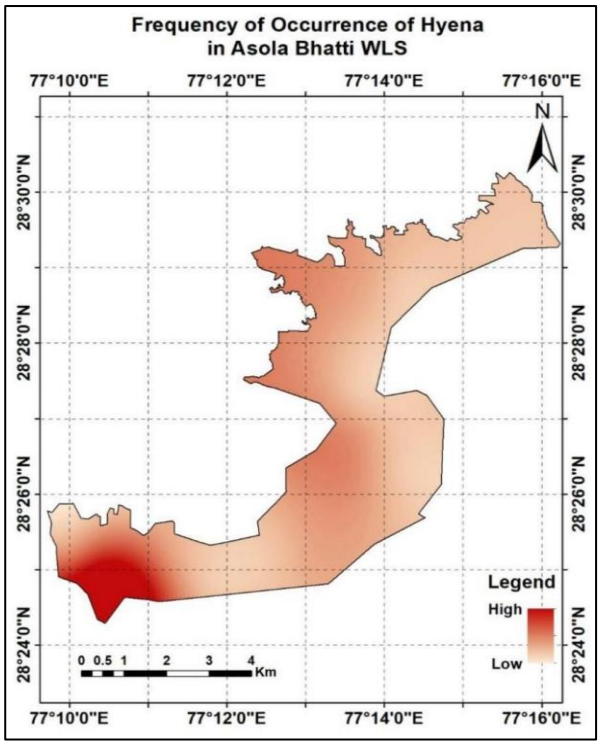


Figure 3.4: Map showing spatial distribution of hyaena

3.3.2 Co-occurrence of Leopard & Hyaena

Niche overlapping is observed considerably in leopard and hyaena due to similar prey base preferences. In this study, estimates of potential distribution and niche overlapping of leopard and hyaena have been produced using spatial methods, factoring in ecogeographical variables of the habitat suitability for the species assessed. The presence of species appeared to be strongly influenced by proximity to water sources, vegetation type, slope, elevation and with positive NDVI.

Normalized difference vegetation index is calculated for the study area using the NIR & Red bands from Sentinel 2 satellite images. Vegetation Index is related to the vegetation cover and primary net productivity, which contributes to soil fertility and plant productivity and positively influences biomass and species distribution. NDVI describes the difference between the vegetation reflectance of red and infrared bands and is used to estimate the density of green cover of the land. The values range from -1.0 to +1.0. High NDVI value suggests high reflectance of NIR and low reflectance of red bands, and vice versa. Areas of settlement, rock usually reflect low NDVI values. Sparse vegetation like shrubs and grasslands result in moderate NDVI values (approximately 0.2 to 0.5). High NDVI values (approximately 0.6 to 0.9) correspond to dense vegetation such as that found in temperate and tropical forests or crops

at their peak growth stage.

In this study, Cartosat-1 (2.5m resolution) image was used for Digital Elevation Modeling (DEM) which illustrates 3-D view of topographic surface is raster format. DEM was used to estimate the slope and elevation of study area.

The slope tool identifies the steepness at each cell of a raster surface. Flat terrains have lower slope values, while steep terrains have higher slope value. For our study, slope values from 0-3.5 were taken as “very gentle”, while values above 24-59.7 (maximum value) were taken as “very steep”. Slope values from 7-12.8 were taken as “moderate”.

Contour maps show the elevations of the surface features, which allows looking at a two-dimensional map to visualize clear image of the land and the surrounding area features in three dimensions. It is easier to sort out different elevation of the landscape by reading contour interval. In this study elevation ranges from 180-260m. The elevation is suggested as influencing factor to determine distribution of species, the study shows overlap between leopard and hyena as they also favored lower altitudes. This pattern is potentially related to the increased distribution of wild prey around perennial water sources in lower elevation ranges.

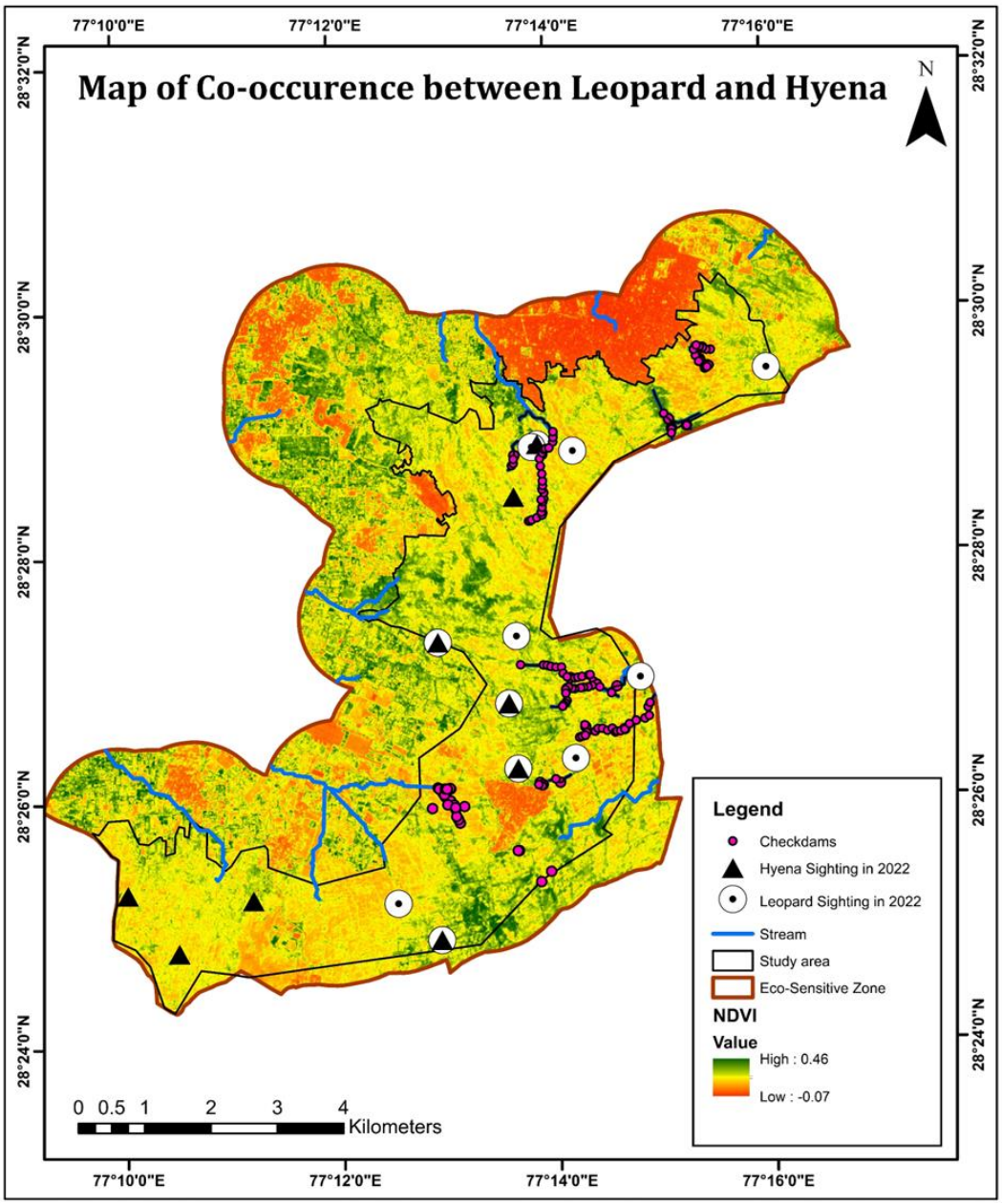


Figure 3.5: *Map of co-occurence between leopard and hyaena (NDVI).*

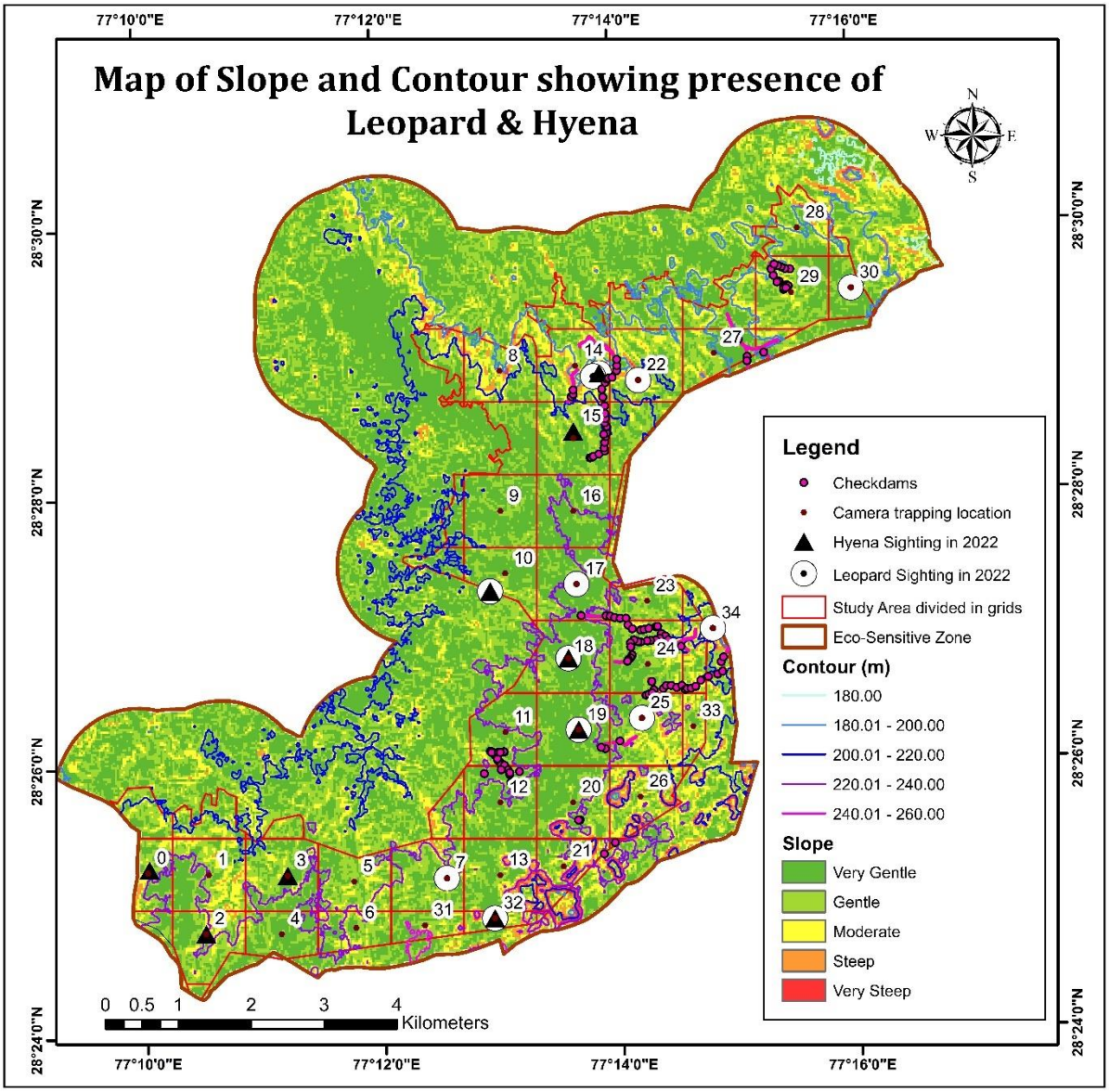


Figure 3.6: Map of co-occurence between leopard and hyaena (contour).

3.3.3 Jungle Cat (*Felis chaus*)

IUCN Category: Least Concern

Jungle cat is one of the 10 species of cats recorded in the Indian Subcontinent (Noor, 2021). Their diet typically includes small mammals such as hares, rats, birds, reptiles and amphibians (Mishra and Bisht, 2019). They are distributed in all habitats within ABWS in most of the sections of forest. Their distribution is found overlapping with most of the mammals indicating a more general habitat preference.

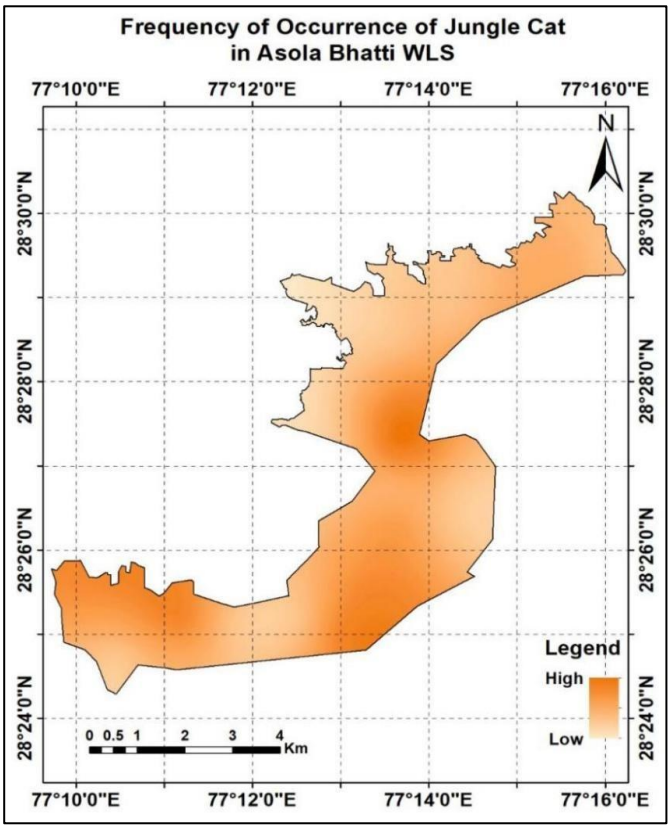


Figure 3.7: Spatial distribution of jungle cat.

3.3.4 Indian Boar (*Sus scrofa cristatus)*

IUCN Category: Least Concern

Indian boar is distributed widely all over India. These omnivores play an important as scavengers as well as part of the prey base for large carnivores (Khan and Ilyas, 2018). Their abundance in the sanctuary is low, and they are localized to few areas near human settlements.

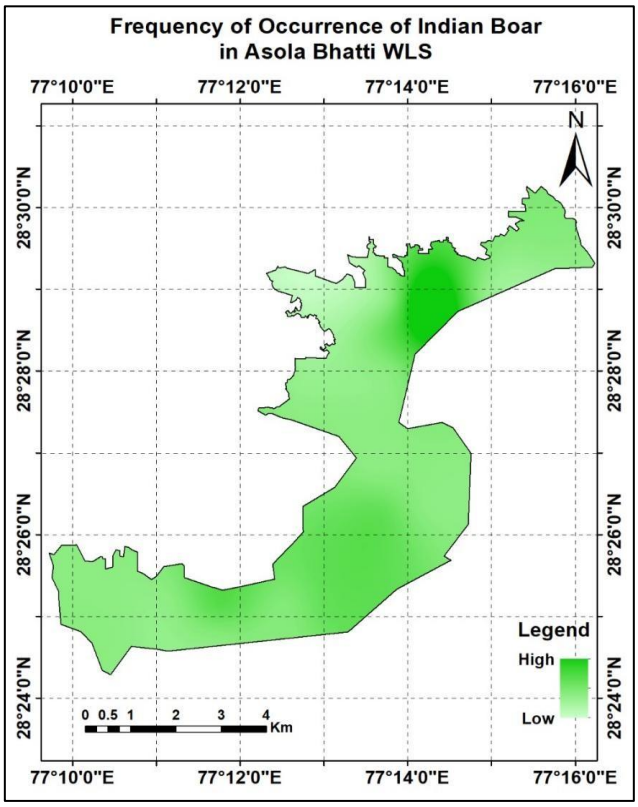


Figure 3.8: Spatial distribution of Indian boar.

3.3.5 Golden Jackal (*Canis aureus*)

IUCN Category: Least Concern

Golden jackal can be traced more commonly near human settlements comparing to other members of its family such as wolf. Small and medium sized animals like hare are included in its diet. They were recorded scavenging as well, feeding on the carrion of nilgai. There is a small population of golden jackals in ABWS, no more than two individuals were spotted together in camera traps.

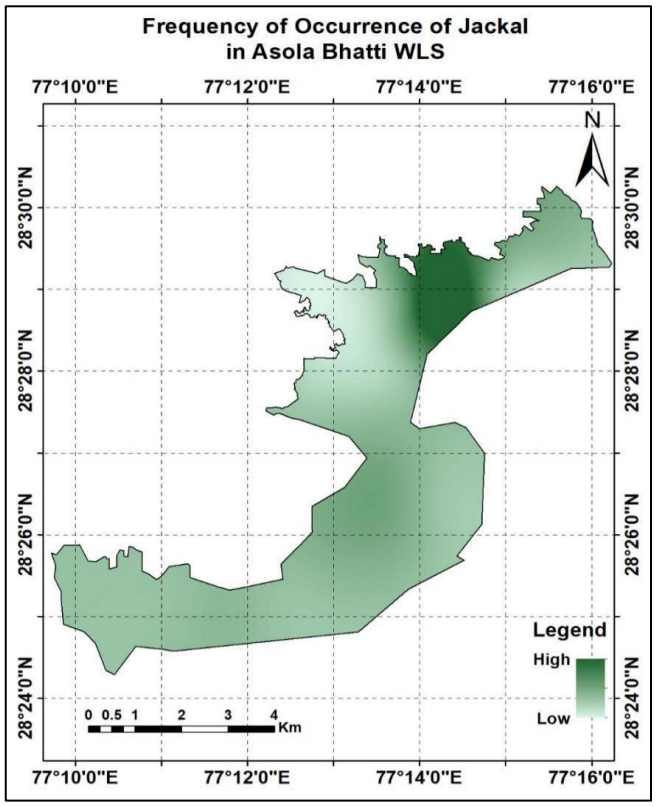


Figure 3.9: Spatial distribution of golden jackal

3.3.6 Spotted Deer (*Axis axis*)

IUCN Category: Least Concern

Indian spotted deer are found throughout dry and mixed deciduous forests in India, where they act as prey for large carnivores. Due population decline of chital in ABWS the Forest Department has constructed an enclosure. Now, large numbers of chitals can be spotted across the sanctuary with highest concentration near the enclosure which has been kept open. They were found sharing habitat with leopard and hyaena in area near Neeli Jheel probably because of permanent water source.

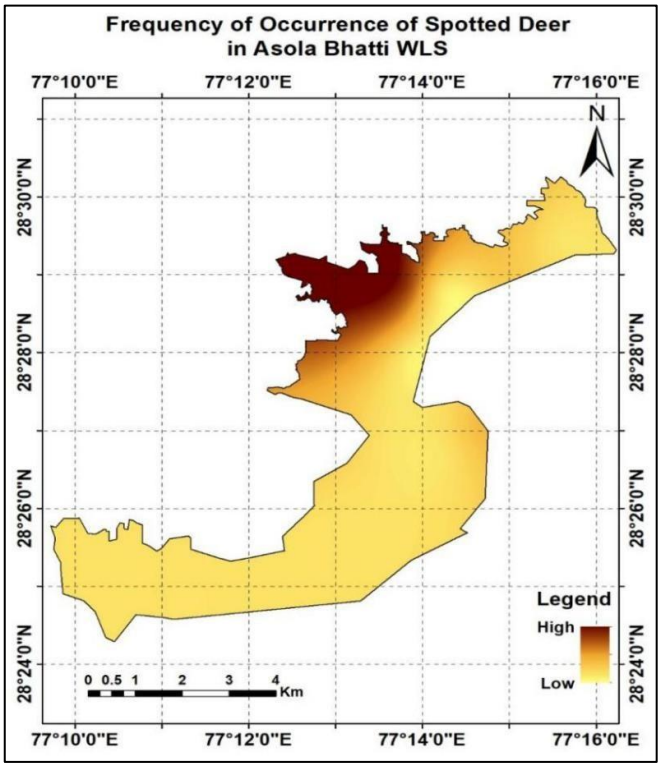


Figure 3.10: Spatial distribution of spotted deer.

3.3.7 Sambar Deer (*Rusa unicolor*)

IUCN Category: Vulnerable

Sambar deer has been recorded from various forest types such as thorny forests of Gujarat and Rajasthan, evergreen and semi evergreen forest of north-eastern India, moist-deciduous forest of peninsular India and pine forest of Himalayas (Sankar and Acharya, 2004). Sambar deer was shifted in forest from the Delhi golf club by the Forest Department. But over the years only two of them have been left alive as they serve as a prey species for large carnivores like the leopard.

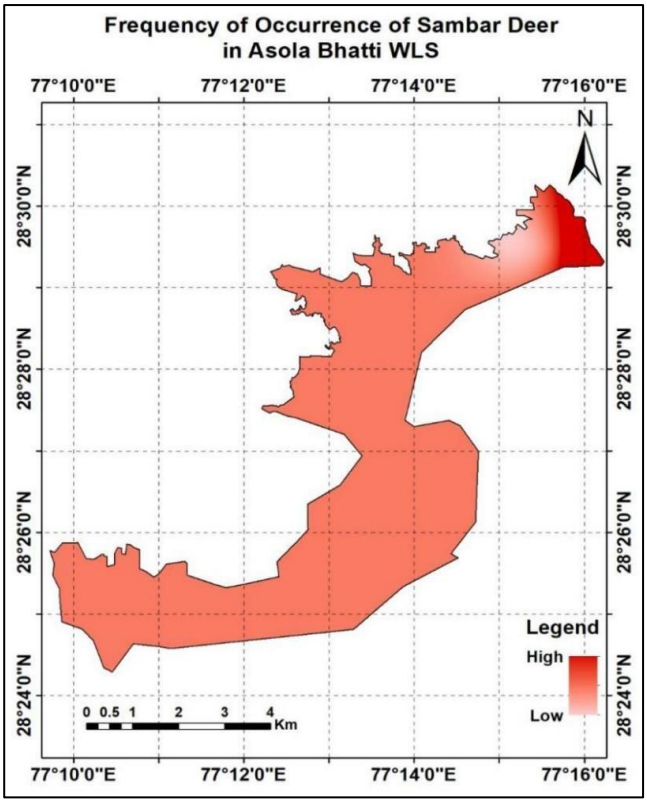


Figure 3.11: Spatial distribution of sambar deer.

3.3.8 Indian Crested Porcupine (*Hystrix indica*)

IUCN Category: Least Concern

Indian crested porcupine is the largest porcupine species of India. The presence of this nocturnal species can easily be confirmed by their elongated scats. The scat records confirm their presence across the sanctuary. Their abundance was remained moderate but consistent throughout the forest.

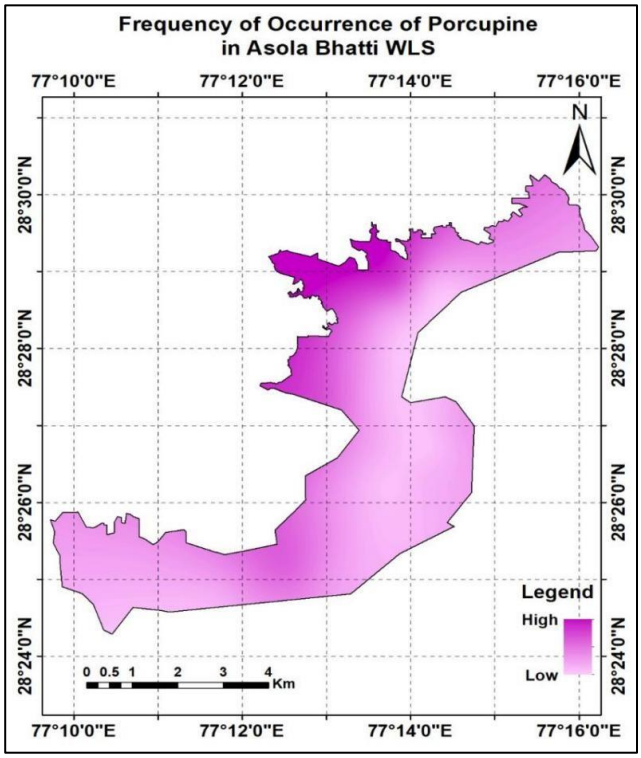


Figure 3.12: Spatial distribution of porcupine

3.3.9 Indian Hare (*Lepus nigricollis*)

IUCN Category: Least Concern

Indian hare act as prey for large and medium sized carnivores, and play an important role in forest food chains. They have been recorded in every type forest across India.

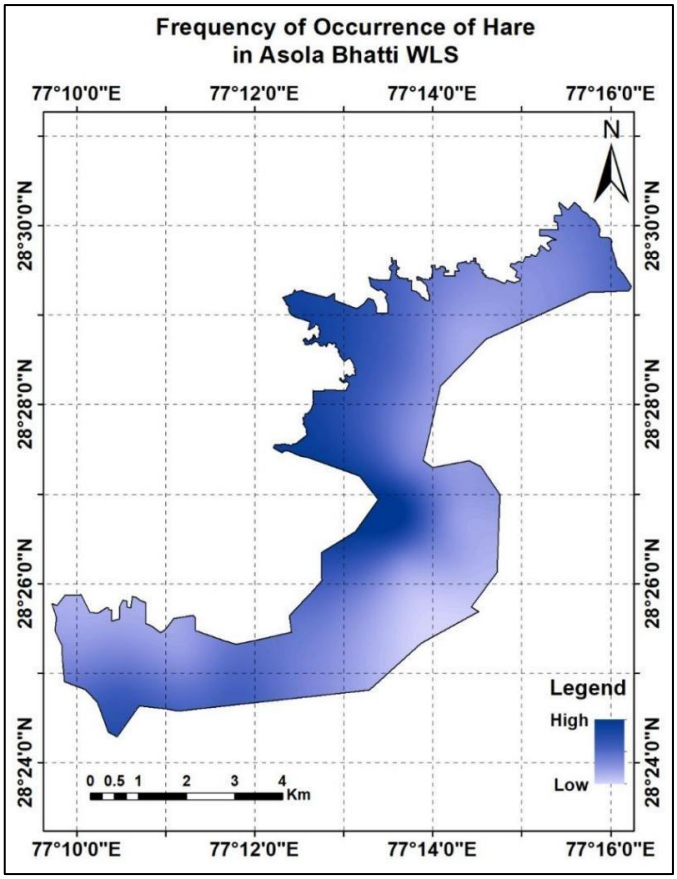


Figure 3.13: Spatial distribution of hare.

3.3.10 Small Indian Mongoose (*Herpestes auropunctatus*)

IUCN Category: Least Concern

Small Indian mongoose can often be seen in cultivated lands, urban and peri-urban areas. They are believed to be carnivore but also considered are opportunistic feeders of seeds, vegetables and human waste (Louppe et al. 2020). With less abundance, Small Indian mongoose was localized to a few locations in ABWS. They were totally absent in many sections of study area. The behavior pattern was diurnal.

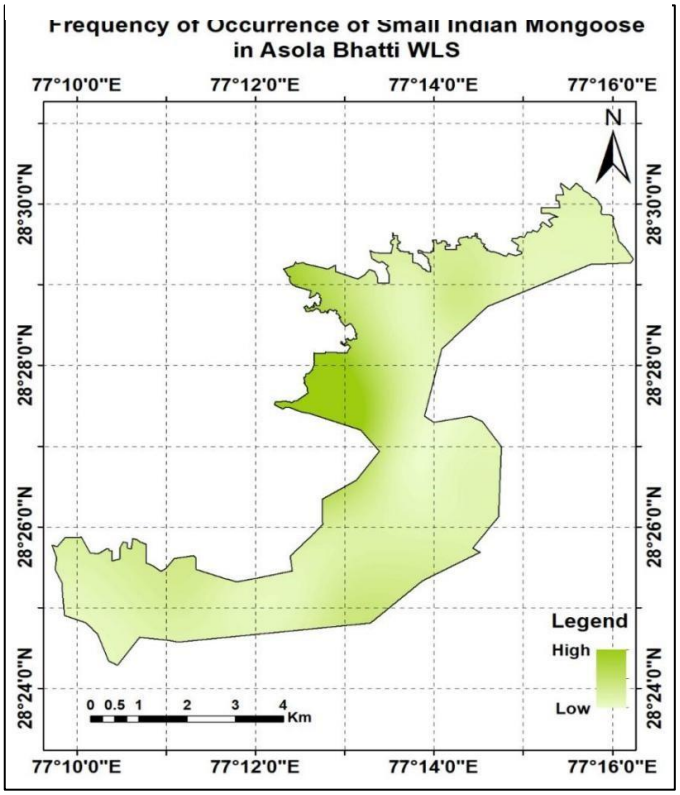


Figure 3.14: Spatial distribution of Small Indian mongoose.

3.3.11 Indian Grey Mongoose (*Herpestes edwardsii*)

IUCN Category: Least Concern

Indian grey mongoose is usually found near human habitation and prefers open forest and cultivated fields. This species plays an important role in the food chain being at the top level (Rajashekara and Venkatesha, 2015). Among the three mongoose species of ABWS, they are found to be the least abundant.

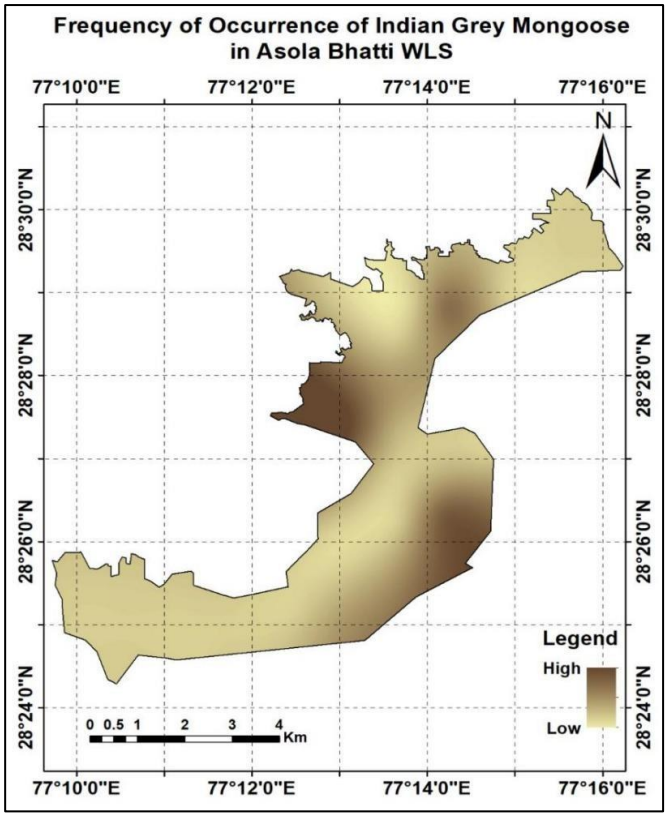


Figure 3.15: Spatial distribution map of grey mongoose

3.3.12 Ruddy Mongoose (*Herpestes smithii*)

IUCN Category: Least Concern

Ruddy mongoose is not dispersed widely in the sanctuary, rather it is concentrated at few places. Mostly diurnal, but at some places in the forest found to be active during the night. Photographic evidences from camera traps have shown they have a preference for feeding on dead carcasses of nilgai.

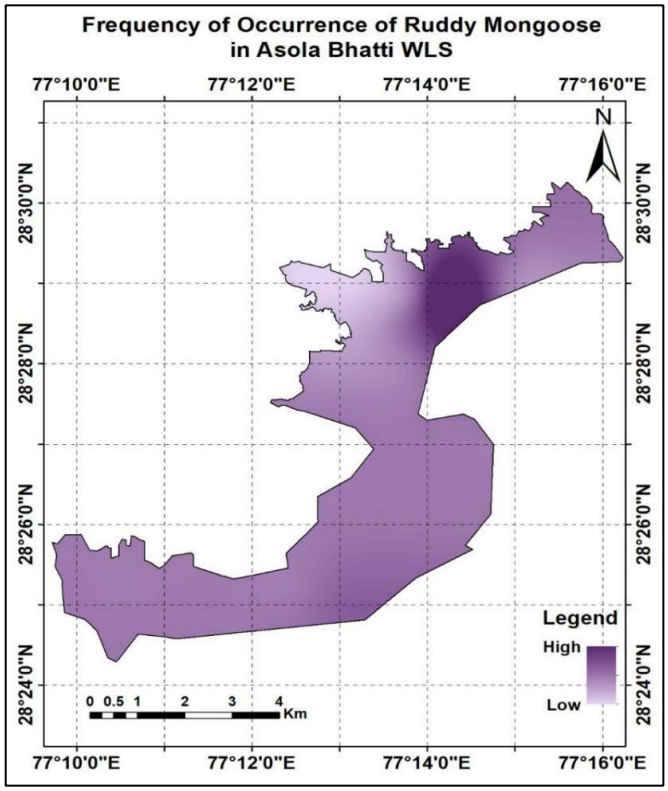


Figure 3.16: Spatial distribution map of Ruddy mongoose.

3.3.13 Nilgai (*Boselaphus tragocamelus*)

IUCN Category: Least Concern

Nilgai is the largest Asian antelope. They are usually seen in agriculture fields. They do not seem to prefer dense patches of forest, rather they were recorded from areas with scattered tree cover. The behavior pattern was diurnal at most times but occasionally observed at night.

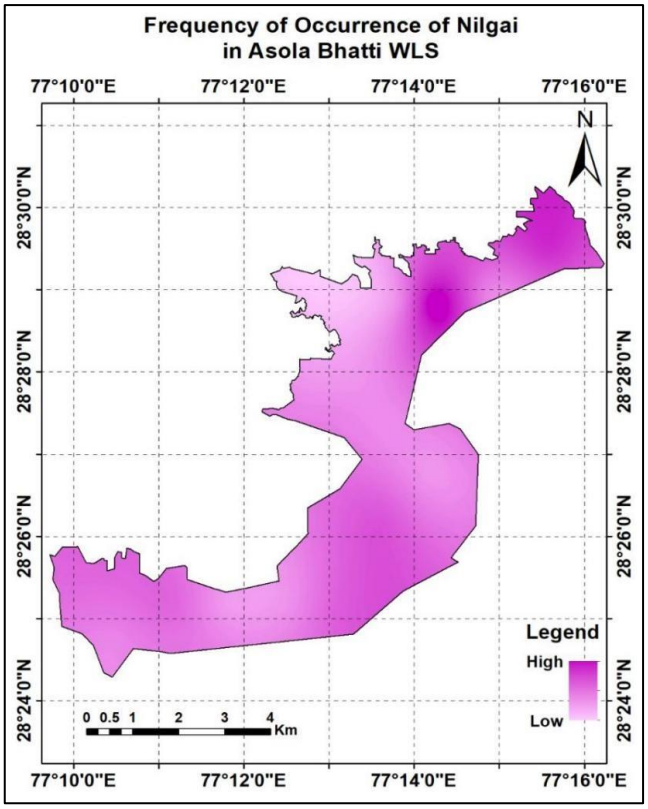


Figure 3.17: Spatial distribution map of nilgai.

3.3.14 Small Indian Civet

IUCN Category: Least Concern

Small Indian Civets are generally nocturnal and solitary mammals. They show an opportunistic type of feeding pattern. Although identified as a carnivore, they can sometimes be found feeding on seeds and fruits. The sightings of small Indian civet were primarily from open and scattered type of forest. No specific habitat was observed but a majority of captured was near Neeli Jheel.

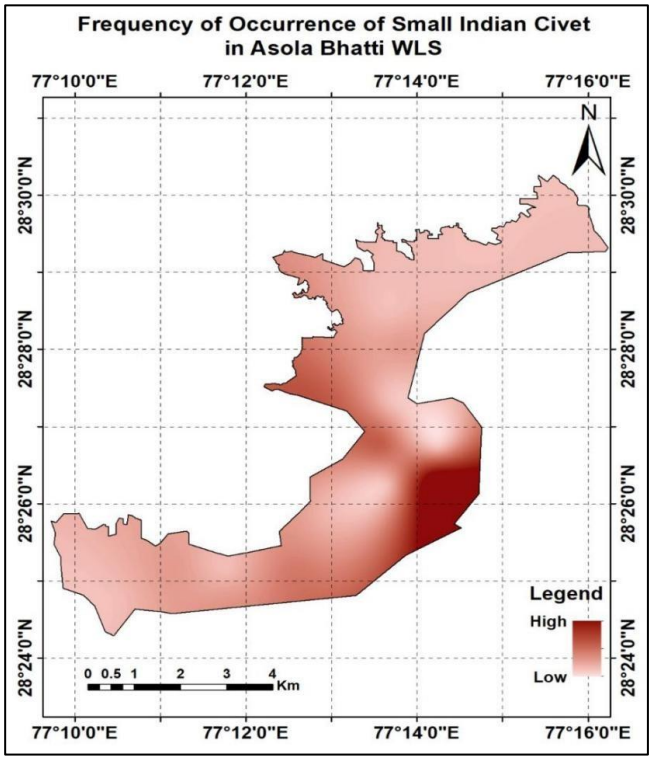


Figure 3.18: Spatial distribution of small Indian civet

3.3.15 Common Palm Civet (*Paradoxurus hermaphroditus*)

IUCN Category: Least Concern

Common palm civets are important seed dispersing species. The name palm civet comes from their fondness for palm flower sap which later becomes "toddy", and thus this species is also known as toddy cat. Few were spotted, but they were seen at significant places sharing habitat with hyaena and other mammals.

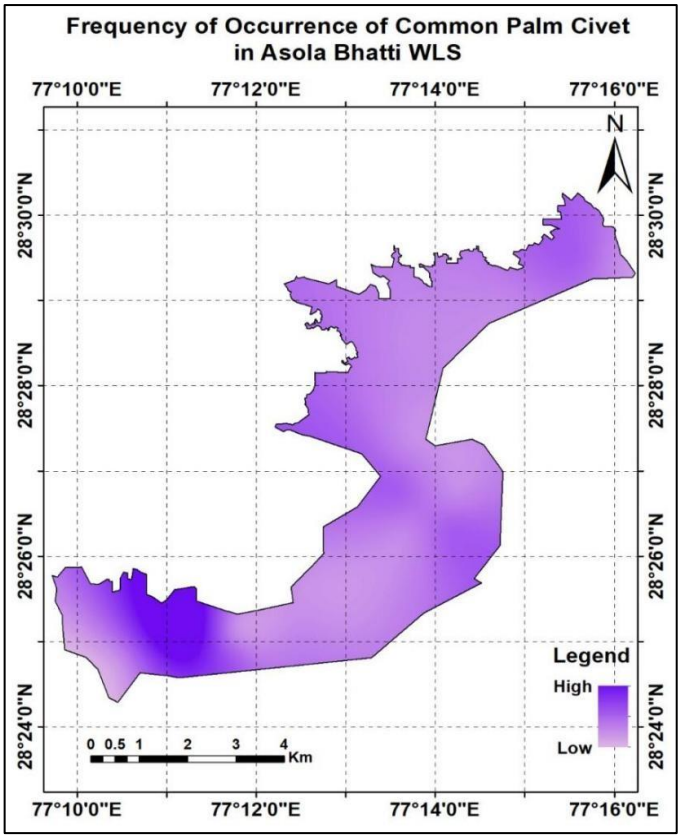


Figure 3.19: Spatial distribution of common palm civet.

3.3.16 Humans and Domesticated Mammals

As can be seen in Fig. 3.20, 3.21 and 3.22, the presence of humans, cattle and dogs are overlapping in the sanctuary with Sanjay Colony being the epicenter. Areas of sanctuary also witnessed tourists and departmental workers on a daily basis. Photographic records have shown leopard feeding upon a carrion of cattle, which can be also true in the case of dogs as dogs are also a preferable prey species for leopards.

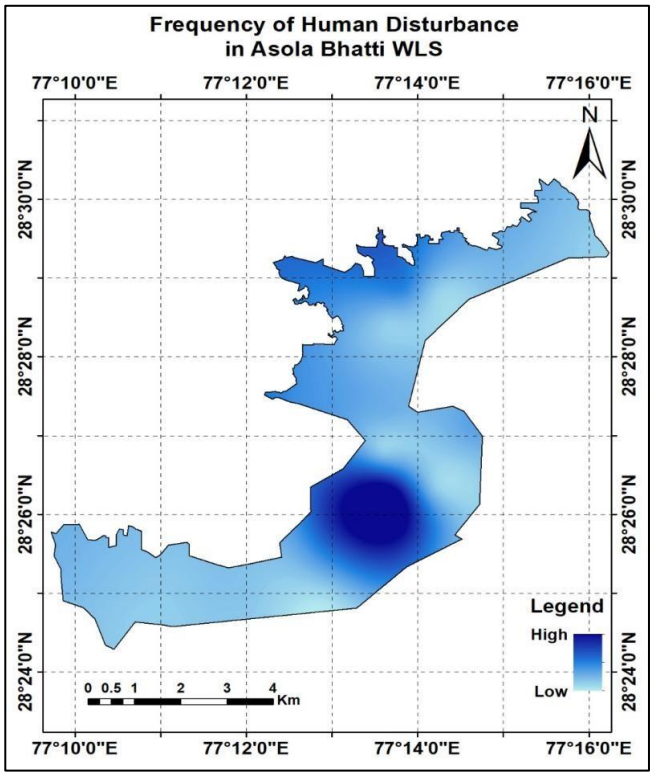


Figure 3.20: Spatial distribution of human presence.

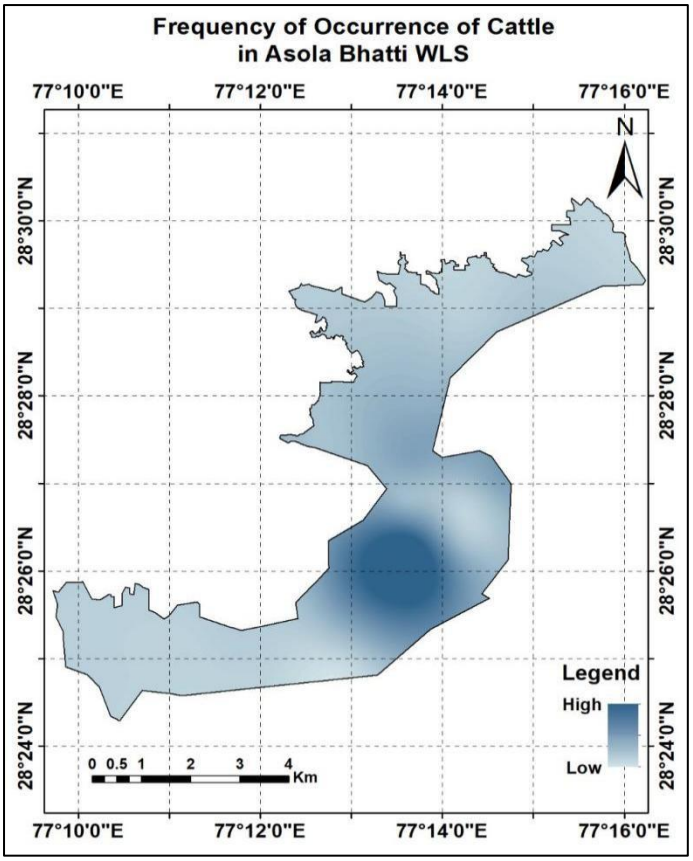


Figure 1.21: Spatial distribution of cattle.

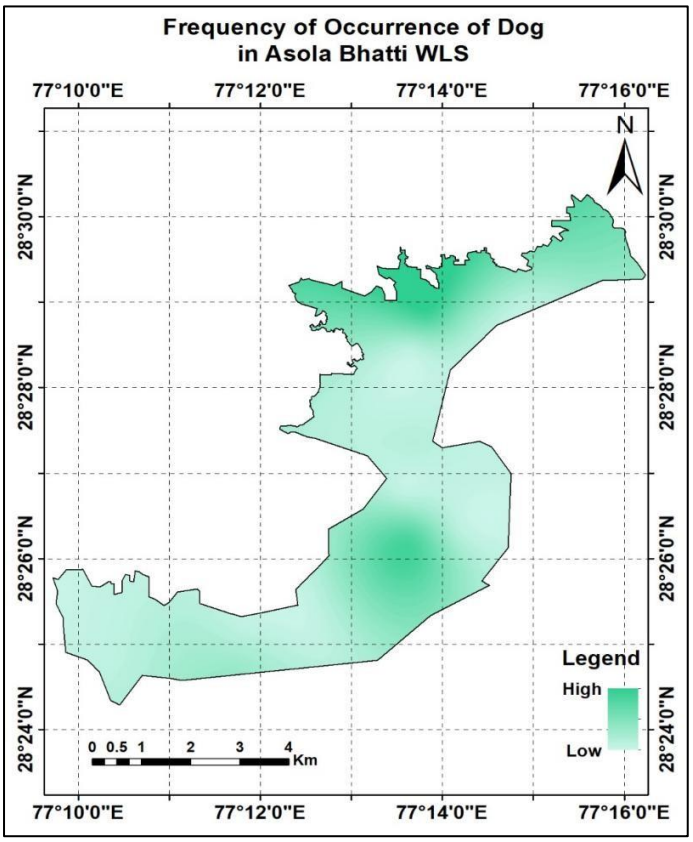


Figure 3.22: Spatial distribution of dog.

4.1 DISCUSSION

This camera trap study was done with the aim to find out the occupancy status of leopard and other mammals residing inside ABWS.

4.1 Status of Leopard in ABWS

The belief that leopards can coexist alongside human settlements holds its ground in this study. A total of 8 leopards were found in ABWS. Of these 8 leopards, 4 males and 1 female have appeared on a regular basis in front of camera traps. They have been found roaming the same tracks once and even twice in the same week multiple times. This suggests that they have made this urban forest their permanent home.

It was found that most of the leopards share their home ranges with each other. Studies have suggested that a leopard's home range largely depends upon the availability of prey and can vary somewhere between 9 km^2 to 451 km^2 (Kumbhojkar et al. 2018). The leopards of Asola share an area of just 32.71 km^2 and probably also occupy the adjoining forest patches of the bordering Faridabad district. The presence of leopard has many implications for the ecosystem of this unique forest. Leopards were not seen for many decades in ABWS after 1940 as per Gazetteer of Delhi. Hence, the question arises, where did these leopards come from all at once? The possible answer to this question is that the Sariska-Delhi Wildlife corridor is still functional and after restoration programmes in ABWS provided a safe habitat for them as well as their associated species. The presence of leopard in Asola also throws light over the importance of this wildlife corridor.

Leopard being the top predator of the moderate forest of ABWS is significant for maintaining the functioning of this food chain. The activity pattern of leopard here in ABWS is also a thing of interest. Leopard can be both diurnal and nocturnal depending on factors such as human disturbances, presence of large carnivores and prey base. In Asola, most leopards were seen moving across the forest at night time, but occasionally they have also visited cameras in day times showing diurnal pattern. Leopard density was maximum at two places. One was near the permanent water source that is the Neeli Jheel. The other being at the boundary near Gate 10 beyond which Asola Farms and Chhatarpur lie. Even Sanjay colony has not remained untouched by the presence of leopards. This again reaffirms the understanding that leopards and humans can coexist.

4.2 Status of Associated Mammals in ABWS

An important carnivore residing inside the sanctuary apart from the leopards is the striped hyaena. Hyenas have major biological role in decomposing carrion of animals. Due to poor photographs, actual numbers of hyena couldn't be estimated but they do have their footprints across the whole sanctuary. Being an important scavenger hyena was seen using same trail as leopard was. Scats and hyena tracks have also been recorded at places where leopard presence was confirmed.

Jungle cat, golden jackal, Indian hare, Indian boar, nilgai, black buck, sambar deer, spotted deer, hog deer, rhesus monkey, Indian crested porcupine, two species of civet, three species of mongoose, dogs, domestic cat, cow, buffaloes and goat are also found in ABWS. Cattle such as cow and buffaloes share a major part in forest biomass. Goats and pigs have also seen roaming within forest. All these cattle species indicate presence of humans.

4.3 Comparing Leopard Population from Other Regions of India

S.No.	Protected Area	Study Year	Location	Leopard Population Density
1.	Asola Bhatti Wildlife Sanctuary	2022	Delhi	4.5 ± 0.019 animals/100 km^2
2.	Sanjay Gandhi National Park	2022	Maharashtra	26.34 ± 4.96 (SE)/100 km^2
3.	Bandhavgarh National Park	2021	Madhya Pradesh	3.03 ± 0.78/ 100 km^2
4.	Dachigam National Park	2020	Jammu & Kashmir	2.8 ± SE 1.18/100 km^2
5.	Achanakmar Tiger Reserve	2017	Chhattisgarh	12.04 ± 2.98/ 100 km^2
6.	Mudumalayi Tiger Reserve	2011	Tamil Nadu	13.41 (SE = ±2.67) to 28.91 (SE = ±7.22) per 100 km^2

7.	Sariska Tiger Reserve	2010	Rajasthan	3.1±0.4 /100 km^2
8.	Sariska Tiger Reserve	2009	Rajasthan	6.2±0.8/100 km^2
9.	Sariska Tiger Reserve	2008	Rajasthan	7.6±0.6 (SE) /100 km^2

Figure 4.1: Table comparing leopard population density across protected areas.

As Figure 4.1 shows, the highest population density of leopards was detected in Sanjay Gandhi National Park which is located in Mumbai, Maharashtra, a metropolitan city. Clearly there is immense potential for urban forests to host large carnivores like the leopard. ABWS leopard population density is comparable to other protected areas in Madhya Pradesh, Kashmir, Chattisgarh, and Rajasthan. Yet there is potential for the sanctuary to support a greater population of leopards.

4.4 Relationship with Humans

Humans have been using the resources of the Delhi Ridge long before the sanctuary was established. The creation of ABWS and the recent introduction of the Eco Task Force (ETF) has reduced human activity in the sanctuary. Delhi's Department of Forests and Wildlife has initiated restoration and plantation activities within the sanctuary to rewild it. Once a barren area with abandoned mining pits and invasive trees, ABWS has undergone transformation into a lush forest with myriad flora. This has subsequently led to the return of leopard and other mammals in this area.

The ETF may have reduced the human activity within the sanctuary, but it still shares boundaries with regions with dense human population such as Sangam Vihar from the North, Chhattarpur, Sainik Farmsand Fatehpur Beri the west, and villages like Mangar and Pali of Faridabad (Haryana) from the south. Sanjay Colony is situated within the boundaries of sanctuary. People from these areas are seen as regular passerby within the forest. Clearly, leopard and other mammals are capable of coexisting with humans in the forest.

On the southern side of the sanctuary, Gurugram-Faridabad highway with fast moving traffic is situated. Since the last several years, deaths of leopards and other mammals have been witnessed on this highway. The highway is a major obstruction to animal movements as it separates the sanctuary from the Delhi-Sariska Wildlife Corridor. Asola Bhatti Wildlife sanctuary surely provides a safe habitat for these creatures, but it is important to factor in the

larger context and the limitations of protected areas. Protected areas can only serve limited purpose, larger policy changes are needed to allow the safe passage of animals and protect from becoming roadkill.

4. CONCLUSION

This camera trap study aimed to assess the status of various mammal species in ABWS was conducted from June 2021 to June 2022. It has provided an estimation of population size, density and spatial distribution of leopard, and shed light on presence and spatial distribution of various other mammals.

The study authenticates the presence of 8 leopards in ABWS which is an indicator of the thriving ecosystem of the sanctuary. Despite human presence large and small mammals are successfully living inside ABWS. Be it ABWS or the Sariska-Delhi Wildlife Corridor, animals have found a way to travel across forests.

A lot has been done in the past, but much more can be accomplished. This study will serve as a pilot study, and be used to design a programme where long-term studies of different mammals will be conducted. Considering leopard an umbrella species, this study can be useful in devising various conservation management plans for other associated species with the goal of transforming Asola Bhatti Wildlife Sanctuary into a true urban wildlife refuge.

REFERENCES

Champion, H. G. and Seth, S. K. (1968). *Forest types of India*. Manager Publications, Government of India, Delhi. 234.

Dwivedi, M., Meena, D., Rather, S., Danda, S and Kasana, S. (2018). Floristic Diversity at Asola Bhatti Wildlife Sanctuary, Delhi, India. *Phytomorphology: An International Journal of Plant Morphology*. 68: 15-29.

Elith, J., Phillips, S.J., Hastie, T., Dudik, M., Chee, Y.E., and Yates, C.J. (2010). A statistical explanation of MaxEnt for ecologists, *Diversity and Distribution*, 17(1): 43-57.

Gil-Sanchez, J.M., Moral, M., Bueno, J., Rodrigues-Siles, J., Lillo, S., Perez, J., Martin, J.M., Valenzuela, G., Garrote, G. and Torralba, B. (2011). The use of camera trapping for estimating Iberian lynx (*Lynx pardinus*) home ranges. *Eur. J. Wildl. Res.* 57: 1203–1211.

Harihar, A., Pandav, B. and Goyal, S.P. (2009). Density of leopards (*Panthera pardus*) in the Chilla Range of Rajaji National Park, Uttarakhand, India. *Mammalia*, 73(1): 68-71.

Karanth, K.U. and Nichols, J.D. (2002). *Monitoring tigers and their prey: a manual for researchers, managers, and conservationists in tropical Asia*. Centre for Wildlife Studies.193.

Karanth, K.U., Chundawat, R.S., Nichols, J.D. and Kumar, N.S., (2004). Estimation of tiger densities in the tropical dry forests of Panna, Central India, using photographic capture–recapture sampling. In Animal Conservation forum, Cambridge University Press. 7(3): 285-290.

Kumbhojkar, S., Yosef, R., Kosicki, J. Z., Kwiatkowska, P. K., & Tryjanowski, P. (2021). Dependence of the leopard Panthera pardus fusca in Jaipur, India, on domestic animals. *Oryx*, *55*(5), 692-698.

Kushwaha, S. P. S., Nandy, S., & Gupta, M. (2014). Growing stock and woody biomass assessment in Asola-Bhatti Wildlife Sanctuary, Delhi, India. *Environmental Monitoring and Assessment*, *186*(9), 5911-5920.

Maheswari, J. K. (1963). *The Flora of Delhi*, CSIR, New Delhi.447

Miththapala, S., Seidensticker, J., & O'Brien, S. J. (1996). Phylogeographic subspecies recognition in leopards (Panthera pardus): molecular genetic variation. *Conservation Biology*, *10*(4), 1115-1132.

Mondal, K. 2006. *Leopard and ungulate abundance estimation in Rajaji National Park*, Uttranchal. Masters thesis. Forest Research Institute (Deemed University), Dehradun.

Nowell, K. and Jackson, P. (1996). *Wild Cats. Status Survey and Conservation Action Plan*. IUCN/SSC Cat Specialist Group, International Union for Conservation of Nature, Gland, Switzerland. 382.

Prater, S.H. (1980). *The book of Indian animals* (3rd edition). Bombay Natural History Society, Bombay, 22: 324.

Ramesh, T., Kalle, R., Sankar, K. and Qureshi, Q. (2012a). Spatio-temporal partitioning among large carnivores in relation to major prey species in Western Ghats. *Journal of Zoology*, 287(4): 269-275.

Ramesh, T., Sridharan, N., Sankar, K., Qureshi, Q., Selvan, K.M., Gokulakkannan, N., Francis, P., Narasimmarajan, K., Jhala, Y.V. and Gopal, R. (2012b). Status of large carnivores and their prey in tropical rainforests of South-western Ghats, India. *Tropical Ecology*, 53(2): 137-148.

Sati, J.P., and Khanna, V. (2003). Some Selected Fauna of Asola-Bhatti Wildlife Sanctuary. *Fauna of Conservation Area.* 16: 1-70

Singh, R., Qureshi, Q., Sankar, K., Krausman, P.R. and Goyal, S.P. (2014). Evaluating heterogeneity of sex-specific capture probability and precision in camera-trap population estimates of tigers. *Wildlife Society Bulletin.* 38(4): 791-796.

Sunquist , M. and Sunquist , F. (2002) *Wild Cats of the World.* The University of Chicago Press , U.S.A. 462.

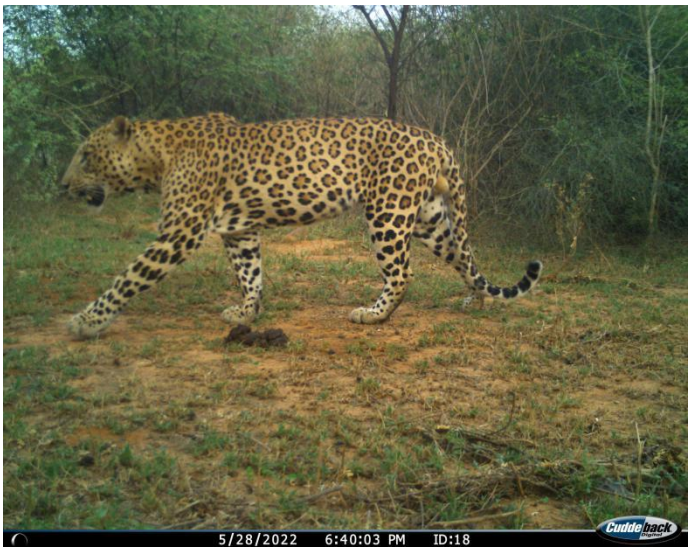
Surve, N., Sambandam, S., Sankar, K., Jathanna, D., Gupta, V., and Athreya, V. (2022). Leopards in the City: The Tale of Sanjay Gandhi National Park and Tungareshwar Wildlife Sanctuary, Two Protected Areas in and Adjacent to Mumbai, India. *Front. Conserv. Sci*. 3:787031.

ANNEXURE A

Leopards of Asola Bhatti Wildlife Sanctuary

A) L_1

B) L_2



C) L_3

D) L_4

E) L_5

F) L_6

G) L_7

H) L_8

ANNEXURE B
Associated Mammals of ABWS

A) Black buck

B) Nilgai

C) Sambar Deer

D) Spotted Deer (Chital)

E) Small Indian Civet

F) Common Palm Civet

G) Golden Jackal

H) Jungle Cat

I) Striped Hyena

J) Indian Boar

K) Indian Crested Porcupine

L) Indian Hare or Black Naped

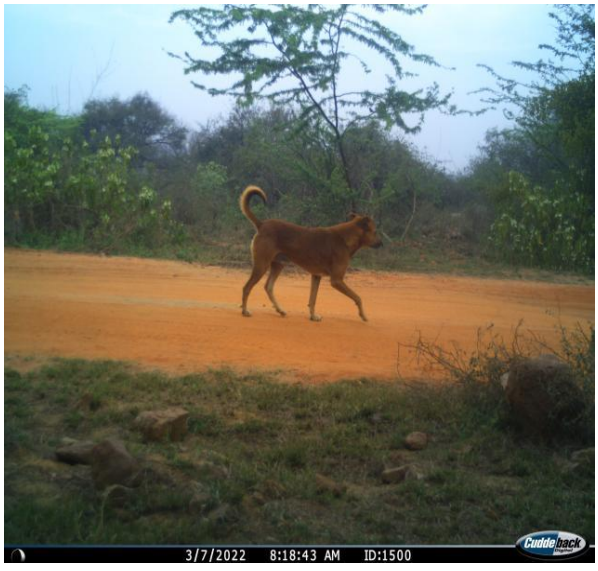
M) Ruddy Mongoose

N) Small Indian Mongoose

O) Indian Grey Mongoose

P) Hog Deer

Q) Domestic cat



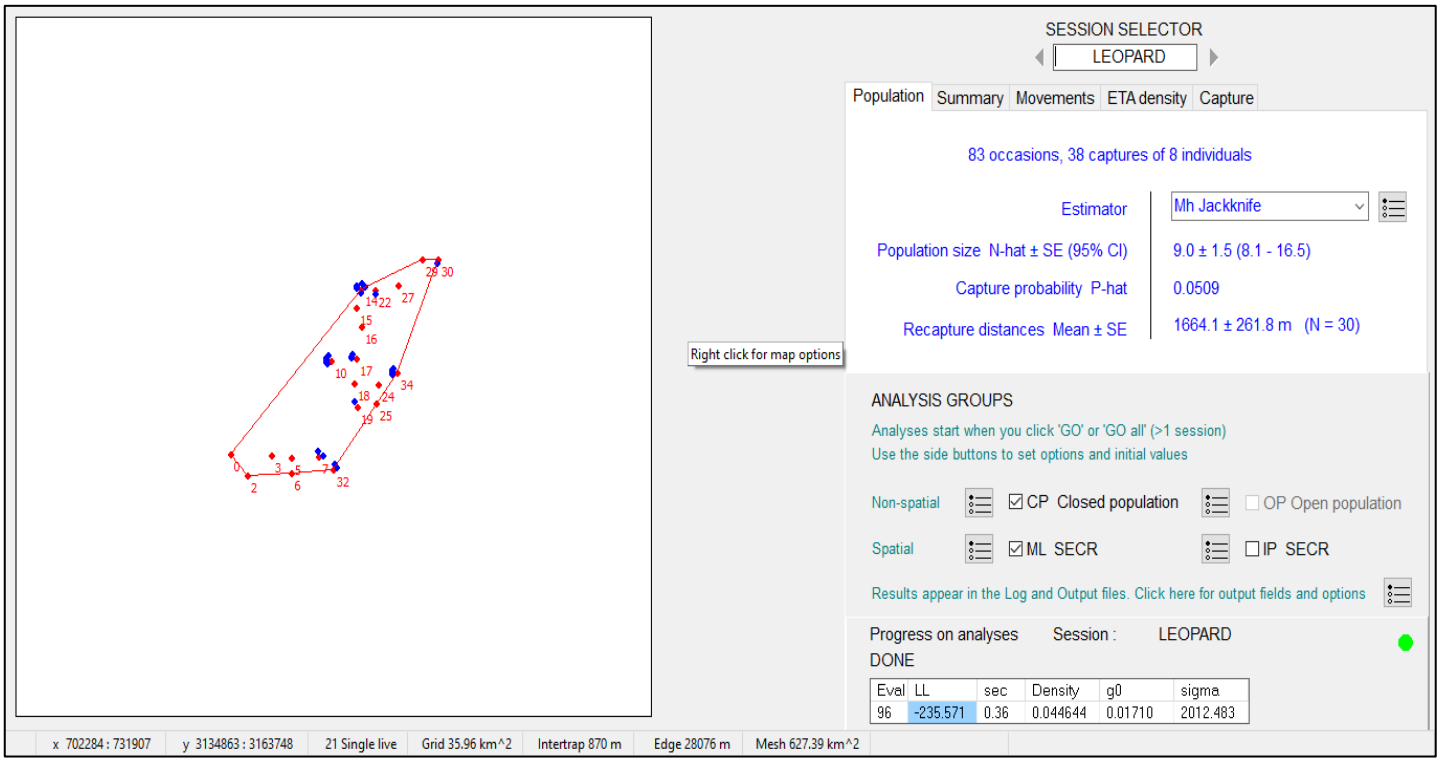
R) Dog

APPENDIX C

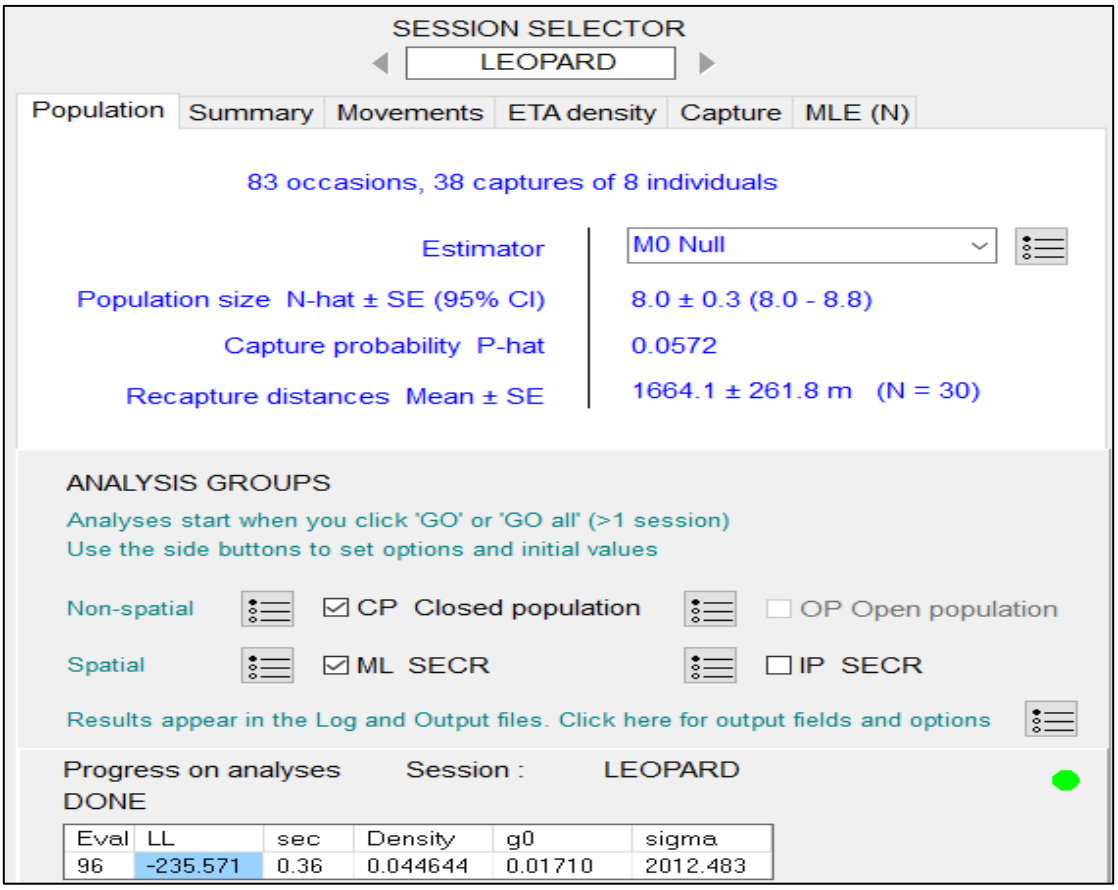
Result of CAPTURE 2.1 - Population Closure Test

```
Mark-recapture population and density estimation program

Input---read input data

          Summary of captures read
                    Number of trapping occasions        28
                    Number of animals captured          80
                    Maximum x grid coordinate          1.0
                    Maximum y grid coordinate          1.0

Input---task closure test

Test for closure procedure.

             Overall test results --
             z-value                              -3.178
             Probability of a smaller value      0.00074

               Test of closure by frequency of capture.
               (Frequencies less than 10 are not computed.)

               Number of captures  z-value  Probability
               ----------------------------------------

                       3            -6.040      0.00000
                       4             2.158      0.98452
                       7            -1.569      0.05828
                      12             0.703      0.75887



 S u c c e s s f u l   E x e c u t i o n
```

Density and Population Size Estimation by DENSITY 5.0



A) Population estimation by Model Mh Jackknife



B) Population & Density Estimation by Model M0 Null and ML SECR

```
TRAP LAYOUT FOR SESSION LEOPARD

    Map limits  X : 702284 : 731907
    Map limits  Y : 3134863 : 3163748
        29623 x 28885 metres
    Map area                      = 855.660 km^2 (includes 10000-m buffer)
    Trapped area (convex polygon) = 35.956 km^2  (21 traps)
    Mean intertrap distance       = 869.95  metres
    Number of trap covariates     = 0
    Habitat mask                  none
    Nominal points in mesh        = 4096
    Actual points in mesh         = 3080


CAPTURE DATA E:\Data Sheets\Capture file Density Leopard.txt
         Session        AnimalID  Occasion          x          y
               1               1        20   721907.0  3153748.0
               1               1        44   718368.0  3152527.0
               1               1        48   718368.0  3152527.0
               1               1        66   718368.0  3152527.0
               1               2        18   718986.0  3152474.0
etc.
CLOSED POPULATION ESTIMATES (Estimator : Jackknife)
         Session Ntimes   NCapture   NAnimal   NotRlsd   NRecapt    CPNhat  seCPNhat  CPphat      RPSV
         LEOPARD     83         38         8         0        30      8.99     1.507  0.0509  2032.142
Legend
   Session  Session identifier
    Ntimes  Number of occasions within session
  NCapture  Number of captures, including recaptures within an occasion
   NAnimal  Number of unique individuals
   NRecapt  Number of recaptures, including recaptures within an occasion
   NotRlsd  Number not released
    CPNhat  CP Closed population estimate N-hat using 'CPEstim'
    CPphat  CP Per occasion capture probability implied by N-hat
      RPSV  Sqrt(spatial variance of capture locations) (m) pooled over individuals

Habitat mask      : None
Session filter    : ALL
Occasion filter   : ALL
Capture filter    : ALL
Area units        : km^2
Confidence level  : 95% (alpha = .05)
```

```
ML SECR numerical options
  Parameters                  : [Density, g0, sigma]
  Link functions              : [log, logit, log]
  Initial value method        : AUTO
  Initial values              : (0.05593, 0.02775, 1529.02081)
  Maximization method         : Downhill simplex (Nelder & Mead)
  Absolute tolerance of LL    : 0.001
  Epsilon (numerical gradient) : 0.001
  Integration buffer          : 10000 m
  Integration mesh points     : 3080
  Integration jitter mesh     : off
  Integration mesh trimming   : on
  Integration mesh spacing    : 451.328 m

ML SECR model
  Detector type               : Single live [using multi-live model]
  Detection model             : Halfnormal
  Likelihood                  : Full
  Distribution                : Poisson
  Within-session model        : g0[.]s[.]
Number of detectors used
         Session     1    2    3    4    5    6    7    8    9   10   11   12   13   14   15   16   17   1
         LEOPARD    21   21   21   21   21   21   21   21   21   21   21   21   21   21   21   21   21   2
Model spans : Session 1 only

ML SECR results
  Number of parameters total  : 3
  Number of parameters fixed  : 0
  Number distinct histories   : 7
  Log likelihood              : -235.5687
  AIC                         : 477.1374
  AICc                        : 483.1374

   Parameter       Value    SE.Value      Link    Par.Name    Estimate          SE         LCL         UCL
           1    -7.71420     0.39862       Log     Density     0.04464     0.01853     0.02044     0.09752
           2    -4.05530     0.28151     Logit          g0     0.01704     0.00471     0.00988     0.02921
           3     7.59952     0.14645       Log       sigma  1997.24667   294.06849  1498.90730  2661.26816

Note: The likelihood was evaluated 96 times during maximization
```

```
Variance-covariance matrix of estimates on link scale
                Density          g0       sigma
     Density    0.158901    0.002281   -0.024957
          g0    0.002281    0.079250   -0.017425
       sigma   -0.024957   -0.017425    0.021447

                          Fitted parameters
                  ------------------------------------
          Session     Density          g0       sigma
          LEOPARD     0.04464     0.01704  1997.24667

ML step for session
```