Assessment of the Mammalian Diversity in MHNP, Islamabad

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By

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Dedication

I dedicate my work to my Parents especially my **Father (late)**, who congratulated me on my admission to this degree but not here today to share the happiness with me, and my best friend and lab fellow **Zubair Shah (late)**, who got martyrdom in his service to the nature and wildlife

Declaration

The material and information contained in this thesis is my original work. I have not previously presented any part of this work elsewhere for any other degree.

Sadam Hussain

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List of Acronyms

MHNP	Margallah Hills National Park
IWMB	Islamabad Wildlife Management Board
IUCN	International Union for Conservation of Nature
GPS	Global Positioning System
RAI	Relative Abundance Index
ICE	Incidence Coverage-based Estimator
ACE	Abundance Coverage-based Estimator
SAC	Species Accumulation Curve
Jack 1	First Order Jacknife Estimator
Km^2	Kilometer Square
Km	Kilometer
%	Percentage
N/A	Not Applicable

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ABSTRACT

Exploring mammalian diversity is a prerequisite to understand health of an ecosystem and plays a pivotal role in conservation planning. For this purpose, a study availing sign surveys and camera trapping was conducted in the Margalla Hills National Park, Islamabad, Pakistan. The sign surveys were carried out from November 2017 to February 2018, while camera trapping lasted from 18th of February to 11th of March 2018. This was the first study of its kind in 38 years since the area was notified as a national park. The study involved 30 motion-triggered infrared digital trail cameras deployed (each for 13 trap nights) across the study area in different potential sites making a total of 364 trap nights and covering 30 grids of 1 km^2 each, with a minimum distance of 500 m between each camera station.

The camera traps captured eighteen species of mammals, representing thirteen families, that included red fox, Indian porcupine, wild boar, masked civet, golden jackal, rhesus macaque, common leopard, leopard cat, barking deer, Indian civet and Indian hare. Jungle cat, grey mongoose, Indian pangolin, yellow throated marten, hedgehog, Rat (genus rattus) and Himalayan Black rat each were captured at only one station. Highest photo-capture events (229) were recorded for red fox, though wild boar generated highest number of photos (3537). Mammalian species accounted for 28.91 % of total photo captures. Human, birds, livestock and domestic animals accounted for 42.80%, 5.64%, 13.54% and 4.11%, respectively, while 4.9% photos were false triggered.

The Relative Abundance Index (RAI) was the highest for Red Fox (36.64), moderate for Indian porcupine (17.12), wild boar (14.72), rhesus macaque (10.08) and masked civet (9.44). Whereas golden jackal, barking deer, Indian civet, common leopard, leopard cat, jungle cat and yellow throated marten had the lowest abundance. Species Richness was estimated using five estimators namely; ICE, ACE, Chao1, Chao2 and Jack1. Chao2 gave the highest estimate of 38.3, ICE gave 28.32, Jack1 gave 24.77, ACE gave 19.09 and Chao1 gave estimate of 18.5 (approximately the same as the observed no of species).

The current study recorded 18 mammalian species, including some rare and threatened ones such as common leopard and Indian pangolin and other rare species like leopard cat

and jungle cat, which were not reported for very long from the area. In contrast to past instigations which were largely based on expert judgements, anecdotes animal spoors, current study provides definitive detections of several iconic species. Though a shear amount of photo belonged to humans and livestock (55%) or non-target species (16%), photo capture of mammalian species (29%) was adequate to recognize species. Presence of large predators like common leopard without serious conflicts is a significant finding, which could be correlated to availability of natural prey (wild board, barking deer), adaptable nature of the cat, and extreme protection efforts initiated by the IWMB staff recently. Seasonal surveys are recommended to better capture species diversity and movements in the area.

The study reports great ecological potential of the area in the form of species richness, as well as an immense challenge in the form huge human and livestock movement in core areas of the park. The results shall inform management strategy adopted by the IWMB so that human substance, recreational and ecological needs are balanced.

INTRODUCTION

Pakistan lies between 24° to 37° north and 61° to 75° east, covering an area of 882,000 km^2. Extending by 1700 km north from the Arabian sea, the country encompasses deserts, plains of Indus basin, and the Hindu Kush, Karakoram and Himalayan ranges (Baig and Al-Subaiee, 2009). Changes in species occur within short range due to the variations in altitude. Pakistan is divided into various vegetation zones encompassing a wide range of ecosystems i.e. permanent snow fields, northern cold deserts, arid subtropical zones, dry temperate coniferous forests, tropical deciduous forests, steppe forests, thorn forests, swamps and mangrove forests and coastal ecosystems (Roberts, 1997) .In addition to four of Earth's ten biomes i.e. desert, meadows, tropical forest and mountains, Pakistan hosts three of the world's eight zoogeographical regions i.e. Palearctic, Oriental and Ethiopian (Baig and Al-Subaiee, 2009). These hallmark biogeographical characteristics make Pakistan a place of diverse array of mammalian species.

Pakistan is home to variety of mammals with 198 recorded species, mainly represented by order Chiroptera having 50 species, followed by order Rodentia with 48, Carnivora with 35, Atriodactyla with 23, Cetartiodactyla with 20, Eulipothypha with 13, while the orders Lagomorpha, Primata, Pholidota and Perissodactyla each with 4, 3, 1 and 1 species respectively. With the exception of Indus Blind Dolphin being inhabitant of fresh water, all the species from the order Cetartiodactyla are marine. Of the total mammalian diversity of the country, only 3% of the species are endemic. Such a low endemism might be due to the habitat connectivity with neighboring countries through mountain ranges, deserts and plains while there is no exotic mammalian species recorded in the wild (Biodiversity and Division, 2014).

Given the geographical diversity within the country, Pakistan has variety of ecosystems with diversified flora and fauna representing a number of protected areas of the country. Some of them are quite unique in their climate. Being at the confluence of temperate (Potohar plateau) and sub-tropical regions (Punjab), the MHNP provides suitable

environmental conditions to the mammals of both the temperate and tropical regions, thus making it a home to a diverse array of mammalian fauna of both of the eco-regions.

Various studies have been conducted in the past to document mammalian distribution and ecology in the park. Anwar and Chapman (2000) studied grey goral *(Nemorhaedus goral)*, and reported 40 – 60 individuals in 28 % of the park area, comprising 72% adults and 28% juveniles with equal sex ratio. They mostly found grey goral close to the ridges. Hameed et al. (2009) reported population of barking deer *(Muntiacus muntjak)* to be 86 in density 0.8 – 1.45 animals / km^2. Most of the sightings i.e. 64.29% were single individuals while the rest (35.71%) were in a group of two. Maximum density was found under medium tree cover i.e. 19% and increase or decrease in the tree cover decrease the density while herbs cover had a positive effect on the density. Shrub cover had no direct effect on density of barking deer.

Mahmood et al. (2013) investigated diet of golden jackal (*Canis aureus*) in the park, and found that jackal mainly predates on wild rodents, mongoose and poultry. Hameed et al. (2009) reported patchy distribution of scaly ant-eater (*Manis crassicaudata*) in elevation range from 462 m to 1046 m, indicated by two types of burrows i.e. sleeping burrows and feeding burrows with different depths. The species was associated with *Lantana camara*, and *Punica granatum* for its living burrows while *Dalbergia sissoo* and *Acacia modesta* for insect feeding burrows. Its population density was 0.36/Km^2 in the park.

The previous mammalian studies provide pivotal understanding of some mammalian species in the park; however these studies have following limitations;

- Past studies mostly focused single or few species, thus could not generate information on overall mammalian diversity of the park.
- Few studies which attempted to document mammalian species diversity, were based on conventional old methods like interviews or sign surveys, which are not reliable for ascertaining presence of elusive species like leopard.
- Except for few species, past studies could not reliably develop distribution pattern of mammalian species.

The current study focused on addressing above stated challenges by employing latest techniques. Camera trapping is a very handy, advanced and cost effective technique used for monitoring terrestrial mammals and birds (Ahumada et al., 2011; Brien et al., 2010; Kinnaird et al., 2010; Rovero et al., 2010, 2009). Contrary to the other field techniques, it is quite suitable for standardization, as it minimizes human error and influence on the security, maintenance and identification of the photographic data. Emergence of digital camera traps and their enhanced affordability has made this tool very applicable to most of the projects especially in thick forests with reduced visibility and encounter rate of many elusive medium and large mammals. With precisely designed deployment methods, camera traps can generate reliable and highly valuable observations about terrestrial animal communities, such as species diversity, occupancy estimation, population abundance and community structure (Ahumada et al., 2011) along with other aspects of behavior like species activity patterns (O'Connell et al., 2011). Moreover, camera trapping provides the opportunity of separately modelling the ecological state variables like abundance or probable species occurrence and also considering the detection phenomenon like the detection probability of species, provided their occurrence at the site (MacKenzie et al., 2003, 2002; Mackenzie and Nichols, 2004). These features allows for unbiased estimations of ecological parameters, making camera trapping considerably suitable for monitoring and assessment surveys aimed at progress and development towards biodiversity conservation.

1.1. Objective

Sign survey in combination with camera trapping was carried out in order to document mammalian diversity of the park. Specific objectives of the study area:

- Reliably document mammalian species of the Park
- Investigate species richness and spatial distribution pattern
- Develop baseline of mammalian species and human impacts in the park to inform park management strategies

MATERIALS AND METHODS

2.1. Study Area

The MHNP lying to the north vicinity to the federal capital of Islamabad at 33°48' N and 73°10' E has been listed as Protected Landscape (Management Category V) in the International Union for Conservation of Nature (IUCN). It was sanctioned as a National Park on 27th April 1980 under section 21(1) of Islamabad Wildlife Ordinance, 1979 (Nawaz et al., 2007). **(Fig. 2.1).** The national park covers Margalla Hills by 12802 ha, Rawal Lake by 1702ha and Shakar Parian by 1376 ha with uneven terrain with steep slopes and the rock composition limestone. It ranges in altitude from 450 m to 1580 m above the sea level (Jabeen et al., 2009). The area is unique in its flora and fauna consisting of 618 different species of vegetation of both medicinal and economic importance. The avian fauna represented by 24 families with 250 species of birds including exotic, song birds and birds of prey. Mammals in the area are represented by 8 orders and 38 species while at least 13 taxa representing herpetofauna and numerous insects (Roberts, 1997).

The study area has a coarse geography with various steeps and valleys. The climate and terrain are quite suitable for hiking, especially from February to April. Notable visiting spots includes; Daman-e-Koh, Pir Sohawa, Gokeena, Mount Happines, Loh-i-Dandi, Saidpur Village, Nicholson's obelisk, The Islamabad Zoo, Shakkar Parian and Rawal Lake. Extended from the Himalayan range, the hills make the northern boundary of Potohar region (WWF, 2011). Being in the vicinity of national capital Islamabad and the most accessible protected area of the country, the park offers incredible educational and recreational opportunities for the public. Over 15 winding trails traverse through over 31,000 acres of reserve forested area and grass fields offering diverse opportunities for trekkers, hikers and riders (Khan, 2004).

2.2. Climatic Conditions and Terrain

For the semi-arid regions of the study area having mild summer and winters, the climate is typical, although the overall climate is temperate, monsoonal and sub humid. Winter temperature resides between the mean maximum of 21°C and mean minimum of 1.6°C with the lowest temperature occasionally drops below 0°C. May and June are the hottest months with mean maximum temperature of 41°C in June. The monsoon starts in July, resulting in the transformation of the harsh weather. The monsoon season remains from July to September with mean monthly precipitation of 254 mm, while August is the month of maximum rainfall. The mean relative humidity for the monsoon varies between 59% and 67% (Masroor, 2011).

Margalla Hills National Park is traversed by two rivers namely; Soan and Korang along with their tributaries, providing drainage for Murree, Kahuta, Margalla Hills, Rawat, Lehtrar and Panjar. The national park lies at the junction of northern mountain ranges of Pakistan and Potohar Plateau, mostly representing arid sub-tropical zone with tropical deciduous forests. The arid subtropical range is characterized by rocky and hilly terrain with the elevation ranging less than 1000 m (Masroor, 2011).

2.3. Dominant Flora and Fauna

Margallah hills host about 245 identified plant species from 77 families with 55 species of trees, 54 shrubs, 105 herbs, 15 climbers, 10 grasses and 6 fodder crops which has a wide ethno-botanical importance for the communities of the national park (Jabeen et al., 2009). The park is represented by subtropical, semi-ever green and pine forests. The semi-evergreen forest is mainly inhabited by phulai, kao, sanatha, granda and ber. The subtropical chir pine being the characteristic canopy species occurs above 1,000 m altitude. Beside this, a number of Non Timber Forest Products (NTFPs) are also present including some invasive species of medicinal use such as; *Lantana camara* (WWF, 2011)

The communities in the park utilize *Dalbergia sisso* (sheesham) for timber, while common fruits are apple, peach, almond, apricot, walnut, mulberry, and *Eriobotrya*

(lukat). The major crops of the area are wheat, maize and mustard. The common trees representing the park are *Acacia catechu* (black catechu), *Acacia nilotica* (babul), *Acacia modesta* (keekar), *Bauhinia variegata* (kachnar), *Butea monosperma* (sacred tree), *Cassia fistula* (golden shower tree), *Ficus carica* (common fig), *Olea ferruginea* (kahu), *Pinus roxburghii* (chir pine) and *Quercus leucotrichophora* (banjh oak) while common shrubs include *Carissa opaca* (carissa), *Calotropis procera* (rubber bush), *Dodonaea viscosa* (hopbush) and *Justicia adhatod* (malaber nut). The widespread herbs of the park include *Allium jacquemontii* (kunth), *Arundo donax* (arundo), *Cannabis sativa* (cannabis), *Centaurea iberica* (iberian knapweed), *Geranium ocellatum* (cambess), *Hibiscus caesius* (garcke), *Pennisetum orientale* (oriental fountain), *Saccharum spontaneum* (kans grass), *Tulipa stellate* (lady tulip) and *Typha elephantine* (typha) (Masroor, 2011).

The MHNP is home to incredible variety of wild animals. There are 250 species of exotic birds, song birds and birds of prey representing 24 families. There are 38 mammal species in this park that belong to 8 orders, with at least 13 taxa of reptiles and numerous insects (Mahmood et al., 2013). The gray goral (*Naemorhedus goral)*, barking deer *(Muntiacus muntjak)*, monkey *(Macaca mulatta)*, kalij pheasant (*Lophura leucomelanos*), grey partridge *(Perdix perdix)* and black partridge *(Melanoperdix niger)* in particular have an eye catching element for wildlife lovers. Among the other mammals we have common leopard *(Panthera pardus)*, wild boar *(Sus scrofa)*, golden jackal *(Canis aureus)*, leopard cat *(Prionailurus bengalensis)*, red fox *(Vulpes vulpes)*, Indian pangolin *(Manis crassicaudata)*, Indian crested porcupine *(Hystrix indica)*, yellow-throated marten *(Martes flavigula)* and fruit bats.

The avian fauna of the park include Himalayan griffon vulture (*Gyps himalayensis*), laggar falcon (*Falco jugger*), peregrine falcon (*Falco peregrinus*), Indian sparrow hawk (*Accipiter badius*), Egyptian vulture (*Neophron percnopterus*), white cheeked bulbul (*Pycnonotus leucotis*), yellow vented bulbul (*Pycnonotus goiavier*), paradise flycatcher (*Terpsiphone*), golden oriole (*Oriolus oriolus*), spotted dove (*Spilopelia chinensis*) , collared dove (*Streptopelia decaocto*), larks, shrikes, and buntings. The park also hosts various species of reptiles such as Russelle's viper (*Daboia russelii*), Indian cobra (*Naja naja*) and saw-scaled viper (*Echis carinatus*) (Khan, 2004).

Fig. 2.1: Demarcation of Margallah Hills National Park, Islamabad.

2.4 Approach of the Study

In order to carry out field surveys for data collection, the study area was divided into grids of 1 km^2 which were used for sign survey and camera trapping survey **(Fig. 2.2).**

The camera trapping and sign survey were conducted throughout the eastern and north-western part of the Margallah hills patch of MHNP. The areas of Rawal lake and Shakarpariyan were not considered for the survey because of lack of potential for large mammals and higher level of disturbance.

Camera trapping covered 27.5 km^2 (25% of the park area) while sign survey covered 45.7 km^2 (42 %) of the total study area i.e. 110.16 km^2. The south western part of the study area could not be surveyed due to camera and personal security. However this area has similar terrain, habitat and climatic conditions, and we do not expect recording new species from that area.

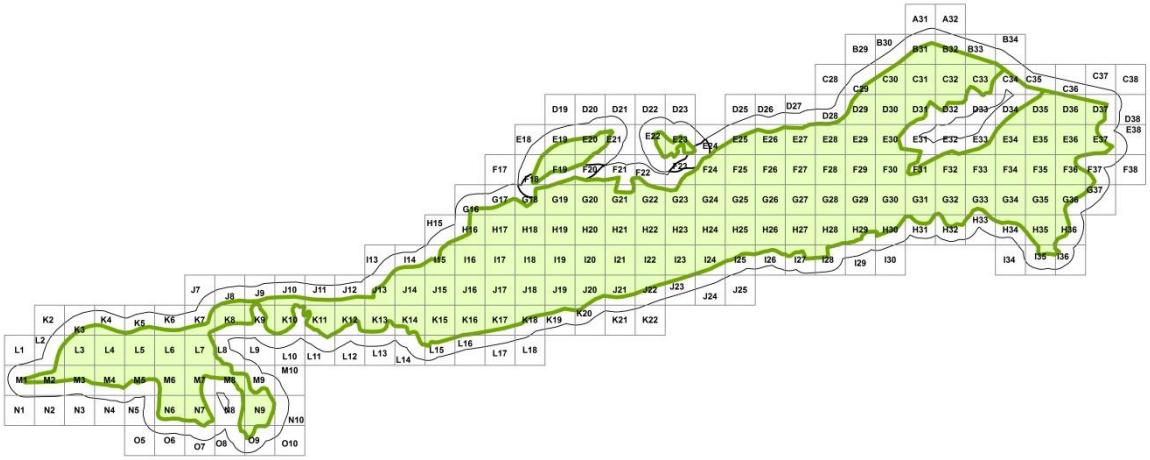

Fig.2.2: Map used for field survey showing grids of 1 km^2

2.4.1. Sign Survey

Sign surveys were conducted in 44 grids, spread across the park. Two-hundred sampling points (about 5 points in each grid) were taken, by searching an area of 50 m radius for animal signs. Animal signs included body parts (e.g. hair/quills), scat, pug marks and scrap etc. The locations of signs were recorded using Global Positioning System (GARMIN InReach SE+) device. Demarcation of the habitats of the mammals was done through sign survey within the park and consequent identification of the potential sites for deployment of camera traps. This approach minimized the time, effort and resources for the camera trap survey and also helped creating an overview of the mammalian distribution in areas where camera trapping was not possible**.**

2.4.2. Camera Trapping

The camera trapping survey was conducted in MHNP from 18th of February to 13th of March 2018. A uniform grid of (1 km × 1 km) was imposed on the map of the study area and potential sites were selected by the survey team for camera installation. Of the 120 grids covering the study area, 30 grids were selected for camera placements considering accessibility and security, covering 25% of the study area. A total of 30 motion-triggered cameras Reconyx™ (HC500 HyperFire™ and PC900 HyperFire™) **(Fig. 2.4)** were installed in each grid such that there is a minimum distance of 500 m between adjacent camera traps (Ahmad et al., 2016). All the camera traps operated continuously for 15 days (deployment time) and the total number of trap nights were calculated from the day of installation to the day of takedown (Datta et al., 2008). **(Fig.2.3)**

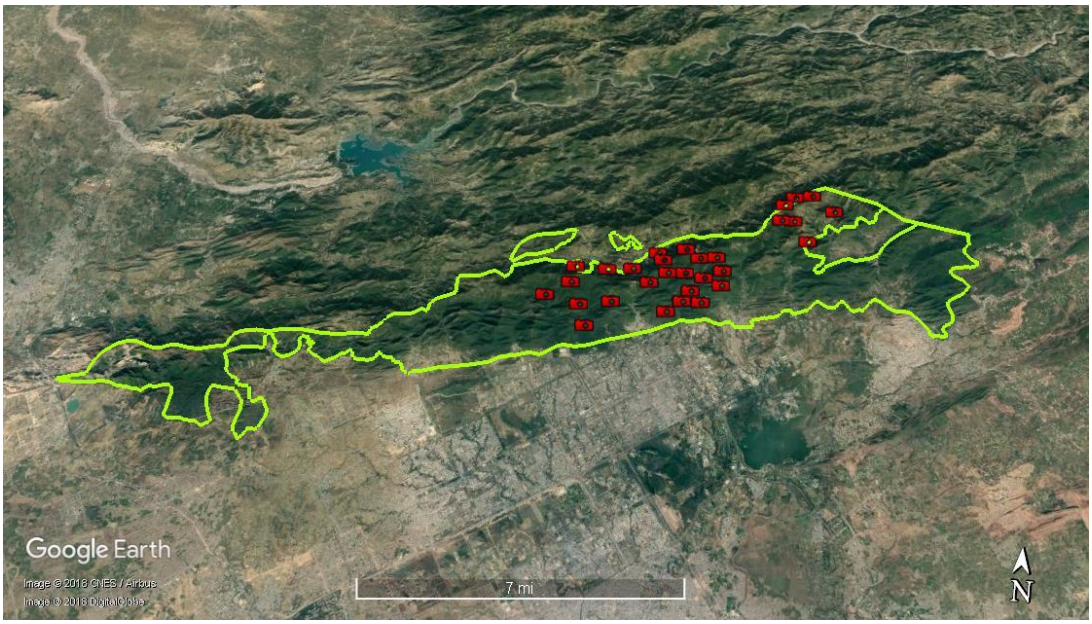

Fig.2.3: Map of the study area showing the camera traps locations.

Three camps were established in the park to monitor camera stations closely and to avoid potential theft of cameras. Nickel-metal hydride (NiMH) rechargeable batteries were used to operate the cameras. All of the cameras were fixed on metal poles except for one that was fixed in rocks **(Fig. 2.4).**

The height of each camera from the ground was kept about 50 cm to increase the capture probability of medium and large terrestrial animals however this height may not be optimum for small and arboreal animals. The cameras were faced north to south in order to avoid direct sunlight on the lens that could cause false triggered images (Ahmad et al., 2016). All the vegetation and grasses facing the lens of camera were removed to avoid false images (Jackson et al., 2006). In order to increase the capture probability, castor base scent lures were applied at the camera station (Bischof et al., 2014; Guil et al., 2010). The lure was pasted on a stone or wood right in front of the camera (trap station) and all of the cameras were set to the frequency of 3 consecutive photos captures with an interval of 1 second on each trigger. The basic information about the station such as habitat, substrate type, topography, terrain, altitude, and locations were noted on camera trap entry sheets (Ahmad et al., 2016).

GARMIN InReach SE+ GPS devices were used for recording locations. All cameras were re-baited after 7 days and memory cards were exchanged and data was monitored. Unfortunately one camera was stolen while the rest of 29 cameras were retrieved safely.

Fig. 2.4: Camera traps being deployed in the study area

2.5. Analytical Approaches

2.5.1 Relative Abundance Index (RAI)

Relative abundance of the species recorded during the entire study, based on sign survey data and camera trap data, was calculated by Relative Abundance Index (RAI) using the formula: **RAI = Ai/N*100**. Where Ai is the total number of Independent photos (capture events) of a species by all cameras and **N** is the total number of Independent photos (capture events) of all species detected during the study period (Wang et al., 2014).

A measure of Trap Success for all 30 camera-trap stations was also calculated as (total capture events / 364 trap nights) * 100 (Gerber et al., 2010).

2.5.2. Species Richness Estimation

Species richness for each sample (camera trap station) was estimated using the software tool **EstimateS (Version 9.1.0).** EstimateS is a free user-friendly software application executable on Windows and Macintosh operating systems designed to assess and compare species diversity data for composition and assemblages. Having an easy to use graphical user interface, EstimateS computes a wide range of biodiversity statistics such as; species richness estimation, extrapolation and rarefaction, diversity indices, hill numbers and compositional comparison among species assemblages (Colwell and Elsensohn, 2014). EstimateS gives a number of estimations in its output file, but we selected only five richness estimator output values for our analyses; **Chao1** (Chao 1 richness estimator), **ACE** (Abundance Coverage-based Estimator), **Chao2** (Chao 2 richness estimator), **ICE** (Incidence Coverage-based Estimator), and **Jack1** (First-order Jackknife richness estimator).

Chao1 estimators are efficient in cases where there are many undetectable or "invisible" species in a considerably diverse species assemblage, which make it statistically impossible to obtain a precise species richness estimate. Instead of a rough point estimate it is more practical to obtain an accurate lower bound of species richness. When a species undetected in the sample has approximately the same chance of being detected as a

singleton, the lower bound estimator works satisfactorily. **Chao2** estimator is the counterpart of Chao1 for incidence data (Chao and Chiu, 2016). There are a set of rigorous statistical demonstrations behind the simplicity of Chao1 and Chao2, making both the robust estimators of minimum richness ("Chapter 4: Estimating species richness," 2011).

The **ACE** of species richness is based on the concept of "sample coverage" or simply "coverage". The coverage of a sample is interpreted as the proportion of the total number of individuals in an assemblage that belong to the species represented in the sample. **ICE** is the incidence data analogue of the **ACE**, however the in this case the "sample coverage" is defined a bit differently as: the fraction of the total incidence probabilities of the detected species in the reference sample (Chao and Chiu, 2016). The Jackknife is a general statistical tool used for the reduction of bias in an estimator while the first-order jackknife **(Jackknife1)** only depends on the species recorded only in one sample because the richness estimate is changed only when a sample that contains one of these species is deleted from the sub-sets of samples ("Chapter 4: Estimating species richness," 2011).

VEGAN (an R package) was also used for the other species richness estimates i.e. Species Accumulation Curve (SAC), Species Pool (Number of unseen species) and Cluster analysis. SAC is generated as more new species are added to the total number of species in the sample ("Chapter 4: Estimating species richness," 2011), in other words it reads the accumulation of new species when the number of sites (samples) increases. According the species accumulation models, not all the species can be seen at any site and these unseen species at any site also belong the species pool so by using "specPool" function of VEGAN, we predict the **Species Pool** (number of unseen species) at a collection of sites in terms of Chao2 and Jack1. Another useful estimator called cluster analyses in the form of a **'Cluster Dendrogram'** was generated by the VEGAN which gives a dendrogram showing the relatedness of species captured on the basis of sharing the camera stations thus forming a cluster (Oksanen, 2018).

2.5.3 Ordinary Krigging Model

Krigging is a strong statistical interpolation tool with a multitude of applications in health sciences, geochemistry and pollution modeling. Krigging explains the surface variations by assuming the spatial correlation demonstrated by the distance or direction between the sampling points. The measures of relationship among the samples predict values by weighted average formula, by using a search radius either fixed or variable. Of several types, the 'Ordinary Krigging' is the most commonly used and it assumes that there is no constant mean for data over an area mean (i.e. no trend), while 'Universal Krigging' accounts also for the overriding trends in the data that can be modelled. We used the ordinary krigging model (Childs, 2011).

RESULTS

3.1 Sign Survey Results

Sign survey conducted in the study area covering 44 (1x1 km^2) grids with a total of 200 sampling points **(Fig. 3.3)**, recorded occurrence of porcupine, Rhesus macaque and wild boar with relative abundance of 50.95%, 15.28% and 9.55% respectively. Small and medium sized carnivores accounted for 22.92% of signs while large carnivores only 1.27%. There were no signs recorded at 97 sampling points **(Table 3.1)**

Table 3.1. Relative abundance indices (RAI) of species from sign survey

S.No	Species	Sign type	Points	RAI (%)
1	Porcupine	Scat/Quill	80	50.95
2	Wild boar	Scat/dig	15	9.55
3	Macaque	Scat	24	15.28
4	Large Carnivore	Scat	2	1.27
5	Small/Medium Carnivore	Scat	36	22.92
	Total		**157**	**99.97**
	No Sign		**97**	

Fig. 3.2. Signs from left to right; common leopard pug mark, porcupine spine, and scat of an unidentified carnivore.

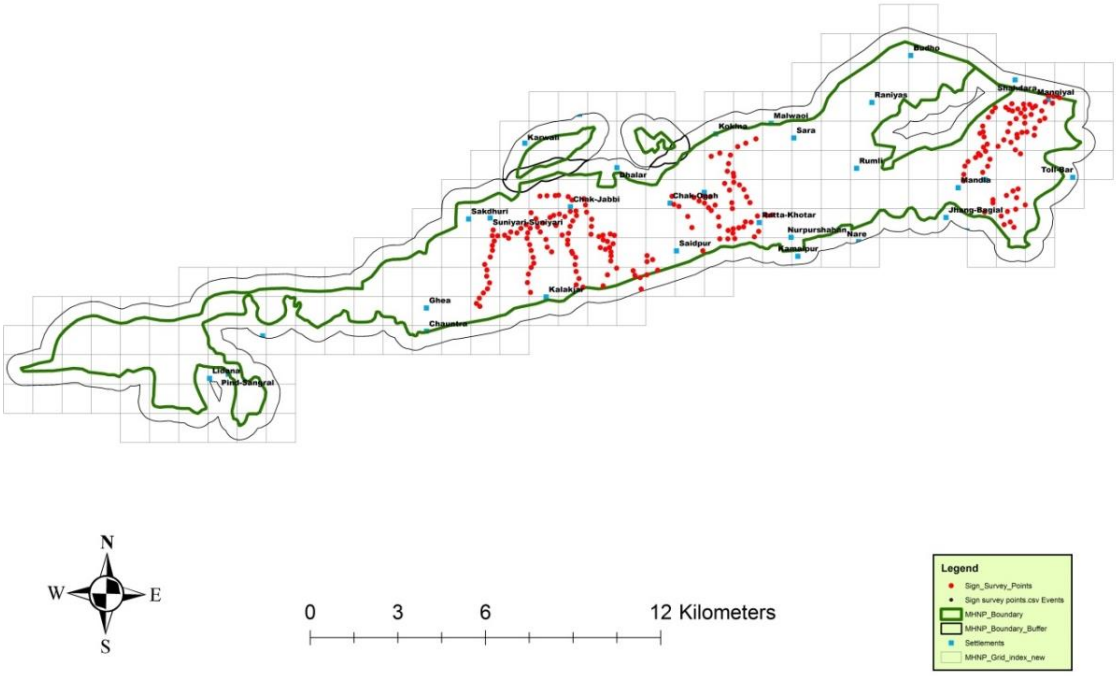

Fig.3.3. Map showing the sampling points of sign survey

3.2. Sightings Mammals

Four species were sighted by the survey teams during this study **(Table 3.2)**

Table 3.2 Records of animal sightings during the study.

S.No	Date	Grid ID	Location	Latitude	Longitude	Species	Number	Observers
1	20/12/2017	I25	trail 5	33.746286	73.086059	Golden Jackal	2	Sadam, Shabeer
2	25/12/2017	I24	trail 3	33.74782	73.07977	Barking Deer	1	Sadam, Shabeer
3	19/02/2018	I25	trail 3	33.743778	73.017975	Barking Deer	1	Asif,Ejaz
4	12/1/2018	H19	trail 6	33.753355	73.017975	Pangolin	1	Sadam, Shabeer
5	22/02/2018	H26	trail 5	33.750873	73.091091	Common Leopard	1	Asif, Islam
6	24/02/2018	H26	trail 5	33.75087	73.091091	Red Fox	1	Sadam,Islam,Asif
7	6/3/2018	D30	Nariyas	33.788820	73.137480	Golden Jackal	1	Asif

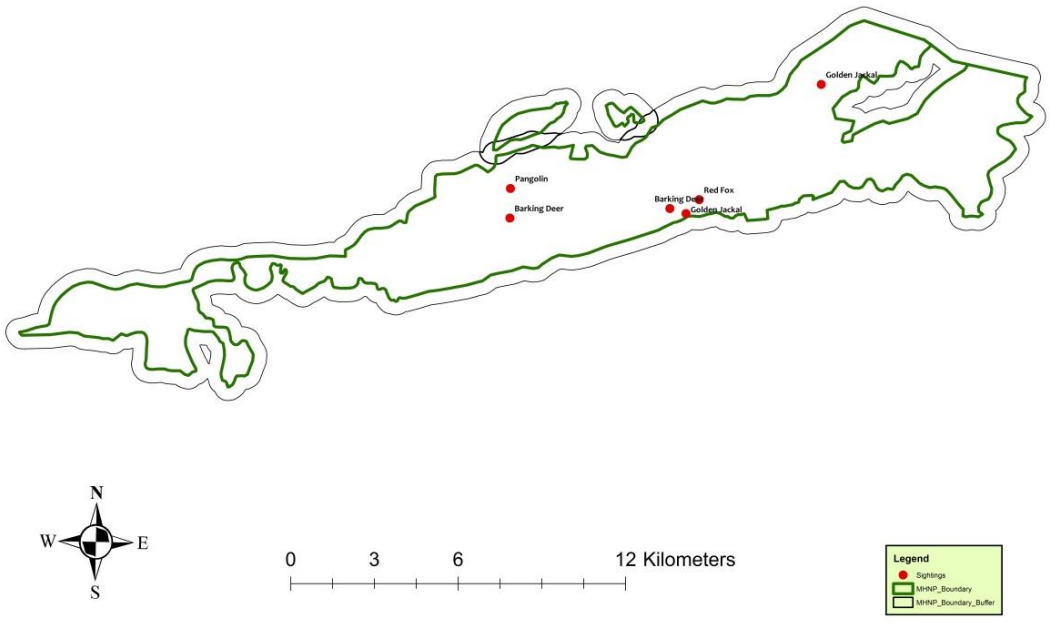

Fig. 3.4. Map showing locations of animal sightings during survey.

3.3. Camera Trapping Results

All of the 30 cameras deployed in the field for 364 trap nights resulted in a total of 37015 photos captured including mammals, birds, livestock, domestic animals, humans and false triggered. Mammals accounted for a total of 10704 photos capturing 18 species of mammals belonging to 13 families **(Table 3.3).**

Table: 3.3. Relative abundance and trapping success of mammalian species in MHNP

S.No	Species	Capture stations	Total Photos	Capture rate (%)	Capture events	RAI	Trap success
1	Red Fox	26	2296	21.44	229	36.64	62.91
2	Indian Porcupine	23	1343	12.54	107	17.12	29.39
3	Wild boar	18	3537	33.04	92	14.72	25.27
4	Rhesus Macaque	11	1276	11.92	63	10.08	17.30
5	Masked Civet *(Paguma larvata)*	17	531	4.96	59	9.44	16.20
6	Golden Jackal	12	1028	9.60	34	5.44	9.34
7	Barking Deer	6	201	1.87	15	2.4	4.12
8	Indian Civet *(Viverricula indica)*	8	111	1.03	13	2.08	3.57
9	Common Leopard	4	102	0.95	5	0.8	1.37
10	Leopard Cat	5	84	0.78	5	0.8	1.37
11	Jungle Cat *(Felis chaus)*	1	25	0.23	2	0.32	0.54
12	Yellow throated marten	1	6	0.05	1	0.16	0.27
13	Grey Mongoose *(Herpestes edwardsi)*	1	15	0.14	1	N/A	N/A
14	Hedgehog *(Paraechinus micropus)*	1	36	0.33	7	N/A	N/A
15	Indian hare *(Lepus nigricolis)*	3	74	0.69	6	N/A	N/A
16	Indian Pangolin	1	27	0.25	2	N/A	N/A
17	Rat (genus *Rattus*)	1	6	0.05	2	N/A	N/A
18	Black rat *(Rattus rattus)*	1	6	0.05	2	N/A	N/A

3.3.1 Relative Abundance

The highest capture was found for red fox and Indian porcupine recorded in 26 and 23 cameras, respectively. Wild boar, masked civet, golden jackal and rhesus macaque were recorded at 18, 17, 12 and 11 stations, respectively. Indian civet, barking deer, leopard cat, common leopard and Indian hare were captured at 8, 6, 5, 4 and 3, respectively,

while jungle cat, yellow throated marten, grey mongoose, hedgehog, Indian pangolin, rat (genus *rattus*) and black rat were captured at single station each.

Out of total 10704 photo captures of mammals, wild boar made the major shear 3537 photos (33.04 %), followed by red fox with 2296 (21.44 %), Indian porcupine 1343 (12.54 %), rhesus Macaque 1276 (11.92 %), golden jackal 1028 (9.60 %), masked civet 531 (4.9 %), barking deer 201 (1.87 %), Indian civet 111 (1.03 %), common leopard 102 (0.95 %), leopard cat 84 (0.78 %), Indian hare 74 (0.69 %), hedgehog 36 (0.33 %), Indian pangolin 27 (0.25), jungle cat 25 (0.23 %), mongoose 15 (0.14 %) while yellow throated marten, rat (genus *rattus*) and black rat had 6 photo captures (0.05 %) each.

Relative Abundance Index (RAI) was the highest for red fox (36.64). Moderate for Indian porcupine (17.12), wild boar (14.72), rhesus macaque (10.08) and masked civet (9.44), while golden jackal, barking deer, Indian civet, common leopard, leopard cat, jungle cat and yellow throated marten had the lowest abundance of (5.44), (2.4), (2.08), (0.8), (0.8), (0.32) and (0.16), respectively.

Trap success was the highest for red fox (62.91). It was moderate for Indian porcupine (29.39), wild boar (25.27), rhesus macaque (17.30) and masked civet (16.20), while golden jackal, barking deer, Indian civet, common leopard, leopard cat, jungle cat and yellow throated marten had the lowest trap success of (9.34), (4.12), (3.57), (1.37), (1.37), (0.54) and (0.27), respectively.

Fig. 3.5. Photo-captured species along with their locations; from top left common leopard, barking deer, wild boar, rhesus macaque, golden jackal and red fox.

Fig. 3.6. Photo-captured species along with their locations; from top left leopard cat, jungle cat, Indian civet, Indian porcupine, masked civet and yellow-throated marten.

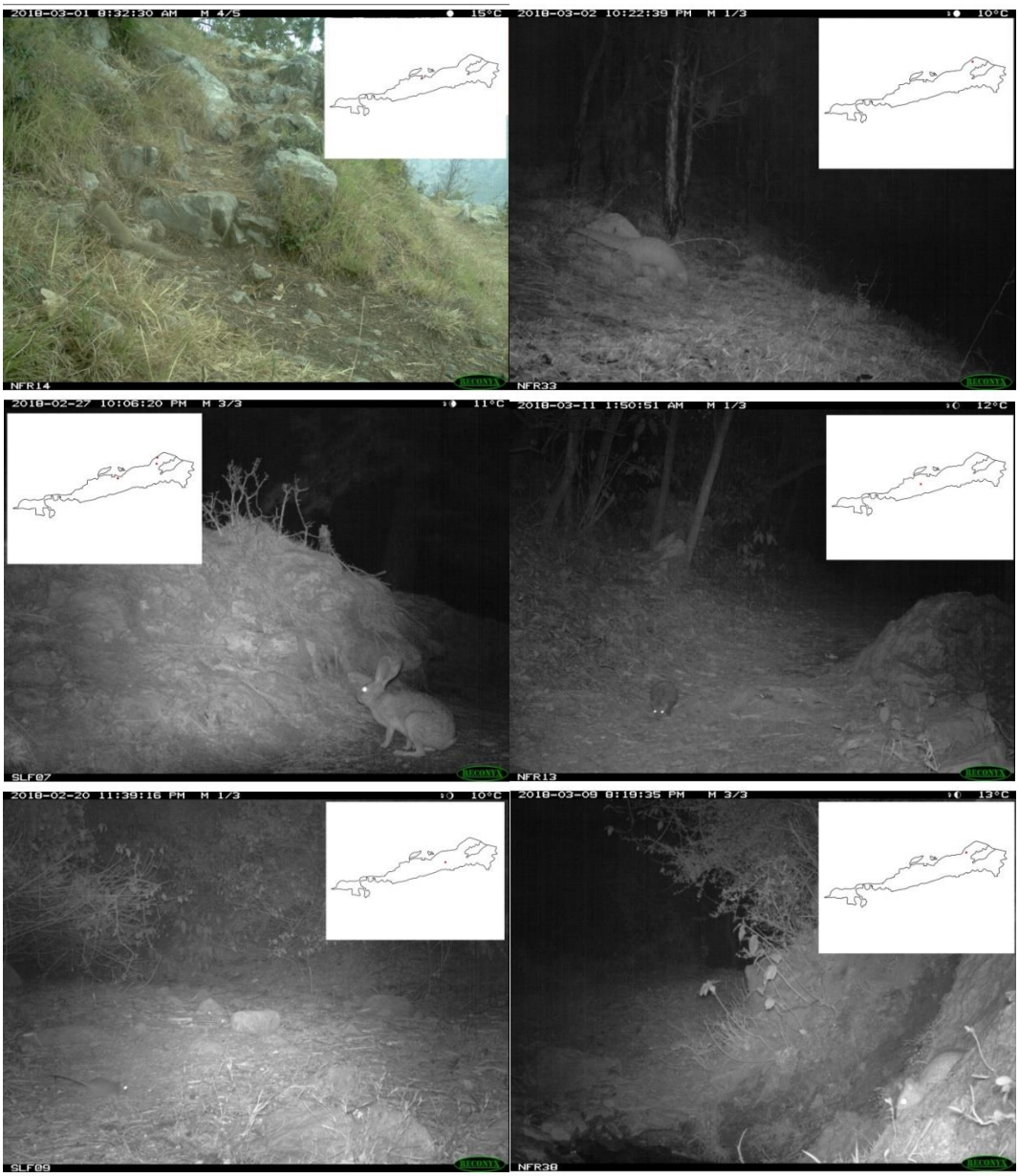

Fig. 3.7. Photo-captured species along with their locations; from top left grey mongoose, Indian pangolin, Indian hare, hedgehog, rat (genus *rattus*) and black rat.

3.3.2 Common Leopard Captures

One of the notable results of the camera trapping study was the photo captures of common leopard *(Panthera pardus* Linnaeus, 1758) which is a rare, vulnerable and one of the three big cats of Pakistan. There were a total of 5 capture events at 4 different camera stations with 102 photos. The photos were evaluated for individual identification which revealed potentially three individuals in the study area. One individual (named 'Asif') was captured at 3 stations **(Fig. 3.8)** while other (named 'Sam') **(Fig. 3.9)** was detected at 1 station. One animal captured at 1 station could not be identified due to unclear image but could be declared a different individual given its geographical location which is quite away from the rest **(Fig. 3.10)**

Fig. 3.8. Photo Captures of the Leopard (Asif) on the basis of similar pelage pattern captured at three different stations.

Fig. 3.9. Photo captures of the leopard (Sam) on the basis of different pelage patterns recorded from same station.

Fig.3.10. Photo capture of an unidentified leopard.

3.3.3 Species Richness

Species richness was calculated for 30 camera stations using software tool ***EstimateS*** (Colwell and Elsensohn, 2014). The output was analyzed for the mean values of the following estimates; ICE, ACE, Chao1 (Chao 1 richness estimator), Chao2 (Chao 2 richness estimator) and Jack1 **(Table 3.4)**

Table 3.4 Outputs for the species richness estimates by various estimators

S. No	Station ID	ICE	ACE	Chao 1	Chao 2	Jack 1
1	H-26 A	4.63	6.28	5.46	4.63	4.63
2	G-25	19.18	8.1	7.55	9.45	8.61
3	G-26	14.11	9.16	8.87	11.24	10.49
4	F-26	14.44	10.91	10.5	13.26	12.06
5	F-25	14.38	11.54	11.53	14.32	13.19
6	F-27	14.69	12.08	12.01	14.99	13.91
7	G-27	15.6	12.76	12.59	16.43	14.8
8	H-26 B	15.84	13.16	12.96	16.76	15.26
9	G-24 A	16.31	13.43	13.12	17.38	15.79
10	H-25	17.05	13.85	13.56	19.04	16.48
11	I-24	17.28	14.12	13.87	19.59	16.85
12	H-27	17.99	14.58	14.24	20.25	17.45
13	I-22	18.49	14.85	14.43	20.94	17.91
14	H-21	18.61	15.02	14.61	21.12	18.17
15	I-21	18.87	15.23	14.85	21.19	18.53
16	H-24	19.3	15.49	15.12	22.24	18.96
17	F-24	19.56	15.69	15.3	23.01	19.27
18	G-24 B	19.83	15.86	15.45	23.64	19.5
19	G-22	20.33	16.13	15.69	24.92	19.91
20	G-23	21.22	16.63	16.16	26.43	20.65
21	G-21	21.69	16.85	16.36	27.16	20.98
22	J-21	22.15	17.07	16.58	28.33	21.32
23	H-20	22.55	17.25	16.78	29.26	21.62
24	D-29	23.05	17.43	16.99	30.57	21.96
25	D-30	23.58	17.69	17.21	31.83	22.36
26	C-30	24.35	17.96	17.47	33.38	22.84
27	C-29	25.22	18.27	17.78	34.91	23.37
28	C-31	26	18.5	17.98	35.78	23.79
29	E-30	27.04	18.8	18.24	37.07	24.27
30	D-32	28.32	19.09	18.5	38.3	24.77

Chao2 (Chao 2 richness estimator) gave the highest estimate of 38.3, while ICE gave the second highest estimate of 28.32. First-order Jackknife (Jack1) gave an estimate of 24.77. ACE gave estimate of 19.09, which is approximately the same as observed i.e. 18 species, while Chao1 gave estimate of 18.5 which is exactly the same as observed. The estimated values of richness by all the given estimators predict the number of species that can be anticipated to occur at each station. The estimator value at the last station predicts the number of possible species richness at all of the stations.

To verify results of EstimateS, species richness was estimated in R using function "SpecPool" (Vegan package) **(Table 3.5)**, however parameter estimates were consistent in both methods. Species accumulation curve **(Fig. 3.11)** was also generated to visually present the results.

Table 3.5: SpecPool richness estimators

Stations	Species	Chao2	Jack1
All	18	38.3	24.76

- **Species Accumulation Curve**

Species accumulation curve was also generated using this package **(Fig. 3.11)**

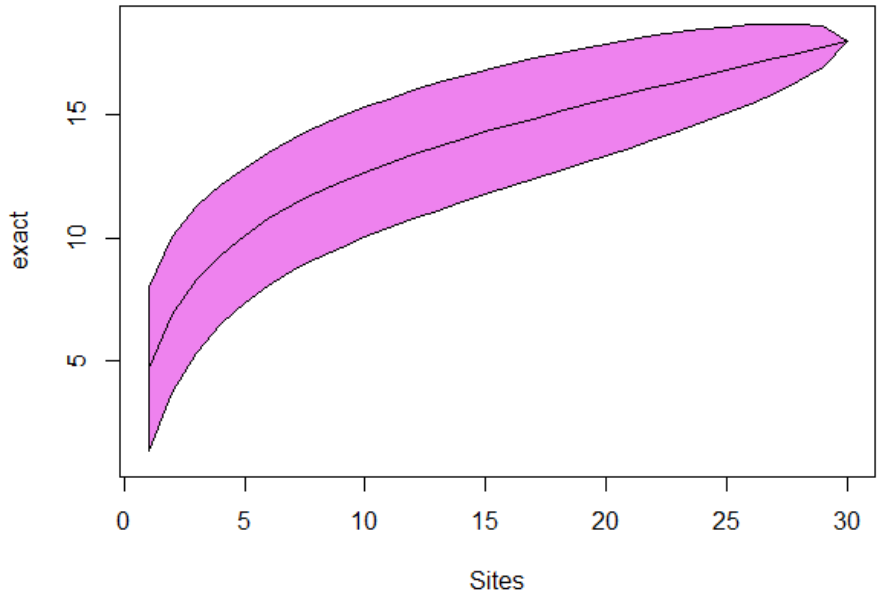

Fig.3.11. Polygon chart representing species accumulation curve (SAC).

Species richness based on ICE was extrapolated on the entire study area by "Ordinary Krigging Model" (Childs, 2011) using "Geostatistical Analyst" tool in ArcGIS **(Fig.3.12)**, which indicated higher diversity levels in eastern parts of the park.

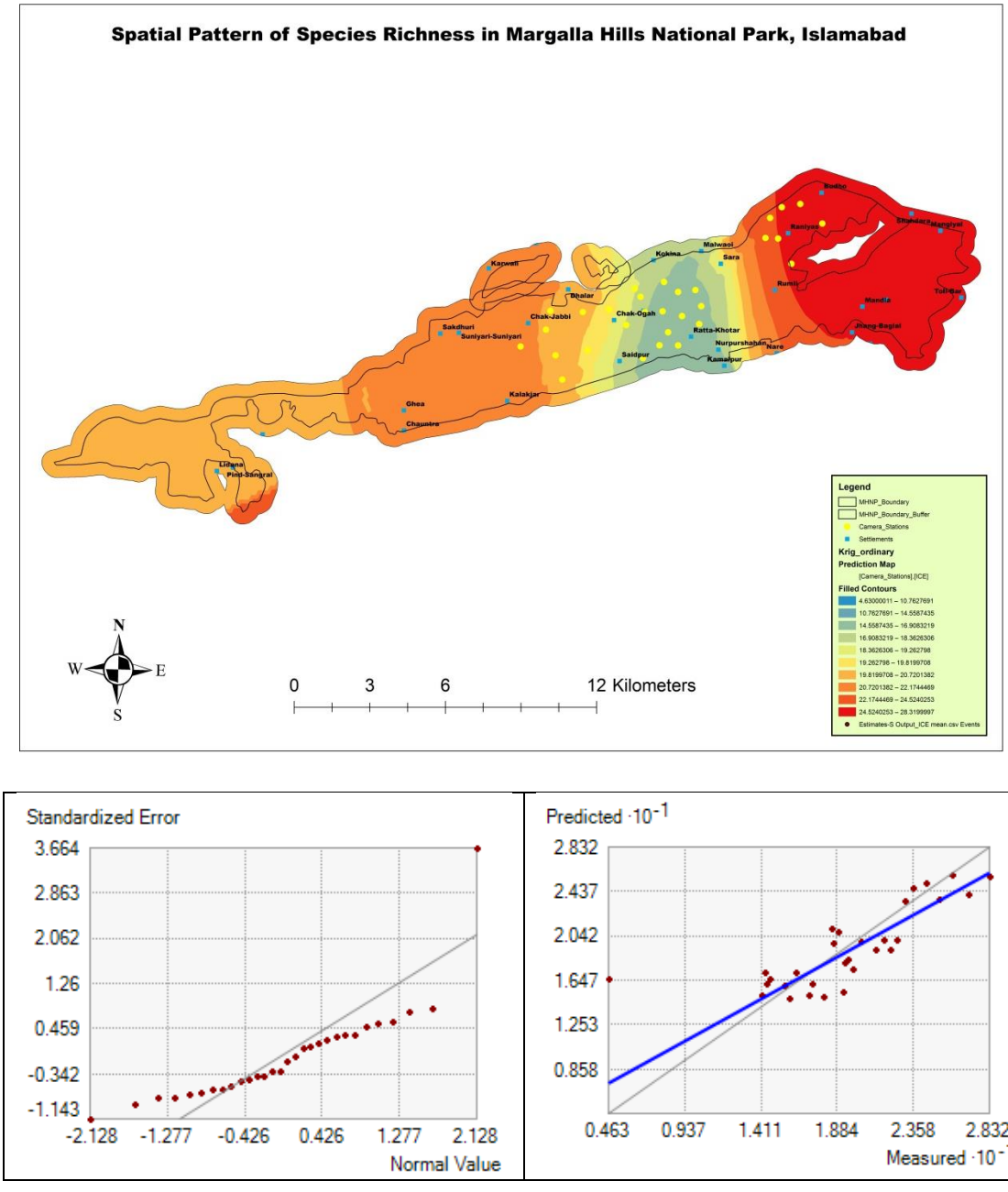

Fig.3.12. Map and graphs showing the extrapolated species richness by Ordinary Krigging Model using ICE richness estimator values.

3.3.4 Species Associations in MHNP

Cluster analysis using "Vegan" package in R, grouped species in three clusters **(Fig.3.13),** on the basis of their geographical detections. Three major groups could be described as:

- **Frequently Captured:** This cluster includes; red fox, rhesus macaque, masked civet, wild boar and Indian porcupine.
- **Moderately Captured:** This cluster includes; golden jackal, barking deer and Indian civet.
- **Rarely Captured:** Common leopard, black rat, hedgehog, jungle cat, Indian hare, grey mongoose, leopard cat, yellow throated marten, Indian pangolin and rat (genus *Rattus*). This group did not show clear isolation pattern due to limited captures.

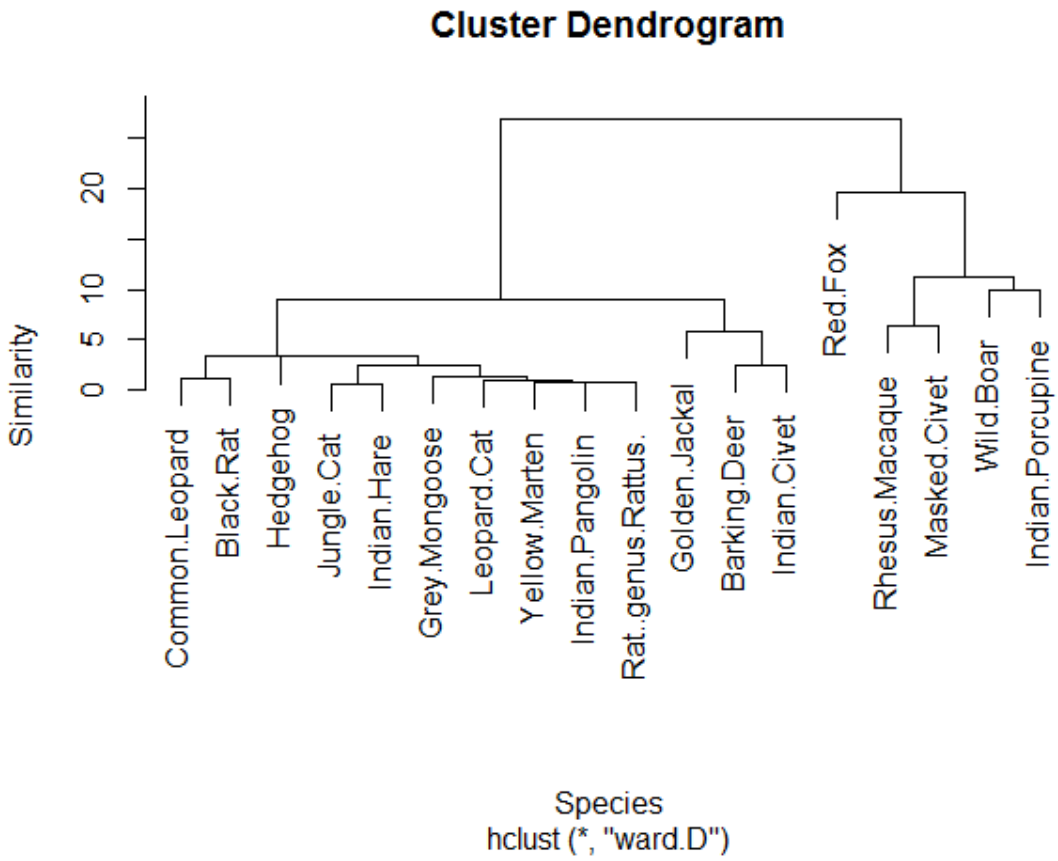

Fig.3.13. Dendrogram showing species geographic associations in MHNP.

DISCUSSION

Camera trapping has become a state of the art technique in various wildlife studies and is used throughout the world with applications ranging from recording animal presence to detailed observation of wildlife ecology on the basis of quantitative and statistical inference (Sunarto et al., 2013). The current camera trapping study was a pioneering initiative in the MHNP, Islamabad. The study photographically recorded presence of 18 species of mammals out of 31 previously reported in the park (Nawaz et al., 2007). Previous reports were based on expert judgements, anecdotes and sign surveys, whereas reliable detection of species through sighting and other source was not available. Therefore previous reports largely suggest potential occurrence of mammalian species, in contrast to the current study where species presence is recorded in a doubtless manner. The recorded species in current study included; common leopard, leopard cat, jungle cat, red fox, golden jackal, Indian civet, masked civet and yellow throated marten. Ungulate species included barking deer and wild boar, while other species include; rhesus macaque, Indian porcupine, Indian pangolin, Indian hare, hedgehog, grey mongoose, Rat (genus *Rattus*) and black rat. Given the protocol of camera trapping and objectives of the study, we focused on large and medium sized mammals; however the study was not designed to capture small and arboreal mammals, consequently these species are missed out in our study and mark difference from reported species numbers in the past.

Camera trapping is not new to Pakistan as several past studies have used this technique in mammalian surveys. Wang et al. (2014) performed camera trapping study to investigate richness and abundance of mammalian species along Karakoram Highway in Khunjerab National Park. In this study of 10 cameras deployed in 4 different locations, five mammalian species were recorded with descending RAI as; red fox, Indian hare, Himalayan ibex, snow leopard and Mustelidae species. Species richness and abundance in roadside forests at the bottom of valley are lower (4 species in 6 cameras with 23.47% RAI) than that of mountain slopes (5 species in 4 cameras with 76.53% RAI). Ahmad et al. (2016) carried out a camera trapping study in Musk Deer National park, Azad Jammu and Kashmir. In this study a total of seven mammalian carnivore species were photo-captured represented by four families i.e. family Felidae; snow leopard and leopard cat,

family Ursidae; brown bear, family Canidae; grey wolf and red fox and family Mustelidae; stone marten and yellow-throated marten.

Bari (2016) conducted a camera trapping study in Terich valley in district Chitral, Khyber Pakhtunkhwa. The study documented five carnivore species including two felids; snow leopard and wild cat both photo-captured at single camera stations, two canids; golden jackal and red fox both photo-captured in 13 and 25 cameras, respectively, and one mustelid; stone marten photo-captured at 5 stations. Din (2017) conducted a camera trapping study in Hopper and Hisper valleys of Central Karakoram National Park, Gilgit Baltistan, by deploying 38 cameras. The study documented eight mammalian species i.e. snow leopard, Himalayan ibex, red fox, stone marten, altai mountain weasel, Indian hare, Black rat and field mouse. Red fox was captured at most of the stations, followed by stone marten, snow leopard, Black rat, Indian hare, altai mountain weasel, Himalayan ibex and field mouse. Though all of the above mentioned studies used the same technique with more intensive effort as compared to the current study, yet species capture rate is much lower as compared to the current study. Higher diversity in MHNP can be attributed to diversity of habitat, terrain, weather conditions and geographic location of the area which can be justified by the fact that MHNP is geographically situated at the foothills of Himalayas which is a merger of temperate region to the north and sub-tropical region to the south making it ecologically suitable for the wildlife of the both eco-regions.

Though camera trapping studies have been rare, Pakistan has a long history of mammalian surveys with conventional methods such as sign surveys and questionnaire. Qureshi et al. (2011) carried out a study on biodiversity including flora and fauna of the Khunjerab National Park. The mammalian diversity of the park was observed through direct and indirect observation methods. A total of 14 species of mammals representing 5 orders, 10 families and 14 genera were recorded. Manzoor et al. (2013) conducted a study to assess biodiversity of the Pir Lasura National Park, Azad Jammu and Kashmir. A total of 16 mammal species were recorded. Faiz and Abass (2016) conducted a survey for mammalian diversity of Tolipir National Park. The survey recorded 30 species belonging to 19 families through direct and indirect observations. Nawaz et al. (2011) documented

the patterns of mammalian distribution in the Chagai desert Baluchistan. The study recorded large proportion of rodents i.e. 22.8 colonies as compared to other mammals however there were signs of fox and jackal with the density of 7.2/km^2 and 3.3/km^2 respectively while signs of the large mammals were rare and limited. Ghalib et al. (2007) documented the status of mammalian diversity of Baluchistan based on the checklists generated on the basis of survey carried out by the Zoological Survey Department in the various eco-regions across the country since 1960. Mammals of Baluchistan are represented by 90 species from 9 orders and 27 families, of which 21 species are threatened and 4 are endemic to Baluchistan. Since actual detection of species was limited, above stated studies reported the expected number of mammalian species from several protected areas across, in a range from 14 to 30. Thus in comparison to other protected areas MHNP appears to be one of the most species rich area in Pakistan, where 38 species are expected Nawaz et al. (2007) and 18 are photographed during the current study.

Common leopard is a big cat listed as "vulnerable" in IUCN Red List (Stein et al., 2016). Its distribution ranges across Africa and Asia, population has considerably declined and marginalized besides extirmination from large part of its historic range. Given its wide geographical distribution, elusive nature and habitat tolerance, it is difficult to categorize them under a single species and it is evident that leopard population have been strikingly reduced due to increased anthropogenic factors and persecution (Selvan et al., 2014; Thorn et al., 2013). One of the key results of the current study was the photo captures of the common leopard. There were a total of 5 capture events recorded at 4 different camera stations with 102 photos. Individual recognition suggests that there were minimum three leopards in the study area. This was an important discovery in the MHNP, as there was no creditable evidence available in past two decades to suggest persistence in MHNP, and area has observed immense growth in human population and infrastructure in recent years.

Shehzad et al. (2015) carried out a human-carnivore conflict assessment study on the common leopard in Ayubia National Park, Khyber Pakhtunkhwa Pakistan. The level of consumption of prey species by the leopards underpins the severity of the conflict. For

this purpose a state of the art DNA-based diet analysis was carried out and the results suggested that common leopard is a generalist predator depending mainly on domestic animals. Results showed 95% of the prey species were domestic animals. Study recommended the investment on local community and increasing availability of wild species as the possible remedies to the problem. Kabir et al. (2014) also worked on conflict assessment by conducting a household survey to quantify livestock loses by leopard inside and in the vicinity of Machiara National Park, Azad Jammu and Kashmir, Pakistan. According to the survey a total of 301 livestock were killed by leopards between June 2007 and August 2008. The study suggested implementing efficient human-leopard conflict management and community education especially through carnivore-friendly livestock protection.

Occurrence of common leopard in MHNP is salient and could be attributed to factors such as the availability of healthy population of prey species like wild boar, barking deer and other medium sized mammals as recorded during this study. Protection of prey population in an area can even restore the presence of an eliminated predator as reported by Lovari et al. (2009) in Sagarmatha National Park, Nepal where snow leopard was eliminated due to heavy hunting but returned back to the area after three decade when Sagarmatha was established a national park. Moreover the dense vegetation cover in the park provides a considerable refuge and shelter, helping in stalking behavior and better hunting opportunities. Suitable climatic conditions with enough biotic resources assist in adaptation to the area. Minimum level of human-leopard conflicts in the presence of leopard is interesting; it is probably related to the sufficient prey population and adaptive behavior of leopard towards the ecosystem of MHNP. The geographical connectivity of MHNP with surrounding habitats in Galliat (where leopard's presence is established) also facilitates seasonal movements across the landscape.

Beside common leopard, two other important cat species were recorded during the current study; leopard cat and jungle cat. The leopard cat is considered as "Least Concerned (LC)" in IUCN Red List and is found widely distributed in some parts of India, western Pakistan and Afghanistan throughout Himalayan foothills, most parts of China, to the north of the Korea and Russian Far East (Ross et al., 2015). The jungle cat

is considered probably the most common species in South Asia where most of the global population occurs in spite of its rapid decline in mainland southeast Asia where the species is very rare and restricted to some remote lowland deciduous forests (Duckworth et al., 2005). Its IUCN status is "LC" but its average global declines are sufficient for its near threatened status (Gray et al., 2016). The current study confirmed the presence of these important cat species; however their occurrence in the park is considerably low i.e. leopard cat at 5 stations and jungle cat at 1 station indicates need for initiating conservation measures for these cat species in the park.

The carnivore species representing canids in this study were the golden jackal and red fox. The golden jackal is listed as "LC" and is a widespread carnivore species. It is pretty common across its range with a minimum population estimate of over 80,000 from Indian sub-continent. Given its omnivorous diet and tolerance of dry conditions, the golden jackal can dwell across vast range of habitats (Jhala and Moehlman, 2015). The red fox also being listed as "LC" has the most vastly distributed geographical range among the order Carnivora. They are opportunistic omnivores, very adoptable to urban areas, sometimes live in close association with humans and agriculture (Hoffmann and Sillero-Zubiri, 2016).

Two species from family Viverridae i.e. Indian civet and masked civet were one of the notable results of the study. Indian Civet in listed as "LC" due to its vast geographical distribution, its preference (in some ecosystems) for the degraded and fragmented patches of habitat with records of healthy populations in cultivated/secondary landscapes from various range states (Choudhury, 2015). Masked Civet is also listed as "LC" due to its vast distribution, considerably large populations and occurrence in many protected areas, resistance to heavy habitat fragmentation, large population in hilly terrain away from deforestation. Therefore its population is not prone to decline at the rate to be considered even for listing as Near Threatened (Duckworth et al., 2016), and considerable captures were recorded in this study i.e. 18 captures of masked civet and 8 captures of Indian civet. Their occurrence is important for the ecosystem health.

Among the wild ungulates, barking deer or Indian muntjak is one of the species of special concern. It has been listed as "LC" in IUCN Red List due to its vulnerability to hunting, logging and other human disruptions (Timmins et al., 2016). It is one of the rare ungulate species of Pakistan and in this park, given its capture at only 6 camera stations. Zulfiqar et al. (2011) conducted a study on population and conservation status of Barking Deer in Pir Lasorha National Park and other areas of district Kotli, Azad Jammu and Kashmir, Pakistan, by collecting information through both direct and indirect observations. The study estimated a population of 45 animals with overall density of 2.14 individuals/km^2. Poaching, overgrazing and forest damage are the major threats to the barking deer population. Compared to Pir Lasora NP, MHNP appears to have lower density of barking deer.

Among the medium sized and small mammals we recorded two rare species i.e. yellow-throated marten and Indian pangolin. The yellow-throated marten is listed as "LC" in IUCN Red List because of its evidently large population in the wild and occurrence in many protected areas without major identified threats (Chutipong, 2016). Indian pangolin is "Endangered" due to severe poaching and hunting pressure for its flesh and scales both in local market and international trade in scales which are primarily used in traditional medicine mostly in East Asia. The population of this species is suspected to decline by almost 50% in the next 21 years (Baillie et al., 2014) and its photo capture in only 1 camera station in this study also predict its low occurrence in the wild and thus needs immediate conservation actions.

This study was important to build a scientifically sound baseline on mammalian diversity in the park, and is first of its kind in the last 40 years since park was created. Camera trapping in combination with sign survey made study more comprehensive and increased detection probability of the mammalian species. Moreover camera trapping recorded human and livestock activities in the park that included livestock movement, woodcutters, visitors and trekkers which could be used to map spatial pattern in intensity of disturbance in the park.

CONCLUSION AND RECOMMENDATIONS

The current study documented 18 mammalian species (47.36 %) of a total of 38 species reported in past including some rare and endangered such as common leopard and Indian pangolin that were seen for very long. The study provided an updated checklist of mammalian species and a baseline for the management to formulate their conservation decisions. The study shows that about 55 % of the photo captures belong to humans and livestock indicating a higher level of accessibility of the park to the public and local community, while mammals accounted only about 29% of the total photo captures.

Keeping in view the results and experiences during the study, it is recommended that the park needs immediate and concrete conservation planning in order to mitigate the threats posed to the mammalian diversity. These threats include encroachment practices, anthropogenic disturbance both by visitors and the local community, littering, wood cutting and most worth mentioning, the fires. All these issues must be taken under consideration on priority basis to cope with the threats faced by the wildlife of MHNP.

- Current study could not adequately capture small mammal species; another study with an appropriate technique (like live trapping) may be conducted to record species missed out in the current study.
- Seasonal surveys should be conducted to better understand temporal variation in mammalian movement and diversity, particularly to establish if common leopard is resident to the MHNP or just a vagrant from Galliat.
- Community should be made aware of the parks mammalian diversity, particularly presence of common leopard, and education should be imparted with respect to co-existence with the large carnivores.

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