

## **EXECUTIVE SUMMARY**

Habitat features may determine spatial distribution of animal species in an area since they exploit a variety of habitats and resources where resource partitioning is the outcome of species coexistence especially for sympatric species. This study aimed to examine the abundance and occupancy of jackal with the application of photographic captures using camera traps and diet composition through scat analysis, investigate species-habitat relationships from habitat features (non-spatial) and remotely sensed features (spatial) to understand how these variables govern occurrence pattern and predict the distribution of jackal in Sariska Tiger Reserve, Rajasthan. In India, jackal populations achieve high densities in pastoral areas such as Kutch, Maharashtra, Rajasthan, and Haryana. Over its entire range, except in Protected Areas, the jackal population is steadily declining (MacDonald and Zubiri, 2004). Traditional land use practices are being replaced by intensive agriculture, while wilderness area and rural landscape are being rapidly urbanized. Jackal population can adapt to this change up to some extent, but eventually disappear from such area. Estimated 80,000 jackal remain on the Indian subcontinent, but there are no estimates for Africa (Jhala and Moehlman, 2004). They suffer from common issues of lack of awareness of their plight and the deficiency of reliable data on their distribution and conservation requirements. Without careful consideration of population dynamics and habitat associations across species and habitats, conservation efforts may be poorly applied, thus delaying species recovery.

This study will vitally improve our state of knowledge to protect jackal and assist the development of theory on their social structure, behavior and habitat preferences in forested ecosystem. The study will help in suggesting localized monitoring mechanisms wherever necessary as this is important in minimizing surprise cases of extinction. The objectives of this study are as follows:-

1. To determine the abundance of golden jackal.
2. To estimate the food availability, food habits and dietary niche overlap between golden jackal and other meso-carnivores.
3. To evaluate the den site selection by golden jackal and,
4. To evaluate the habitat use by golden jackal.

The study was conducted from 2010-2013 in Sariska Tiger Reserve (79° 17' to 76°34'N and Longitude: 27° 5' to 27° 33' E), Rajasthan. I selected 160 km<sup>2</sup> of intensive study area which was divided into four blocks. A total of 160 locations were selected for the placement of camera traps where, each block having 21 camera trap stations. Total 84 trapping locations covered minimum convex polygon area of 118.7 km<sup>2</sup> and an effective trapping area (ETA) of 223.8 km<sup>2</sup>. Total 42 units of digital cameras that worked on passive infrared motion and heat sensors were deployed in grid of 2 x 2 km<sup>2</sup> ( 20 units of Spy-point FLA1 and 22 units of Moultrie cam). The mean inter-camera trap distance was 750 m.

I calculated Relative Abundance Index (RAI) for each camera trap location by dividing the total number of independent records from the total trap nights x 100 (Carbone et al., 2001, O'Brien et al., 2003). Hence the RAI for species is presented as the number of photo captures per 100 trap nights. To compare RAI of jackal, hare and porcupine between year and seasons, I used Student's t-test in program SPSS 16 (SPSS 2007). I used Royle and Nichols (2003) heterogeneity model and repeated count method (Royle 2004). Both models were analyzed in program Presence 4.1 (<http://www.mbrpwrc.usgs.gov/software/presence.html>).

I assessed differences in detection probability, occupancy rates and average abundance between seasons in two years. Mean abundance estimates were compared between years and seasons using Student's t-tests in program SPSS 16 (SPSS 2007). I performed a Pearson correlation test between mean abundance ( $\lambda$ ) as obtained from occupancy approach and relative abundance index (captures/100 trap nights).

Totally, 6720 trap-nights yielded 202 photographs of golden jackal, of which 11.88 % (n = 17) was obtained in summer 2011, 40.56 % (n = 58) in winter 2011-12, 14.69 % (n = 21) in summer 2012 and 32.87 % (n = 47) in winter 2012-13. Average capture frequencies of jackal across the years ranged from 1.26 captures/100 trap-nights to 4.31 captures/100 trap-nights. Jackal RAI differed significantly yearly (t test; t = 6.23, df = 2, P = 0.00) but, did not differ seasonally (t test, t = 9.51, df = 1, P = 0.06).

Estimates of detection probability of jackal varied from 0.039 to 0.069, with standard errors from 0.012 to 0.014 (table.3.2). Detection probability varied across the years (t test, t = 7.26, df = 3, P = 0.01) and did not differ significantly in summer (t test, t = 1.48, df = 1, P = 0.07) and winter (t test, t = 10.5, df = 1, P = 0.06) across two years.

Detection probability ( $r$ ) of jackal was estimated high in winter ( $0.07\pm 0.01$ ) as compared to summer ( $0.04\pm 0.01$ ) and the probability of site occurrence ( $\Psi$ ) of jackal was found high in winter ( $0.31\pm 0.06$ ) than summer ( $0.23\pm 0.19$ ). Seasonal estimates of occupancy varied from 0.22 to 0.31, with standard errors from 0.07 to 0.12 and the average abundance ranged from 0.22 to 0.38 with standard errors from 0.09 to 0.13 in two years. Modeled site occupancies were observed greater than naïve occupancy. Abundance ( $N$ ) and relative abundance index (captures/100 trap nights) were not significantly correlated (Pearson correlation test,  $p = 0.93$ ,  $n = 4$ ,  $P = 0.07$ ) with each other and there was a significant positive relationship between mean abundance ( $\lambda$ ) and RAI (Pearson correlation;  $R_2=0.87$ ,  $n = 8$ ,  $P = 0.004$ ).

Densities of ungulates and ground birds were estimated using line transects (Anderson *et al.*, 1979; Burnham *et al.*, 1980; Buckland *et al.*, 1993, 2001) of length varied from 2 km to 3 km. All transects (total length = 61.0 km) were walked thrice in a season amounting total effort of 183 km per season. The data was analyzed using DISTANCE 5.0 software (Laake *et al.*, 1998). Density of rodents and shrews were estimated using a trapping web design (Anderson *et al.*, 1983) and conducted in 14 locations using 41 Sherman traps (H. B. Sherman Traps, Inc., Tallahassee, Florida). Trapping was conducted for two years amounting to a total effort of 5740 trap-nights in each season. All rodents and shrews captured were sexed, weighed, measured, marked and released at the trap site. Density was estimated using program Distance 6.0 (Thomas *et al.*, 2009) and Mark (White and Burnham 1999). Camera trapping was used to estimate abundance of hare and porcupine in the study area using the same design as used for jackal abundance estimation. Ten *Zizyphus mauritiana* trees were permanently marked with tags at 12 different locations ( $n = 120$  sampling trees). For fruit biomass estimation, fruit production of the tagged trees was monitored every week. Ten iron mesh frames of size 50 x 50 cm were deployed under the canopy of sample tree. I estimated the availability of fruits in g/ha and g/km<sup>2</sup> for various analysis.

For dietary analysis, total 18 trails, each 5 km in length were surveyed systematically once a month. Jackal scats were collected and analysed using method described by Mukherjee *et al.* (2004). I calculated biomass of different prey types consumed per predator by multiplying the average prey biomass with number of prey items consumed by small carnivores. I estimated the diversity of each predator's diet using the Shannon diversity index (Magurran 2004), randomizing the original order of scat

samples (1000 iterations) using the software EstimateS (Colwell 2006). I expressed diet composition in three complementary ways: fresh biomass consumed (D), percentage of occurrence, and expected number of individual consumed (C). Biomass consumed was calculated as frequency of occurrence of prey remains multiplied by correction factor Y i.e. number of collectible scats produced per prey ( $F \times Y$ ) and number of individual consumed was calculated as relative biomass consumed divided by average body weight of a prey ( $D/B$ ). Shannon's (Pielou 1966) diversity index ( $H'$ ) and Levins' (1968) index ( $B = 1/\sum p_i^2$ ) was also calculated. To assess similarity of food composition between jackal, jungle cat and hyena, the Pianka's niche overlap index was calculated (Pianka 1973) for the entire study period. I used Ivlev's index ( $E$ ) to determine food selectivity of small carnivores. Mann-Whitney  $U$  test was applied to evaluate for the seasonal differences between species. I used SPSS 16 (SPSS 2007) statistical package to process data.

Peafowl was observed to be the most abundant prey species throughout the study period. Amongst the wild prey species, nilgai was observed to be the most abundant wild ungulate prey species followed by, chital, wild pig and sambar in the study area. The density of common langur in the study area varied across the study years. The abundance of livestock was comparatively high in the study area. The density of young once of common langur was observed highest 9.19/ km<sup>2</sup> during the study period followed by wild piglets 4.70/km<sup>2</sup>, nilgai calf 3.34/km<sup>2</sup>, peafowl chickens 2.72/km<sup>2</sup>, chital fawn 2.21/km<sup>2</sup>, sambar fawn 1.67/km<sup>2</sup> and cow calf 0.71/km<sup>2</sup>. In the intensive study area, the available total prey biomass was calculated to be 7506.5 kg/ km<sup>2</sup> in 2010-11, 13291.6 kg/ km<sup>2</sup> in 2011-12 and 18354.2 kg/ km<sup>2</sup> in 2012-13.

**Rodent and shrew abundance:** The recorded abundance of rodents was higher in winter (45.23 individuals/ha) than summer (1.09 individuals/ha). Species recorded with highest density in summer were *Mus budooga* ( $3.51 \pm 1.59$ ) followed by *Golunda ellioti* ( $1.77 \pm 0.69$ ) and *Tatera indica* ( $1.21 \pm 0.49$ ). Species recorded with highest density in winter were *Mus budooga* ( $9.71 \pm 7.74$ ) followed by *Mus platythrix* ( $8.12 \pm 4.21$ ) *Suncus montanus* ( $5.89 \pm 4.61$ ) and *Vandeleuria oleracea* ( $5.55 \pm 4.62$ ). Difference in capture rates was observed for the entire study period where, female capture rates were significantly lower than that of male capture rates (t test,  $t = -4.85$ ,  $df = 6$ ,  $p = 0.003$ ). Body weight of females were higher than males but the difference was not found significant (t test,  $t = 0.99$ ,  $df = 9$ ,  $p = 0.35$ ).

**Porcupine and hare abundance:** Estimates of detection probability of hare varied from 0.072 to 0.126, with standard errors from 0.009 to 0.014. Estimates of detection probability of porcupine varied from 0.045 to 0.088, with standard errors from 0.009 to 0.010. Seasonal estimates of hare occupancy varied from 0.39 to 0.59, with standard errors from 0.05 to 0.07 and, average abundance ranged from 0.50 to 0.90 with standard errors from 0.05 to 0.07 in two years. Seasonal estimates of porcupine occupancy varied from 0.70 to 0.80, with standard errors from 0.04 to 0.07 and, average abundance ranged from 1.21 to 1.63 with standard errors from 0.16 to 0.31 in two years. Modeled site occupancies were observed greater than naïve occupancy. Data showed that there was a positive relationship between site occupancy ( $\Psi$ ) and RAI of hare (Pearson correlation;  $R_2=0.94$ ,  $n = 4$ ,  $p = 0.06$ ) and porcupine (Pearson correlation;  $R_2=0.91$ ,  $n = 4$ ,  $p = 0.09$ ).

**Zizyphus Fruit biomass availability:** The *Zizyphus mauritiana* species was examined for fruit availability, as they were identified as important species based on their percent occurrence ( $\geq 17\%$ ) in jackal scat. The species contributed to 17.61 % (246 *Zizyphus* seeds) out of total 26.76% of fruit frequency of occurrence in the diet of jackal in 2011-12 and, during the year 2012-13, the contribution was 16.91% (290 *Zizyphus* seeds) out of total 24.64% of fruit frequency of occurrence in the diet of jackal.

**Prey selection and food habits:** In total 104 jackal scats were collected during 2010-11, 284 scats during 2011-12 and 349 scats were collected during 2012-13. In total, 12 prey species were identified in jackal's scat in 2010-11, 13 prey species in 2011-12, and 14 prey species were identified in 2012-13. Amongst all the food items, four highest occurring food types during the year 2010-11 was vegetative material, which contributed maximum (17.57%) in jackal diet followed by rodent (15.77%), cattle (15.32%) and chital (10.81%). In 2011-12, vegetative material again contributed the most (14.18%) followed by nilgai (12.20%), fruit (11.59%) and rodents (8.08%). In 2012-13, vegetative material contributed maximum (18.23%) in jackal's diet followed by chital (13.61%), nilgai (13.48%) and fruit (10.74%).

**Estimation of biomass consumption using feeding trials on Jackal:** Of the scats produced, the percentage of non-collectable scats ranged from 2.6% to 18.4%, for an average of 9.9%. The consumption of carcasses by jackals in 15 feeding trials ranged from 25.7% to 100%, for an average of 79.4% and was negatively correlated with size of prey ( $r=0.72$ ,  $P=0.001$ ). Loss of moisture from the prey bait carcass accounted

for a 0.5% (in chicken) to 50% (in buffalo) weight loss in 72 hr. Moisture loss was recorded less for bird and fruits and high for rabbit and buffalo. Consumption of prey biomass (Y) per collectable scat increased with an increase in live body weight of prey (X). The correction factor so derived as:  $Y = 0.003x + 0.228$  ( $R^2 = 0.825$ ;  $F = 37.6$ ;  $df = 1$ ;  $p < 0.001$ ). The conversion of prey body mass into a number of scats and their weights excreted by an individual carnivore is inferred using seven quantities (Wachter et. al. 2012) to establish the relationship between consumed prey mass and the number of consumed prey individuals derived from carnivore scats collected in the field. Data on utilization (from scat analysis) and availability (from distance sampling analysis) of prey species was compared and index of selection were obtained (Ivlev 1961). During 2010-11, rodent ( $p < 0.01$ ), hare ( $p < 0.01$ ), chital ( $p < 0.01$ ) and *Zizyphus* fruits ( $p < 0.01$ ) were consumed more than their availability, while wildpig ( $p < 0.01$ ) goat ( $p < 0.01$ ) and nilgai ( $p < 0.01$ ) were consumed less than their availability. Sambar, cattle and bird was preyed in proportion to its availability ( $p > 0.05$ ). In 2011-12, rodent ( $p < 0.01$ ), hare ( $p < 0.01$ ), bird ( $p < 0.01$ ), chital ( $p < 0.01$ ) and *Zizyphus* fruits ( $p < 0.01$ ) were preyed more than their availability, while wildpig ( $p < 0.01$ ), cattle ( $p < 0.01$ ), goat ( $p < 0.01$ ) and sambar ( $p < 0.01$ ) were preyed less than their availability. Nilgai was preyed in proportion to its availability ( $p > 0.05$ ). In 2012-13, *Zizyphus* fruits ( $p < 0.01$ ), rodent ( $p < 0.01$ ), hare ( $p < 0.01$ ), goat ( $p < 0.01$ ), bird ( $p < 0.01$ ) and chital ( $p < 0.01$ ) were preyed more than their availability, while wild pig ( $p < 0.01$ ), cattle ( $p < 0.01$ ) and sambar ( $p < 0.01$ ) was preyed less than their availability. Nilgai was preyed in proportion to its availability ( $p > 0.05$ ).

***Trophic niche overlap and niche breadth:*** No significant diet difference was observed between jackal and hyena (Mann–Whitney U test:  $U = 99$ ,  $p = 0.28$ ), jackal and jungle cat (Mann–Whitney U test:  $U = 88$ ,  $p = 0.14$ ) and hyena and jungle cat (Mann–Whitney U test:  $U = 124.5$ ,  $p = 0.89$ ) in the study area. The estimated dietary overlap (Pianka's index, Pianka 1973) for three years between striped hyena and golden jackal was found to be (0.81) 81%. The estimated dietary overlap between jungle cat and golden jackal was found to be (0.67) 67% and between striped hyena and jungle cat it was (0.31) 31% during the entire study period. Niche breadth for golden jackal was calculated as 0.73, for striped hyena it was 0.40 and for jungle cat it was 0.36. The calculated value of niche overlap of jackal on hyena was observed to be (1.04) 100%, niche overlap of hyena on jackal was calculated as 0.62 or 62% and, value of niche overlap of jackal on jungle cat was observed to be 0.87 or 87%.

For den site surveys I systematically searched the study area on foot and spent a total of approximately 1752 man hours along with a field assistant searching for jackal dens in the  $\sim 160 \text{ km}^2$ . Active dens were identified by signs of fresh digging, pup and adult scat deposition around the den site and tracks along the ramp of the den openings. All the active dens of different pairs were monitored simultaneously. The distance between the two dens was estimated using the GPS. The orientation of den openings was noted. I used circular plot of 10m radius, with the den site at the centre, to measure surrogate variables, also measured the same variables outwardly at a distance of 100 m in four cardinal directions from the den site (Lesmeister et al. 2008). I recorded the substrate and terrain type at the den site, measured tree and shrub density in the 10m radius circular plot and recorded percentage canopy cover using a spherical densiometer. I also measured visibility, ground layer height, measurements on den openings and den temperature. The distance to nearest settlement, distance to nearest water source and distance to the nearest road was measured using spatial analyst tool in ArcMap software. For this, I used a GIS land cover classification layer, land and water hole layers from WII's GIS laboratory. For micro site selection, variables in consideration were i) substrate, ii) terrain, iii) tree number, iv) shrub number, v) vegetation composition, vi) grass cover and vii) distance to road, water and settlement. I used use-availability design along with discrete choice models (Cooper and Millsbaugh, 1999) for micro site selection using SPSS 16 (SPSS 2007) statistical package for data analysis. For macro site selection, variables in consideration were i) proportional value of forest type, ii) proportional value of forest cover, iii) densities of various prey items, iv) elevation, v) slope, vi) ruggedness and vii) distance to road, water and settlement. I evaluated prey density for different prey classes by exploratory analysis using DISTANCE 5.0 software in conventional distance sampling (CDS) and multiple covariate distance sampling (MCDS) framework. To examine factors that influenced den site selection at the micro scale by the jackal, I used four ecological hypotheses created by Punjabi *et al.* (2013), which might best predict den site selection. These hypotheses were: habitat and prey availability, thermoregulation (substrate and terrain), predatory avoidance (cover) and edge effects (distance to road, water and settlement) and, are represented by explanatory variables measured at each den and available sites. I used an information theoretic approach of testing *a priori* models by Akaike's information

criterion (AIC) to assess model weights ( $\omega_i$ ) and ranked candidate models using  $\Delta$  AIC (Burnham and Anderson 2002).

**Physical attributes:** Thirty six jackal dens were located in the intensive study area (0.23 den / km<sup>2</sup>) where NVD (*Zizyphus nummularia*, *Adathoda yasica*, *Capparis decidua*) and EC (*Balanites aegyptiaca*, *Capparis sepiaria*) vegetation classes were observed more in denning sites but no significant difference was observed (chi-square test:  $\chi^2 = 6.25$ , d.f. = 3,  $p = 0.10$ ) among four vegetative classes between natal and resting dens. Among the four substrate types, selectivity of natal dens were recorded more than expected for mud-loam and for resting dens the selectivity for rock-mud was recorded more than expected but were not found at significant level (chi-square test:  $\chi^2 = 1.97$ , d.f. = 3,  $p = 0.58$ ).

**Cover dependence:** The average size of den opening was recorded as 47.11 cm, ranging from 18 cm to 90 cm (n=36). The percentage cover for natal and resting den were not different (One way ANOVA test:  $F = 0.01$ ,  $p = 0.92$ ) and, in areas with high percent cover, significantly lesser number of dens were observed ( $r = -0.76$ ,  $p = 0.02$ , n=9). Natal den selection sites were indifferent to water availability (One way ANOVA test:  $F = 1.02$ ,  $p = 0.32$ ) and other human induced disturbance such as to road (One way ANOVA test:  $F = 1.45$ ,  $p = 0.24$ ) and human settlements (One way ANOVA test:  $F = 2.53$ ,  $p = 0.12$ ).

**Thermoregulation:** The mean 'minimum' ambient temperature in den site was recorded as 31.7°C and the mean 'maximum' ambient temperature was recorded as 34.7°C. Difference in temperature oscillation inside and outside dens ranged between 0.4°C and 3.6°C in 'minimum' scale and 'maximum' temperature difference ranged between 0.1°C and 5.8°C. The variation in 'minimum' ambient temperature and den temperature was not much (One way ANOVA test:  $F = 1.02$ ,  $p = 0.32$ ) but, the variation in 'maximum' ambient temperature and den temperature was recorded high at significant level (One way ANOVA test:  $F = 4.20$ ,  $p = 0.05$ ). The 'maximum' temperature were recorded less in natal dens but not at significant level (One way ANOVA test:  $F = 1.53$ ,  $p = 0.26$ ). Temperature variation was neither significant in the four substrate types nor for natal and resting dens (Kruskal-wallis test,  $\chi^2 = 3.00$ ; df = 3;  $p = 0.39$ ). The 'maximum' temperature variation was not found significant among aspects (chi-square test:  $\chi^2 = 5.49$ ; df = 7;  $p = 0.60$ ) although 'maximum' temperature recorded for SW was lower than N and NE.



**Aspect dependence:** No selectivity was observed for spatial orientation of den entrances of jackal in terms of aspect (pearson's chi-square test:  $\chi^2 = 633$ ;  $df = 7$ ;  $p = 0.50$ ) however the natal den facing aspect SW (20%), NW (20%) and NE (13.3%) were observed more than expected, and for resting dens aspect N (16.7%) was observed more than expected.

**Den placements:** There was a negative correlation observed at significant level between average 'maximum distance' among Jackal dens and the size of regional area (Spearman's rho correlation test;  $r_s = 0.89$ ,  $n = 5$ ,  $P < 0.04$ ). The larger areas have dens that are closely located to each other ( $\geq 1$  km). The 'region two', having area of 28.11 km<sup>2</sup> was recorded to have the smallest average 'maximum distance' between dens, where the composition of forest types were significantly different (One sample  $t$  test;  $t = 2.63$ ,  $df = 5$ ,  $p = 0.03$ ) suggesting the clumpy distribution of favorable habitat prevailing close allowance of dens with each other. No relation was observed between average 'minimum distance' among dens and region (Spearman's rho correlation test;  $r_s = 0.36$ ,  $n = 5$ ,  $P < 0.55$ ).

**Micro site selection:** At the micro scale (314 m<sup>2</sup>), the hypothesis 'ease of excavation' received much support as the underlying factor for den site selection. The substrate suitable for excavation i.e. mud-loam and rock base and vegetation classes NVD (*Zizyphus nummularia*, *Adathoda vasica*, *Capparis decidua*) and LJV (*Lentana camara*, *Prosopis juliflora*, *Acacia nilotica*) were found as determining variables for the selection of denning site as represented by the top model (AIC = 69.22;  $\omega_i = 0.096$ ). All other models representing the predatory avoidance, vertical cover (tree number, canopy cover) and disturbance received no support. Variables favoring natal den selection were no different than that of overall selected den sites (Kruskal-wallis test,  $\chi^2 = 5.00$ ;  $df = 5$ ;  $p = 0.42$ ). Results suggest an idea that the choice of plain areas is frequent in jackal 'natal den' sites and no significant selection or avoidance for any forest types (*Anogeissus* dominant forest, *Boswellia* forest, *Acacia* mixed forest, *Zizyphus* mixed forest, *Butea* dominant forest and Scrub forest) was observed by jackal.

**Macro site selection:** At the macro scale (3.14 km<sup>2</sup>), the hypothesis 'cover and resource' received most support to infer the underlying factor for den site selection by jackal at macro scale. The presence of small mammal density in respective forest types and favorable distance from settlements and roads, that occasionally offer food supplements in terms of garbage and road kills respectively, were evaluated as the

most influential factors at macro scale as represented by the top model (AIC = 66.50;  $\omega_i = 0.82$ ). Jackal showed no significant avoidance for large carnivore presence (tiger, leopard and hyena). Rodent abundance and visibility were the most important predictors for selection of den-sites at larger scale.

Habitat use by jackal was studied using an approach proposed by Hirzel *et. al.* (2002). The Species distribution data was collected from camera trapping, direct sighting records, scat locations and track locations and was pooled for the entire study period 2010-2013, collectively making 413 observed point locations in the intensive study area. These were plotted in ArcGIS 9.3 and overlaid on 2 km<sup>2</sup> grid cells giving distribution map of jackal. Topographical variables, biological variables and anthropogenic variables were extracted using Zonal Statistic tool in the Spatial Analyst toolbox and, an evaluated variable values were assigned in each 4 km<sup>2</sup> pixel (201 grids of size 2 x 2 km<sup>2</sup>). Digital data on contour and drainage were used for Digital Elevation Model (DEM). Surface ruggedness, Slope and aspect were calculated from elevation layer using Surface analysis tool from spatial analyst toolbox. All village locations and water points were recorded using GPS. I used the Euclidean distance tool to create a raster “distance to” (km) layer. Spatial prediction of species’ distribution was supplemented using occurrence-only records and environmental covariate by the combination and comparison of ENFA and regression modeling. Requiring only presence data as input, the Ecological-Niche Factor Analysis (ENFA) computes suitability functions by comparing the species distribution in the EGV space with that of the whole set of cells. Species are expected to be non-randomly distributed regarding eco-geographical variables. The final data set used were 9 variable layers which were projected to the UTM zone to match their coordinates, clipped to the boundary along with 2 km buffer, and entered with the occurrence data into *idrisi selva* version 3.2 (Eastman, 2012 Clark University). Maps usable by *Biomapper* and *idrisi* were used to derive biologically meaningful map with reference to the focal species (Eco-Geographical Variable, EGV). Species presence map was boolean map (containing 1 and 0 only). I selected the medians algorithm for Habitat Suitability (HS) computation. The predictive power of HS map was evaluated by cross validation process for which, the *Biomapper* software use method described by Boyce *et. al.*, (2002).

Application of the ENFA method to the calibration set provided an overall marginality of  $M = 0.64$  and an overall specialization value of  $S = 3.01$  indicating a tendency of a species to live in extreme habitats and that the jackal are rather open on the range of conditions they withstand. Tolerance ( $1/S$ ) value ( $= 0.33$ , close to zero) indicates that a species is not very discriminating on its living environment. The three factors retained (out of the nine computed) accounted for 91.25 % of the total sum of Eigen values. The marginality factor alone accounted for 87 % of this total specialization, meaning that jackal showed restricted range on conditions mostly differed from background intensive study area conditions i.e. forest area, whereas the affinity was observed towards open plain areas. Marginality coefficient factor showed that jackal are essentially linked to moderate ungulate density (0.31), optimum distance to village (0.08), water (0.04) and rodent density (0.07). By contrast, jackal tend to avoid rugged terrain (-0.98), high hare density (-0.11) and ground bird density (-0.04). Distance to road and vegetation type had only marginal effects. The distribution of habitat suitability values were differed slightly from the global distribution. Predicted suitability exceeded with marginal value of  $0.60 \pm 0.25$  whereas, the absolute validation index (AVI) value obtained was  $89.9 \pm 33.9$  which differed notably from contrast validation index (CVI) value of  $28.9 \pm 3.2$ . Distribution models performed 'reasonably' based on the area adjusted frequency (AAF) curve inferring selection of a marginal habitat by jackal, which is in accordance with the generalist behavior of the species. Since, the Boyce index value was average, multi models were constructed and analyzed using binary logistic regression in generalized linear model in same size grids ( $4 \text{ km}^2$ ). The 'resource' factor received most support to infer the habitat selection by jackal. The presence of small mammal density and favorable distance from water source in open to moderately dense forest, were evaluated as the most influential factors at the scale of  $4 \text{ km}^2$  grid ( $AIC = 528.7$ ;  $\omega_i = 0.51$ ). The selected habitat factor variables obtained from logistic regression were compared with the ENFA factor spectrum and further used for preparing the habitat suitability map. There was no significant difference observed between the selected models of ENFA and GLM (student  $t$  test;  $t = 0.57$ ,  $df = 14$ ,  $p = 0.58$ ). The little disparity observed was due to unreliability of absences data used in logistic regression. ENFA was found more robust since the predictive power of the maps was better.

The distribution of the jackal in the study area was consistent with information available from other areas where scrubland, *Zizyphus* woodland and human habitation was important for deciding its distribution (Moehlam, 1983, 1986 and 1989; Mukherjee, 1989). Their responses to habitat were consistent with predictions based on ecological characteristics of the species. The habitat suitability for jackal in Sariska highlighted the importance of maintaining landscape configuration, by combination of spatial elements, and landscape connectivity in agreement with other studies on meso-carnivores (Kareiva and Wennergren, 1995; Gehring, 2000). The conservation of species should begin with habitat protection and restoration (e.g. Danielson, 1994; Fahrig, 1997) and arrangement of spatial elements that can strongly affect the ability of species to move among and between elements (Gehring, 2000). The niche modeling in the present study depicts contrast spatial distribution pattern between jackal and leopard (Mondal *et. al.*, 2012), also the site has fair density of hyena population (24.5/100 km<sup>2</sup>, Gupta *et. al.*, 2011). The future surveys in forested and non forested regions of adjoining Alwar and Jamwa Ramgarh forest division is recommended since the, insufficient occurrence data exist from bordering areas to investigate spatial or temporal changes in ecological niches of jackal, and too little is known about the other biotic factors, such as predation and disease, or the presence of key resources outside the reserve (e.g., den sites, food distribution), which also have played a role in determining jackal distribution patterns. The jackal in Sariska appeared spatially separated towards the open bordering areas, probably to avoid competition however; more detailed field studies are needed to determine each species' microhabitat usage, behavior, food habits and the adaptive threshold of jackal towards anthropogenic activities. It is suggested to promote the species as pest controlling agent to ensure its safety and acceptance in agro ecosystem surrounding the reserve boundary. Linkage of ecological and social sciences to answer complex questions about human aspects, interactions and benefits from jackal is yet to be explored. I am hopeful that herein I have encouraged the process by highlighting species-specific ecology at a regional scale.