Distribution and assessment of the population status of Critically Endangered Kondana Soft-furred Rat *Millardia kondana*, with special emphasis on implementation of the conservation management plan at Sinhgad

Kondana Soft-furred Rat (*Millardia kondana*) Photo credit : Amol Lokhande

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Sameer B. Bajaru
Scientist - B
Natural History Collection Department
Bombay Natural History Society
Mumbai - 400001
India
E-mail : sameerbajaru@gmail.com
Website: www.bnhs.org

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EXECUTIVE SUMMARY

The number of planter pads was determined as most consistent key character for identification of *Millardia kondana* and morphological identity of the species was confirmed based on large sample size (n=238) with proper spatial distribution. Preliminary molecular investigation also indicated the distinctness of the species, however, true/pseudo absence of *M. meltada* from study site was mystifying and lack of tissue samples for molecular sequencing made difficult to draw any strong conclusions. A new site for occurrence of the species was discovered at an aerial distance of ~ 22 km from closest occupied site. The multimodel inferences revealed that ruggedness terrain index (RTI) was the most powerful variable for predicting landscape level occupancy of the species. On the contrary, the increasing percentage cover of grassland and agricultural fields were predicted occupancy of the species might decline.

Microhabitat selection analysis showed percentage of obscurity (POB) and perennial herb density (PHD) were strong predictors of presence of *M. kondana*. Prediction models also suggested that species avoid completely open grassland and dense woodlands, instead it prefers intermediate habitat. The species showed strong seasonal variation in habitat preference in synchronisation with seasonal fluctuation in herbaceous plant communities of rocky outcrops. Generally, occupancy of the species was determined by POB in winter and by PHD and WSD (Woody Stem Density) in summer. Apart from temporal variations, the species also had spatial variations in habitat preference, and these variations seems to be associated with differences in human disturbance, plant and rodent communities at study sites.

Single season occupancy estimation models fitted to Kondana Soft-furred data were found consistent with spatial and temporal pattern emerged through microhabitat selection analysis. In occupancy and population estimations generally simple and null models were selected. Both analysis methods revealed similar pattern of abundance of the species i. e. population at its peak during winter and it declines towards summer. This pattern was in synchronisation with productivity of the habitat and also supported by other studies. The pooled mean population estimated using individual heterogeneity model at Sinhgad - 44.73/ha, Torna Fort -13.65/ha and Rajgad - 20.92/ha.

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1. INTRODUCTION

South Asia is one of the richest mammalian diversity regions in the world. It harbours 185 species of non-volant small mammals, of which 62 are endemics. Most of them are included in the IUCN Red List of Threatened Species - 11% are Critically Endangered (CR), 32 are % Endangered (EN), 18 % are Vulnerable (VU), 10 % are Near Threatened (NT) and 3% are Data deficient (DD) (Molur *et al.* 2005). One of the species rich and diverse families of rodents is Muridae, commonly known as Rats and Mice. It contained several endemic and threatened species in South Asia. One of them is Kondana Soft-furred Rat *Millardia kondana.* It belongs to genus *Millardia*, which is commonly known as soft-furred rats. This genus is represented by four species; Soft-furred Field Rat *M. meltada,* Sand-coloured Soft-furred Rat *M. gleadowi,* Kondana Soft-furred Rat *M. kondana* and Burmese Soft-furred Rat *M. kathleenae.* Except the latter species which found in Myanmar, the rest of members are endemic to the Indian sub-continent. They are nocturnal, fossorial and inhabit in diverse habitats such as deserts, semi-deserts, grasslands, agricultural fields, rocky hills, scrub forests and dry deciduous forests (Prater 1998, Pradhan *et al*. 2008).

Mishra and Dhanda (1975) are discovered *M. kondana* at Sinhgad, a small highland with an area approximately one sq. km. It has been only known population of the species exists and efforts to find it in other similar localities are unsuccessful (Pradhan *et al.* 2008). It differentiated from other species in genus *Millardia* with having larger cranial and external measurements; six distinct planter pads; proportionally small ear, hind feet and bullae; and long toothrow and diastema.

Considering restricted distribution of *M. kondana* (extent of occurrence and area of occupancy both less than one sq. km.) IUCN classified it as an Endangered in 1996 and Critically Endangered in 2008 (Pradhan *et al.* 2008). Besides that Alliance for Zero Extinction (AZE), global non-governmental body working on prevention of extinction of world’s highly restricted and threatened species, included Sinhgad as an AZE site. Evolutionarily Distinct and Globally Endangered (EDGE) research and conservation initiative of the Zoological Society of London (ZSL) also included *M. kondana* in their top 100 most endangered mammal species in the world based on its evolutionary distinctness and globally endangered status. The major threats to the species are general loss of habitat, overgrazing of vegetation and disturbance from tourism (Pradhan *et al.* 2008).

Almost after three decades of its discovery, no attempts have been made to examine status and ecology of the species except Talmale (2013) and our short term study conducted in 2011-2012 (Unpublished). Our previous investigation showed that except six number of planter pads, there was no consistency and pattern among the linear morphometric measurements of *M. kondana* which can differentiated it from other sister species. Presence of *M. kondana* at Rajgad and Torna Fort were the first records of species outside its type locality, Sinhgad, after four decades of its description. Although absence/pseudo-absence of species in similar potential habitat was mystifying. We also observed that the species prefer thickets rather than open grassy patches and not found in human settlement.

This project was undertaken to fill knowledge gap about *M. kondana* which would be essential for effective conservation and management of the species. The objectives of the project were as follows

1) Examine the taxonomical status of Kondana Soft-furred Rat- testing species validation using morphological and molecular data.

2) Distribution and assessment of the population status of Kondana Soft-furred Rat: It involves estimation of population of the species at Sinhgad, Rajagad and Torna fort, and the assessment of occurrence of the species at potential sites.

3) Develop landscape level conservation management plan of the species.

4) Capacity building of the forest staff for monitoring and implementation of conservation management of the species.

2. STUDY AREA

The study area was located in the northern Western Ghats - a mountain range runs parallel to west coast of India. The study area was classified in two categories based on presence or absence of *M. kondana* - occupied sites and potential sites.

a) Occupied sites:

Three occupied sites known in this area were Sinhgad, Rajgad and Torna Fort

Sinhgad **–** It is well known hill fort situated (18° 21' 56"N, 73° 45' 26" E) in Bhuleshwar Hill range, stretched East-West in the northern Western Ghats, near Pune city, Maharashtra, India (Fig 2.1). It is a small highland of an area c. 23 ha with an elevation 1280m. The average temperature range and average annual rainfall recorded was 9.6 - 36.7 °C and 2500 mm respectively (http://pune.nic.in/punecollectorate/Gazette). The terrain was very steep and rugged (Fig 2.4). Forest patches were found at base of the hills, on the gentle slopes and around gullies and nullahs. However, the steep slopes and mountain tops were covered with bed rocks (basalt) or shallow and loose layer of soil and they dominated with herbaceous plants.

Based on anthropogenic disturbance and vegetation composition, the study area was broadly categorized as a) human habitation and b) grassland surrounding human habitation. a) Human habitation: It was covered c. 30% of the total area of Sinhgad. Local food vendors' houses, lodges, telecommunication offices, ancient structures such as cisterns and ruined temples etc. occupied this area. Vegetation was dominated with planted and exotic species. b) Grassland surrounding the human habitation: It occupied c. 70% of the total area. No human settlement was found in this area, except very few residential structures. Vegetation observed in this area was similar to that of typically found on the rocky highlands of the northern Western Ghats, dominated by herbs with scattered shrubs and stunted trees. Vegetation on the rocky highlands, especially herbs, show remarkable seasonality - the luxuriant growth of the herbs in monsoon followed by almost barren highlands with patches of grasses and few perennial herbs.

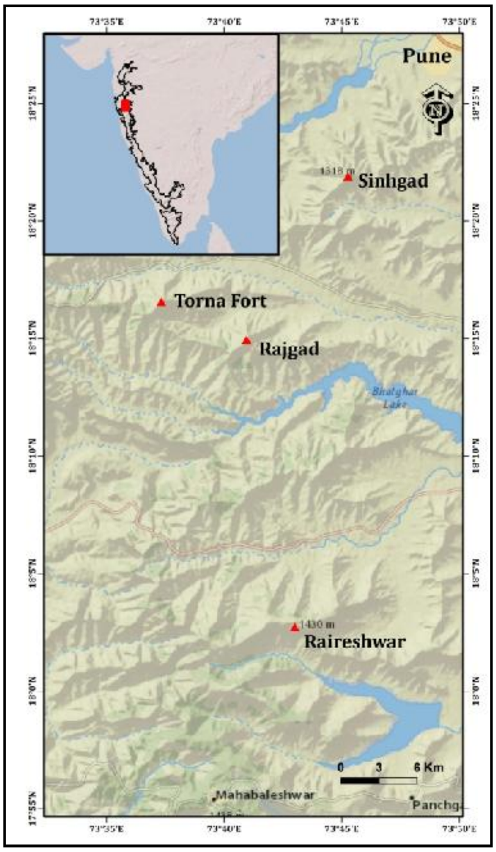


Fig. 2.1. Map of known localities of occurence of the *M. kondana*. Raireshwar - New locality for species discovered during this study. Inset - position of study area in the Western Ghats

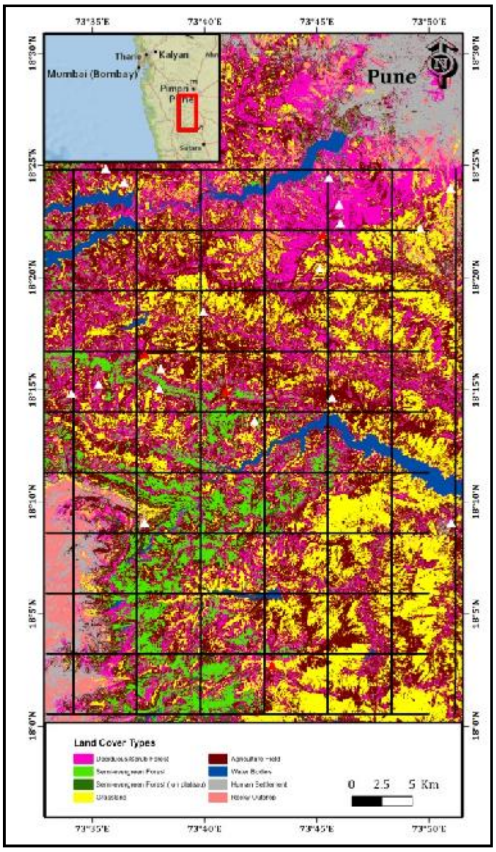


Fig. 2.2. Map showing landscape level sampling girds (5X5 km), sampling points (▲ = species recorded, ▲ = species not recorded) and land cover types.

Rajgad – It is situated c. 30 km south west of Sinhgad. Terrain was similar to that of Sinhgad, whereas the vegetation was different. Dry deciduous forest (dominant at Sinhgad) was replaced with semi-evergreen to moist-deciduous forest at Rajgad. At elevation of 1100-1200m ASL, most of the area of the fort was covered with mosaic of forest and grassy patches. Huge basaltic outcrop formed peak of the fort, 1450m ASL. It was almost treeless and covered with grasses (Fig. 2.3, a). This site is under heavy tourists pressure.

Torna Fort – It is located c. 40 km south west of Sinhgad. Terrain and habitat features were similar to that of Rajgad. The highland was almost flat with a gentle slope. *Strobilanthes* spp., grasses and few scattered *Actinodaphne hookeri* dominated habitat on the plateau (Fig. 2.3, b). This site had comparatively less tourist pressure than that of Rajgad and Sinhgad and no human settlement.

b) Potential sites:

Potential sites for occurrence of the species sites were sampled in 45x35km block, which included all three sites occupied by *M. kondana* (Fig. 2. 2). This sampling block was representative of typical terrain and habitats in the northern Western Ghats. Western side of the block was occupied with steep, high elevated and rugged hills, except some part of south-west where elevation dropped down sharply as low as >300m ASL and transformed into lowland rocky outcrops. On the contrary, elevation dropped down gradually on eastern side and area covered with low elevated and less rugged hills.

Most of the sampling block, especially hilly area, covered with dry deciduous and scrub forest, except south western part of high elevated and rugged hills occupied with semi-evergreen forest. Low elevated hills and generally eastern side of the block covered with grassland and they appears to be result of anthropogenic activities such as intensive grazing, deforestation and burning. Areas around water bodies, bases of hills and low lying plains amongst the hills were used for dry land or irrigated agriculture practices.

a) b)

Fig. 2.3 Typical habitat of the species a) open grassy area with seasonal and perennial herbs at Rajgad in winter and b) burned area left with very less herbaceous cover and scattered trees *Actinodaphne hookeri* at Torna Fort in summer.

Fig. 2.4 *M. kondana* found on rugged and high elevated peaks such as Sinhgad (left) and Torna Fort (right).

3. METHODS

3. 1. LANDSCAPE LEVEL SAMPLING

For landscape sampling the study block (45x35 km) was divided in 5x5 km grids. Except three grids occupied by *M. kondana*, the remaining 10 grids (out of 54 potential grids i.e. 24 %) were selected randomly. The number of random sampling points generated per grid varied from one to three. Trapping was conducted in 700m radius circle around random sampling point.

I used 40 live Sherman traps (4"X4.5"X12") baited with mixture of pakora (deeply fried batter of gram flour with onion and chilli powder) and peanut butter. Traps were placed in various habitat, especially away from human settlement to avoid trapping commensal species, such as open grasslands, scrublands, forests and agricultural fields. Also, I searched for indirect evidence such as pellets, burrowing signs and runways for occurrence of the rodents to improve the efficiency of trapping. Traps were placed on ground at dusk and collected at dawn. Trapping efforts at each sampling point were 40 trap nights.

Trapped individual were sexed, weighed and measured for their head and body length (HB), tail length (TL), hind feet length (HF), ear length (E). Reproductive condition of the individuals was assessed through position of testes in the males and vaginal perforation, pregnancy and lactation in the females.

The landscape variables were derived from geospatial data sources such as Landsat 8 satellite image (30m resolution, dated 8 April 2015, www. landsat.usgs.gov) and 30m resolution ASTER Global Digital Elevation Model (ASTER GDEM, www.gdem.ersdac.jspacesystems). I did the pan-sharpening with panchromatic image of 15m resolution to enhance spatial resolution of the multispectral image. Land cover map of the study area (block) was created using Landsat 8 satellite image in ArcGIS 10 with supervised classification method. Signatures used for classification of the images were collected from ground truthing and Google Earth imagery of the study area. Accuracy of the classification was assessed through generating 50 random points in ArcGIS 10 and extract corresponding cover type for each point and verified those points in high resolution Google Earth image. This procedure was repeated for five times and classification accuracy obtained was between 70 - 80%. Slope and ruggedness index (Riley *et al.* 1999) were derived in Quantum GIS (2.4.0 chugiak).

I have created buffer of 200, 400 and 700m around 13 sampled points in Arc GIS 10 for extracting landscape variables such as ruggedness index, slope and percentage of land cover types - forest, grassland, agricultural field, water body, human settlement and rocky outcrop. These variables were extracted from respective buffers and therefore total 24 landscape variables (8 variables x 3 buffers = 24 variables) were derived from the geospatial data.

3. 2. TRAPPING

Intensive trapping was carried out at Sinhgad, Torna Fort and Rajgad for investigating population density, occupancy, habitat selection and natural history of Kondana Soft-furred Rat.

All three sites were divided into 20x20m grids, of which 50 grids were selected randomly for trapping. In Sinhgad I used two traps/grid, whereas at Rajgad and Torna one trap/grid due to logistic problems. Mainly traps were placed 5m of north/ south/east/west of the centre point of the sampling grid (at Sinhgad two traps set in opposite cardinal directions). The traps were set in different cardinal directional on each day in order to increase spatial coverage of trapping. A capture session was of six days with trapping at alternative nights i.e. three nights/occasions.

I conducted one trapping sessions/site during each season - winter (December - February), post-monsoon (October -November) and summer (March -May); therefore, in total three trapping sessions for each site. Trapping sessions were conducted on at Sinhgad (December-2013, October-2014, April-2014), Rajgad (February-2014, May-2014, November-2014) and Torna (January-2014, April-2014, November-2014).

Trap specification, timing, baiting and post-trapping procedures were similar to described in landscape level sampling section (3.1). In addition to this, during first trapping sessions each individual trapped was marked with uniquely numbered ear tags but the tag removal rate was rather high; hence, thereafter tattooing was used as marking method. The unique number was tattooed with red permanent tattoo ink on sole of hind feet of the individual. The marked individuals were released at trapped locations. I strictly followed the animal handling guideline provide by Gannon *et al.* 2007, during this study.

3. 3. MICROHABITAT VARIABLE MEASUREMENTS

Most of microhabitat variables were measured in 5 m radius circle around the centre of grid and other variables in entire grid. Two ropes, each 10m in length and with marking at every 50cm, were stretched on ground in NS and EW directions in cross manner (formed four cardinal sampling units - N, E, S and W directions). Metal pole (with diameter 5mm) was released vertically downward towards the ground from height of 1m and ground cover category (herb, grass, rock, soil and dry matter) touching to the pole was noted and this procedure was repeated at every 50cm interval in four cardinal directions. I have also recorded presence/absence of canopy cover at ground cover sampling points using vertical sighting tube. Obscurity was measures using Robel pole of height 1.5m and marked with 10cm alternative red and white bands (Robel *et al.* 1970). An observer was sat on haunches at central point of grid and second person hold the pole vertically at every 1m distance (5 points in one direction) in four cardinal direction and highest band on the pole with more than 90% obscured by vegetation was recorded. A number of trees, shrubs and perennial herbs found in entire grid (20 x 20m) were counted.

Count data of ground cover categories and presence/absence data of canopy cover were converted into percentage data. Percentage of obscurity was obtained using formula - Mean obscurity/15*100 (15 - maximum number of units on Robel pole). A number of trees and shrubs in a grid were treated as woody stem density (in 400 m^2), whereas perennial herb count as perennial herb density (in 400 m^2). In total, 8 microhabitat variables were measure per grid were as follows

	Microhabitat Variable
1	Percentage of herb cover (PHR)
2	Percentage of grass cover (PGR)
3	Percentage of rock cover (PRO)
4	Percentage of soil cover (PSO)
5	Percentage of dry matter cover (PDM)
6	Percentage of canopy cover (PCA)
7	Percentage of obscurity (POB)
8	Woody Stem Density (WSD)
9	Perennial herb density (PHD)

Fig. 3 Measuring visual obscurity in sampling grid using Robel pole.

3. 4. STATISTICAL ANALYSIS

3. 4. 1. Exploratory data analysis (EDA)

I used GLM(Binomial) in most of the analysis and violation of assumptions of the model might lead to misleading final results, therefore EDA was carried out before actual analysis of data (Zuur *et al.* 2010). More emphasis was given towards outlier, normality and collinearity in data, which can severely affect the analysis. The outliers may cause overdispersion and they can determine final results and conclusions (Zuur *et al.* 2010, Hilbe 2007), hence they were visualized through the Cleveland dotplot (Cleveland 1993). Although normality is not major concern in GLM, transformation of non normal data improves the outliers and homogeneity of variance (Zuur *et al.* 2010). Therefore, data with non-normal distribution and strong outliers was transformed before analysis. To avoid the redundancy in data I computed Pearson's correlation coefficient and only ecologically meaningful variable(s) selected from significantly and highly correlated variables ($r > 0.80$, $P < 0.05$). In addition to this, collinearity among variables can be cause for variance inflation which may lead to spurious results, and therefore this issue was addressed by removing the variables having variance inflation factor (VIF) > 3 (Zuur *et al.* 2010) from analysis. All EDA was carried out in R Package.

3. 4. 2 Landscape level analysis

Information theoretic or 'IT' approach was used while considering its advantages over traditional single model hypothesis testing with arbitrary significance threshold criterion (Grueber *et al.* 2011). This approach determines best model (hypothesis) or several set of models (hypotheses) based on information criteria such as Akaike's information criterion (AIC) (Burnham & Anderson 2002, Anderson *et al.* 2000). These models are ranked and weighed according to relative support for each competitive hypothesis. In addition, if more than one models have similar level of support, model averaging provides robust estimates of parameters for predictions (Burnham & Anderson, 2002).

Except ruggedness index and slope, due to their normal distribution, all other landscape variable were arcsine transformed. The statistical analysis was conducted in R using *AICcmodavg* package (Mazerolle 2011). Only main effect were included in analysis and interactions were ignored due to their complexity and computational limitations. Global set of model was generated using landscape variables (explanatory variable) and response variable (presence/absence of the *M. kondana*). The Hosmer–Lemeshow test was performed to check goodness of fit of the global model. The model with Δ value > 9 were considered for interpretations (Burnham *et al.* 2010). I used AICc model weights (w_i), model average estimates with 95% unconditional errors and weight of predictor (w_p) for drawing inferences from the models (Burnham *et al.* 2010, Symonds & Moussalli 2011).

3. 4. 3 Microhabitat selection analysis

Percentage and count variables were arcsine and square root transformations respectively. After EDA, only ecologically meaningful microhabitat variables were retained for the modelling. In GLM, presence/absence of Kondana Soft-furred Rat was used as response variable and microhabitat variables as explanatory variables. General multimodel data analysis procedure was similar to that of described in landscape level analysis section (3.4.2). Microhabitat selection analysis was carried out for three sites - Sinhgad, Rajgad and Torna Fort and for three seasons - winter, summer and post-monsoon. I have generated the following ecologically important models for examining habitat preference of Kondana Soft-furred Rat.

	Model
1	POB
2	PHR
3	PGR
4	PCA
5	WSD
6	PHD
7	POB+ WSD
8	POB+ PHD
9	PHR+ PGR
10	PHR+ WSD
11	PGR+ WSD
12	PGR+ PHD
13	PRO + PSO†
14	POB+ WSD+ PHD
15	PHR+ PGR+ WSD
16	PHR+ PGR+ PHD
17	PHR+ PGR+ PCA
18	PRO + PSO + WSD
19	PRO + PSO + PHD
20	PHR+ PGR+ WSD+ PHD
21	PRO + PSO + WSD+ PHD
22	INTERCEPT

† - Soil and rock were provided redundant piece of information (i.e. openness of habitat), therefore when they both were present included together (not treated separately) otherwise the one of them which was present included in the modelling.

Note - There was difference in a number of models and combination of variables for difference seasons and sites due to removal of highly redundant variable and above mentioned reason.

Percentage of herb cover (PHR), Percentage of grass cover (PGR), Percentage of rock cover (PRO), Percentage of soil cover (PSO), Percentage of dry matter cover (PDM), Percentage of canopy cover (PCA), Percentage of obscurity (POB), Woody Stem Density (WSD) and Perennial herb density (PHD).

3. 4. 4 Occupancy estimation

Modelling 'presence-absence' data with binomial regressions had been old practice in ecology, however until recently not much thoughts are given on the imperfect detection of species i. e. a species may not be detected always though it occurs at sampling unit (MacKenzie & Kendall 2002). It also means that detection probability is generally less than one ($p < 1$). And false absence of species could lead to misleading conclusion about occurrence and distribution of the species. Detection probability issue is addressed through repetitive surveys of sampling units. The surveys may be spatially or temporally replicated in single or multiple visits at each sampling unit. These multiple surveys with detection/non-detection data are providing necessary information for differentiating true absence from false absence (MacKenzie *et al.* 2006).

Program PRESENCE (Hines 2006, version 6.9) was used for occupancy modelling. I have transformed abundance data of *M. kondana* trapped in 50 sampling grids into binary data (1=presence, 0=absence). Detection histories were generated based on three night trapping i.e. three occasions. Only the most important and ecologically meaningful microhabitat variables obtained through habitat selection analysis (section 3.4.3) were included as site level covariate in occupancy modelling. Trap happy and trap shy rats may violate the assumption of independence of detection histories i.e. detection/non-detection of rats on succeeding occasion depend on preceding occasion. To address this issue, survey specific covariate was created with coding the trap happy and trap shy rats and incorporate it in occupancy estimation. PRESENCE fit the multiple models, equivalent to multiple hypotheses, to the data with maximum likelihood technique and ranked according to Akaike's Information Criterion (MacKenzie *et al.* 2006). Best fitted models are appeared at top while least supported one are relatively at bottom. Occupancy modelling was carried out for three sites - Sinhgad, Rajgad and Torna Fort and for three seasons - winter, summer and post-monsoon.

3. 4. 5 Population estimation

Population estimations are very crucial in wildlife conservation studies, government bodied routinely asked for it from researchers and wildlife managers for making polices or wildlife management practices. These estimates can also be used to asses impact of threats, monitor the consequences of the management practices and emphasized on knowledge gaps for future research (Lettink & Armstrong 2003). Though the theories of population estimation had developed long back, actual boost in utilization of various population estimation models started after creation of user friendly program MARK (White and Burnham 1999).

Population estimation was main objective of this study and trapping session was also very short; therefore, I used closed population estimation models (Otis *et al.* 1978, White *et al.* 1982) in MARK. Huggins (1989, 1991) and Alho (1990) estimator of N based on conditional likelihood is used for estimations. MARK works on theory based on log likelihood function to estimate the parameter value, its standard error, and profile likelihood confidence intervals. One of the assumptions of closed population estimation models is all individual have equal capture probability; however, which is not true and capture probability varies with age, sex, individual behavioural attributes etc. And repetitive capture of same individuals could lead to under estimation of the population, this issue can address with including individual heterogeneity in population estimation models (Norris & Pollock 1996, Pledger 2000). Hence, head and body length of individual (measure of heterogeneity in capture probability) of *M. kondana* was included as a covariate in individual heterogeneity models to minimize bias in population estimations. Three capture and two recapture sessions per site per season data available for *M. kondana* was used for population estimation at Sinhgad, Rajgad and Torna Fort. The global model fitted to the data was checked for goodness of fit using median c-hat approach and over dispersed models (median c-hat >3) were adjusted for c-hat value. Subsequently, simplified and ecologically meaningful models were generated from global model. I used model averaging approach for estimation of population size of *M. kondana,* considering the advantages, especially its robustness, discussed by Burnham *et al.* (2010) and Symonds & Moussalli (2011).

4. RESULTS

4.1 MORPHOLOGY AND NATURAL HISTORY

Morphometric analysis revealed the great variations in size, pelage and weights of *M. kondana.* The data pooled from all the sites showed large variations in head and body length (HB), ranged from 103 - 207 mm (Fig. 4.1. 1, n=205) and in weighted, ranged from 28 to 218 gm (n = 238). The mean weight of females were higher than males - Sinhagd (M - 144 gm , F-155gm, n= 83, 52), Torna Fort (M-135 gm, F-149 gm, n= 26, 8) and Rajgad (M-145 gm, F-156 gm, n= 32,4). Individuals were broadly categorized in two age groups base on HB, weight and examining reproductive organs, Adults (breeding males and females)- they had HB > 150mm and weight >100gm; and sub-adult or juveniles (non breeding males and females) - they had HB < 150mm and weight <100gm. The second category was heterogeneous and not finely resolved and it had different sub-groups with consistent variations. All the individuals of *M. kondana* trapped during this study had six planter pads, a key character differentiate it from other sister species.

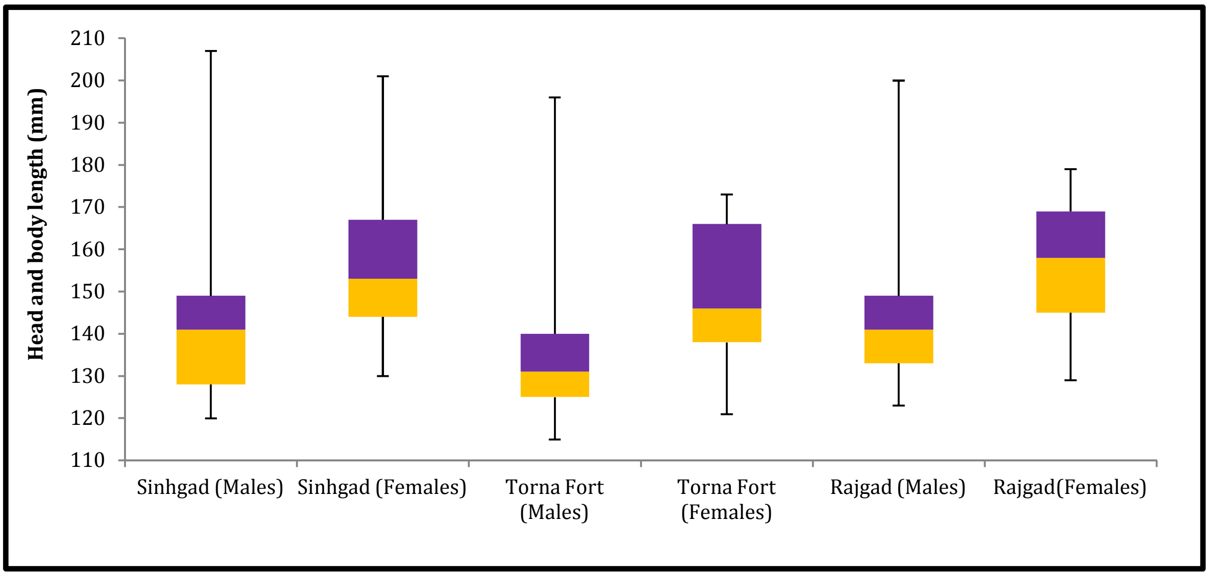
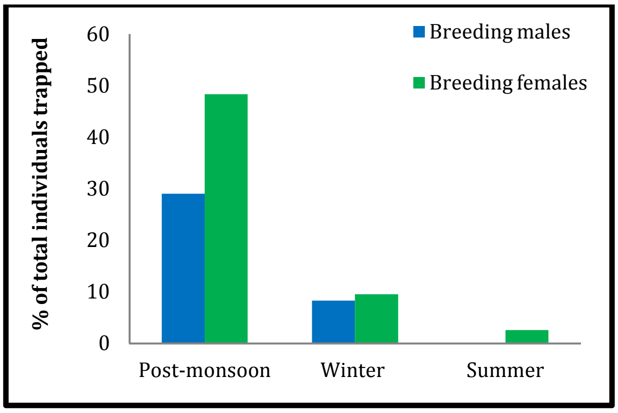


Fig. 4.1. 1 Box plot of variations in head and body lengths (HB) of males and females trapped in Sinhgad (n=135), Torna Fort (n=34) and Rajgad (n=36).

The juvenile were thinly haired; greyish on dorsal side with light greyish on ventral side. Sub-adults or non-breeding males were found in two pelage forms - grey form and brown form, but it was not clear whether they were actual forms or different growth stages. Grey form had greyish on dorsal (hairs with greyish tip and black base) and greyish white on ventral (hair with white tip and grey base), the brown form had brown to greyish brown (hairs with brown and grey or brown tip and black base) on dorsal and greyish white on ventral. Both the forms had soft and lustrous pelage. Though adults also greyish brown on dorsal and greyish white on ventral, their pelage was dull in colour and comparatively harsh.

A general temporal pattern of fluctuation in composition of breeding males and females in population of the species was observed at all three sites. About half of the population in post-monsoon composed of breeding males and females which reduces to less than quarter in winter and almost negligible in summer (Fig. 4.1. 2). This pattern was coincide with temporal variations in weight of the rats which was highest in post-monsoon and decreased very rapidly towards summer, roughly 30-60% loss in weight (Fig. 4.1. 3). At three occasions during post monsoon surveys, two at Sinhgad and one at Torna Fort, I observed female were given birth to young ones in the trap. In all three cases the litter size was 5-6, and I have noticed a case of cannibalistic behaviour of female - it fed on two young ones.



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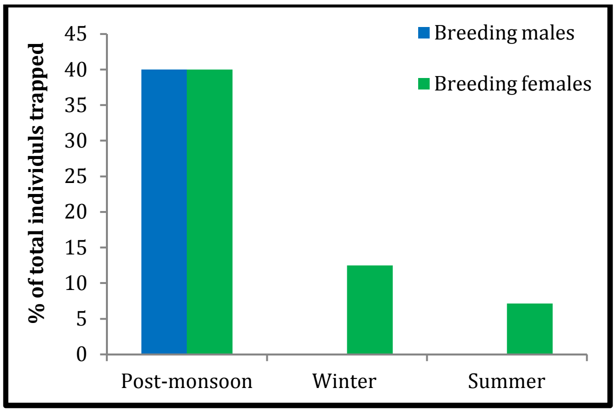

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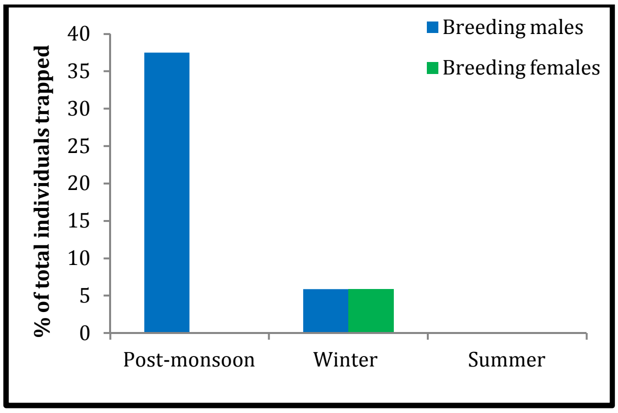


c)

Fig. 4.1. 2 Seasonal variation in proportion of breeding males and females of *M. kondana* trapped at Sinhgad (a, n = 154), Torna Fort (b, n = 43) and Rajgad (c , n = 41).

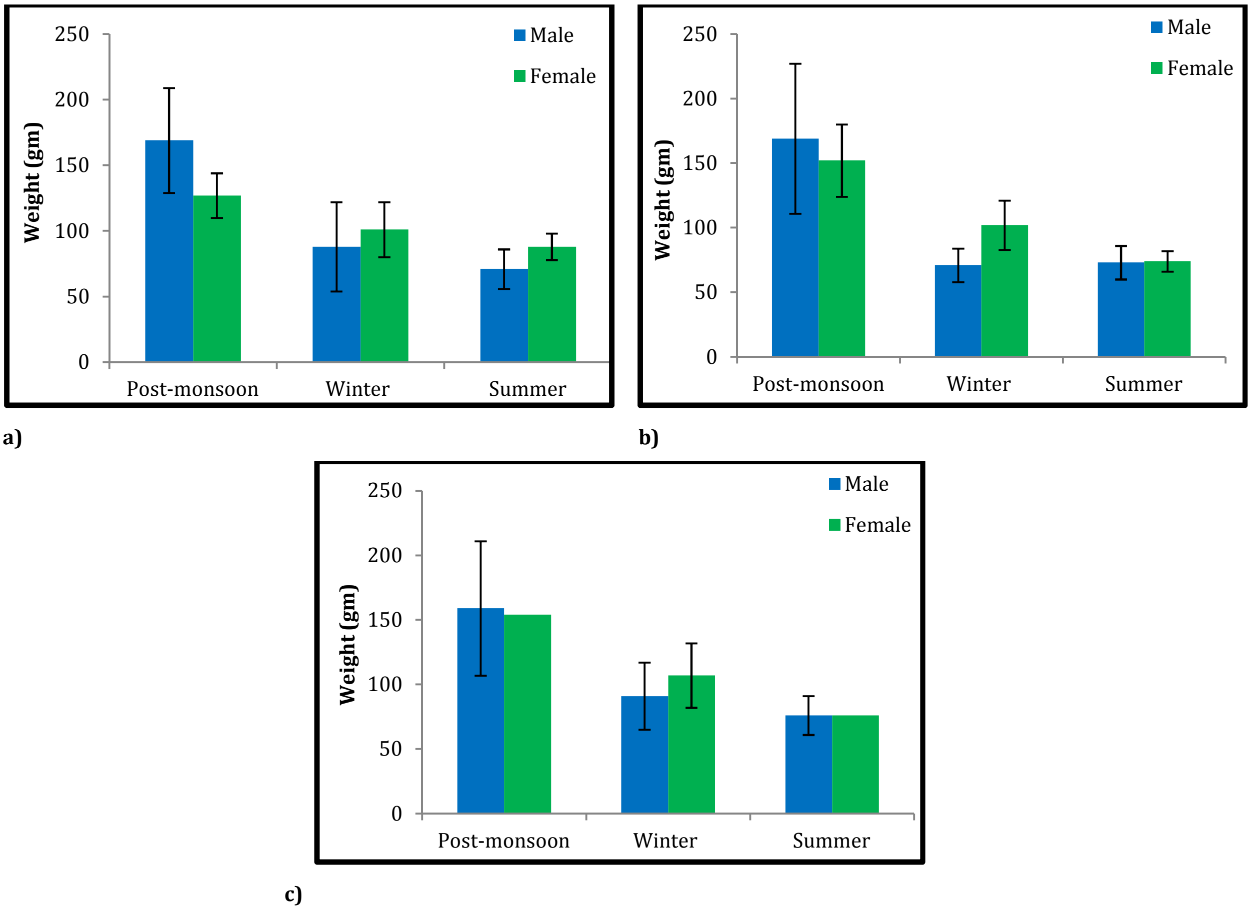


Fig. 4.1. 3 Seasonal variation in weights (mean ± SD) of males and females of *M. kondana* trapped at Sinhgad (a, n = 135), Torna Fort (b, n = 34) and Rajgad (c , n = 36).

The DNA of *M. kondana* was successfully extracted and sequenced. Preliminary results of phylogenetic analysis indicated the distinctness of *M. kondana*. However, these inferences were based on secondary DNA sequence data of *M. meltada* (from NCBI database). And though common and widely distributed it was not trapped at any of sampling sites during this study. Considering the secondary nature of DNA sequence of *M. meltada*, not sure about authenticity, and its absence/false absence from the study area, I did not drawn any firm conclusion about molecular identity of *M. kondana*.

A new population of *M. kondana* was found at Raireshwar, Pune. It was highland (~1300m ASL) located approximately 22 km (aerial distance) south of Rajgad. It had small human settlement and covered with mosaic of grassland and woody patches. I have trapped a male individual near rocky bund between grassland and agricultural field.

A Roof Rat (*Rattus rattus*) was only trapped 5 times out of 900 trap night efforts at Sinhgad and mostly captured in grids close to human habitation. Therefore it seem to be rare in grasslands surrounding human habitation at Sinhgad, in which *M. kondana* was a dominant species.

4.2 LANDSCAPE LEVEL ANALYSIS

After EDA, especially using Pearson's correlation coefficient and VIF, only four landscape variables - Topographic ruggedness index in 200m buffer (TRI_200), Percentage of grass cover in 400m buffer (Per_grs_cov_400), Percentage of agriculture cover in 400m buffer (Per_grs_cov_400) and Percentage of Forest cover in 700m buffer (Per_for_cov_700) were retained for final analysis.

Table 4.2. 1 Summary of result of four best ranked models fitted to landscape level occupancy data of Kondana Soft-furred Rat. AIC- Akaike Information criterion, w_i -weight of model, w_p-Weight of predictor/variable

	Model	AIC	w_i
1	TRI_200	17.46	0.33
2	Per_for_cov_700 + TRI_200	18.76	0.17
3	Per_grs_cov_400 + TRI_200	19.18	0.14
4	Per_agr_cov_400 + TRI_200	19.41	0.12

Table 4.2. 2 Model average results shown in order of weight of landscape level predictor variables.

	Estimate	Unconditional variance	No. of models	w_p	± (95 % CI)
Intercept	-0.238	0.060	7	1.00	0.513
TRI_200	0.018	0.000	7	1.00	0.013
Per_for_cov_700	0.068	0.023	3	0.31	0.316
Per_grs_cov_400	-0.029	0.009	3	0.27	0.199
Per_agr_cov_400	-0.015	0.011	3	0.25	0.217

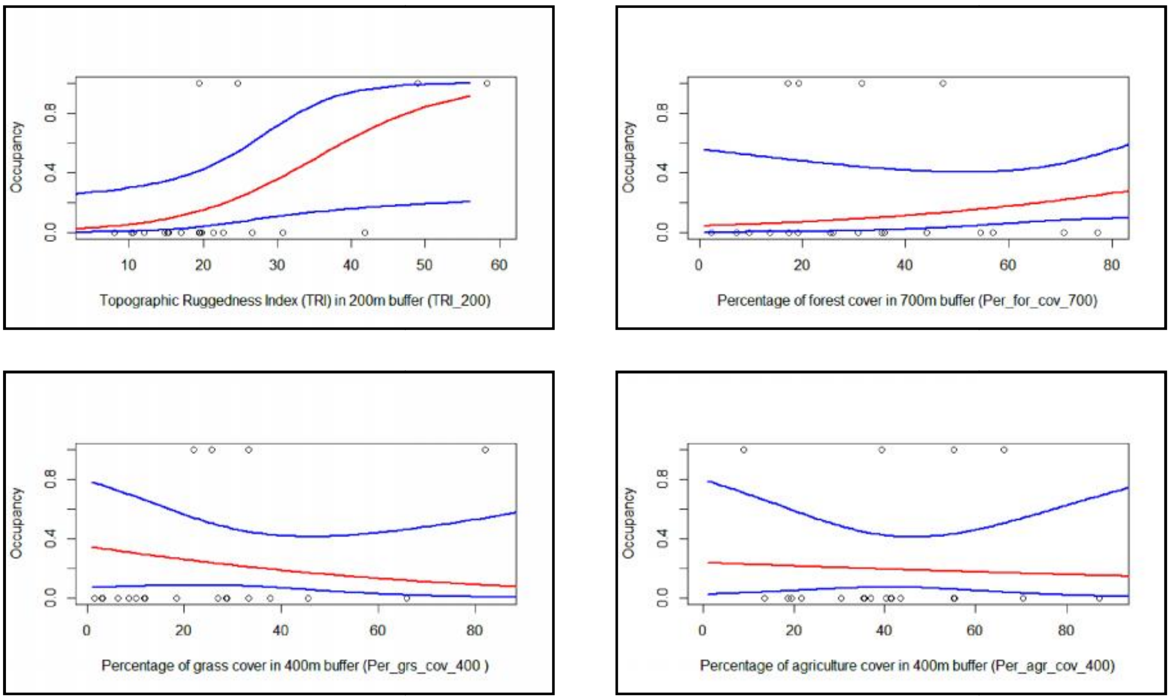


Fig. 4.2. 1. - Occupancy and 95% confidence intervals (blue lines) versus landscape level predictor variables. Occupancies and intervals were computed from simple generalized logistic regression models for each variables.

The most parsimonious model explaining landscape level occupancy of *M. kondana* was included TRI_200 (Table 4.2. 1). Importance of TRI_200 was further strengthened in model averaging, almost 100% of the evidence base supported for inclusion of TRI_200 as predictor variable for estimating landscape level occupancy of the species. However, evidence support for other predictor variables was comparatively very low - 31 % for Per_for_cov_700 and < 30 % for Per_grs_cov_400 and Per_agr_co v_400 (Table 4.2. 2).

The TRI_200 and Per_for_cov_700 have positive and Per_grs_cov_400 and Per_agr_cov_400 have negative correlation with probability of occurrence of *M. kondana* (Fig. 4.2. 1.). In TRI_200 graph there was gradual increase in occupancy until value of 20, after crossing that value there was sharp increase in probability of occupancy of the species. Similar pattern was found in Per_for_cov_700 graph, rapid increase in occupancy after > 40% of forest cover in 700m buffer. In both Per_grs_cov_400 and Per_agr_cov_400 graphs, there was rapid decline in probability of occupancy of the species for increasing value of percentage of grassland and agriculture cover in 400m buffer till 40-50 %, then it reduces gradually.

4.3 MICROHABITAT SELECTION ANALYSIS

Sinhgad (**A1**-appendix 1)

In post-monsoon analysis of habitat preference of *M . kondana,* a model with POB was selected as a best model. Though the best model, it had low certainty (w_i= 36.5%) and limited empirical support from evidence ratio, ER - 1.43 times second best model. It suggests the model was slightly better than second best model 'POB+PHD' in given set of models (Table 4.3 1a). However, top three models included POB, PHD and WSD as a predictor variables were explained presence of the species with strong certainty (Cumulative w_i=74.5%). In model average POB had obtained greater evidence support (w_p =82.4%) for elucidating habitat preference of Kondana Soft-furred Rat and then it was followed by PHD and WSD (Table 4.3 1b). All these three predictor variable had positive correlation with presence of the species; on the contrary, PSO,PRO,PGR had negative correlation with relatively low support (w_p <15%).

In winter data analysis, PHD was best model describing habitat preference of *M . kondana*. However, it had low evidence support (w_i= 17.8%, ER=1.14 times second best models) (Table 4.3 1c). Collectively top four models also performed moderately in predicting the presence of the species, they had cumulatively model probability of 56.2%. Model averaging findings could be more reliable in this situation. PHD had highest evidence support (w_p =63.1%) followed by POB, PGR and WSD, w_p ranged between 23 - 34% (Table 4.3 1d). Except, PGR other three predictor variable were directly influenced presence of the species; However, PSO, PRO, PCA with their negligible support (w_p < 1%) had inverse relationship, excluding PCA.

In summer data analysis, first two models were competitive with low model probabilities 19.6% and 18.2% respectively (Table 4.3 1e). All remaining models had evidence support < 1%. In model averaging, PHD strongly explained habitat preference of *M. kondana* (w_p =64.3%) along with PGR (w_p =37.3%). The low empirical support, w_p ranged between 12-20%, suggested poor performance of WSD, PHR, POB, PSO and poorest of PCA (w_p <1%) in these predictive set of models (Table 4.3 1f). Except PGR, all variables were positively correlated with presence of the species.

In brief, at Sinhgad *M. kondana* was showed temporal variation in habitat preference. The evidence support for POB in explaining habitat selection of the species was decline from post-monsoon to winter and was negligible in summer. This declining trend in POB was contrasted with increasing evidence support for perennial herb density (PHD), which was highest at summer. Percentage grass cover (PGR) gained its importance form winter and peaks at summer, however woody stem density (WSD) was most constant and less important variable in all seasons.

Torna fort (A2)

Despite of selected as a best model ,PHD+WSD, for describing habitat preference of the Kondana Soft-furred Rat in post-monsoon, it had low evidence support (w_i= 19.0%, ER=1.16 times second best models) (Table 4.3 2a). Cumulative evidence support of top four models, those have relatively high AICc weights, was also moderate 57.6%. PHR was most important predictor variable after model averaging , with 70% evidence supported for inclusion of the variable in models would be resulted in successful prediction of presence of the species. Including of other predictor variables such as PGR, WSD, PHD had low (w_p =32-37%) and PRO and POB had lowest (w_p < 1%) support in the prediction models (Table 4.3 2b). PGR, WSD and POB were inversely related with occurrence of the species.

In winter data analysis, top model 'POB' had moderate model probabilities 45 %, but low evidence ratio support i.e. 1.58 times second best model (Table 4.3 2c). Top five models had 98% evidence support. In model averaging, POB alone very strongly explained habitat preference of *M. kondana* (w_p =94.6%), followed by PHD and WSD (Table 4.3 2d). The lower empirical support suggested poor performance of PHR, PCA, PGR, PRO (w_p <1%) in these predictive set of models. Except PHR and PRO, all variables were positively correlated with presence of the species.

Except top models, the second one was not ecologically meaningful/interesting, with low evidence support (w_p =22.2%) remaining models had lowest model probabilities <1% in summer data analysis (Table 4.3 2e). Although relative better within summer dataset, POB had low evidence support for elucidating habitat preference of Kondana Soft-furred Rat and then it was followed by PGR, WSD, PHD, PHR, PRO and PCA (Table 4.3 2f). Variables such as POB, WSD and PHR had inversely related with presence of the species.

In short, at Torna Fort PHR had strong evidence support for it was most preferred microhabitat variable by *M. kondana* in post monsoon. PGR had almost equal order of evidence support with contrasting effect, influence the species negatively in post-monsoon and positively in summer. Similarly, POB topmost predictor of the microhabitat selection of the species in winter (+ve correlation) and summer (-ve correlation). On the contrary PHD, had relatively weak and strong predictive support in post-monsoon and winter respectively. WSD had comparable model probabilities in all seasons with weak pattern of influence on the species.

Rajgad (A3)

In post-monsoon data analysis, top model' POB+WSD' had low model probability 26%, and low evidence ratio support i.e. 1.49 times better than second best model (Table 4.3 3a). Top five models had 64.5% evidence support. In model averaging, WSD strongly (w_p =68.8%) and POS moderately (w_p =55.5%) explained habitat preference of *M. kondana* (Table 4.3 3b). The low empirical support suggested poor (PHD, PHR) and poorest (PRO, PSO) performance of the variable in these predictive set of models. WSD, PRO and PSO were negatively correlated with presence of the species.

Best model 'POB +WSD' for elucidating habitat preference of Kondana Soft-furred Rat in winter had moderate model probabilities and low evidence support (w_i= 52 %, ER=1.83 with respect to second best models) (Table 4.3 3c). Cumulative model probability of top four models was also strongest 99.7%. POB and WSD were strongest predictor variables after model averaging, with 99.7 % and 80.5% evidence supported for inclusion of these variable in models can be resulted into successful prediction of occurrence of the species. On the contrary, PHD, PRO, PSO and PHR had highest uncertainty (w_p < 1%) in the prediction models (Table 4.3 3d). WSD and PSO were inversely related with presence of the species.

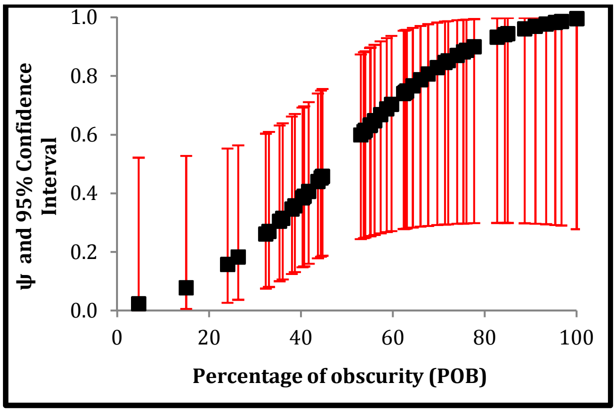
In summer data analysis, top model 'PRO' had low model probabilities 28.8 % and low evidence ratio support i.e. 1.89 with reference to second best model (Table 4.3 3e). Top four models had 65.7 % model probabilities for predicting habitat preference of *M. kondana*. Model averaging revealed that , PRO had strong (w_p =60.2%) and WSD, PHD and POB had low (w_p = 19-30%) performance in this model set (Table 4.3 3f). Except WSD and POB, all variables were negatively correlated with presence of the species

In brief, At Rajgad WSD had strong evidence support with negative correlation in post monsoon and summer and comparatively low positive correlation in summer for predicting habitat selection of Kondana Soft-furred Rat. POB had moderate, strong and low model probabilities in consecutive seasons. However, PHD had relatively comparable evidence support with positive correlation, except summer (-ve correlation). Percentage of rock cover (PRO) appeared as strong predictor variable in summer.

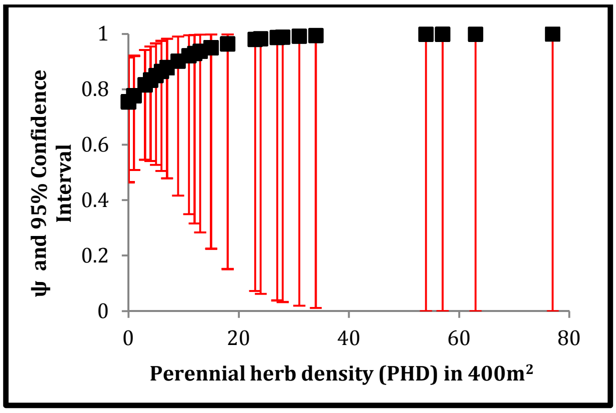
4.4 OCCUPANCY ESTIMATION

Sinhgad (A4)

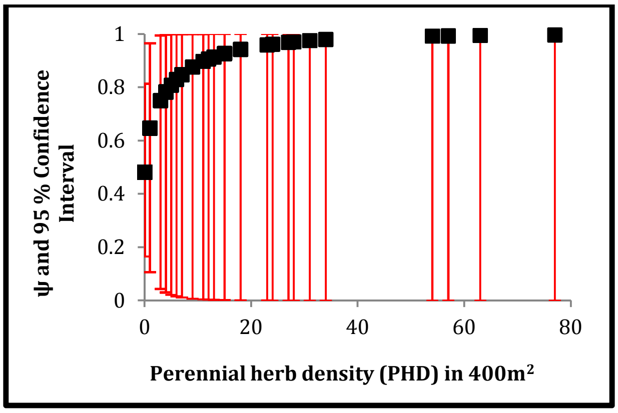
Total trapping efforts were 900 trap nights (300/season) at Sinhgad. Most of the top ranked occupancy models (ΔQAIC >3) had constant detection probability across trapping occasions (trap nights) and the individuals ('trap shy' and 'trap happy') of *M. kondana* (Table 4.4 1a).



a)



b)



c)

Fig. 4.4. 1 - Occupancy estimation (ψ) and 95% confidence interval (red lines) versus predictor variable from best and simple occupancy models for Kondana Soft-furred Rat Sinhgad data (a- post-monsoon, b-winter, c-summer).

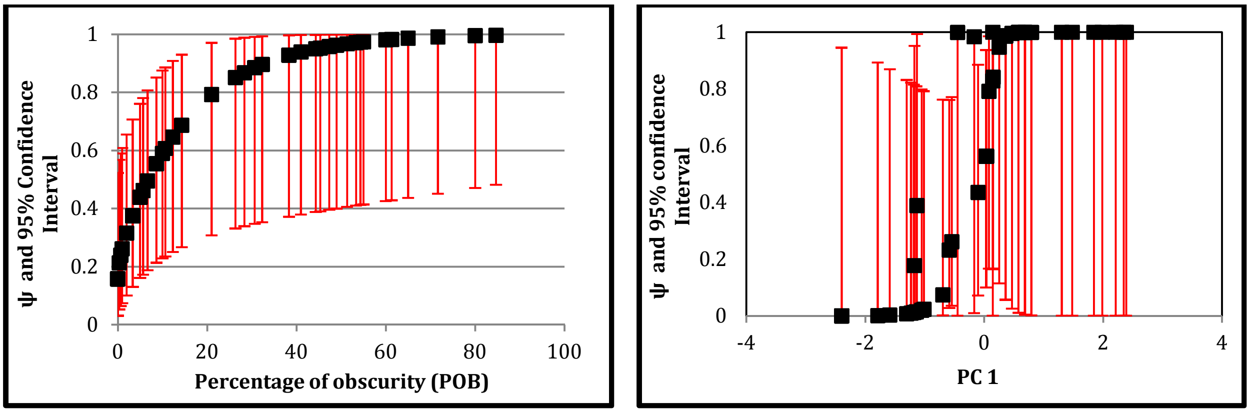
In post-monsoon top models, POB and PHD explained occupancy of the species, however models had low evidence support ($w_{i} = 9 - 40\%$) (Table 4.4 1a). In topmost model plot of ψ vs POB showed that initially occupancy of Kondana Soft-furred increased gradually and after crossing value of 60% (POB) it risen very sharply (Fig. 4.4 1a). Occupancy estimated using this model was ranged between 0.02 - 0.99. Both covariates had positive correlation with occupancy of the species.

In addition to POB and PHD, WSD was included in topmost models elucidating occupancy of *M. kondana* using survey and site specifics covariates for winter data and they had low to lowest model probabilities ($w_{i} = 3 - 13\%$) (Table 4.4 1b). I used second model for graphical representation of ψ against PHD due to its simplicity and also equally competitive with topmost model. The graph revealed that occupancy increase above 0.90 after density of ~20 perennial herbs in 400m^2, though the uncertainty in results was very high i.e. large 95 % CI (Fig. 4.4 1b). Occupancy estimated using this model ranged between 0.75 - 1.00. All the covariates had positive correlation with occupancy of the species.

In summer data top three models, with covariates PHD and PGR, collectively had 72 % of evidence support (Table 4.4 1c). Graph of ψ vs. PHD showed similar pattern described above, however occupancy estimates were ranged 0.48 - 0.99 with very large 95 % CI (Fig. 4.4 1c). The predictive covariates had contrasting effects, PHD had direct whereas PGR had inverse relationship with occupancy of the species.

Torna Fort (A5)

At Torna Fort total trapping efforts were 450 trap nights (150/season). Due to very low trapping success (naive occupancy = 10%) occupancy was not estimation for post-monsoon.



a) **b)**

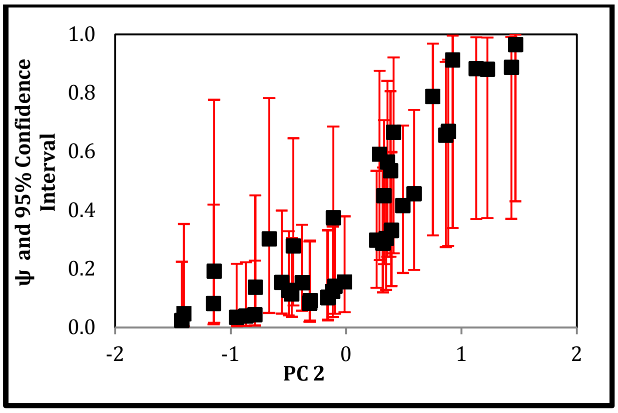
Fig. 4.4 2- Occupancy estimation (ψ) and 95% confidence interval (red lines) versus predictor variable from best and simple occupancy models for Kondana Soft-furred Rat Torna Fort data (a- winter, b -summer).

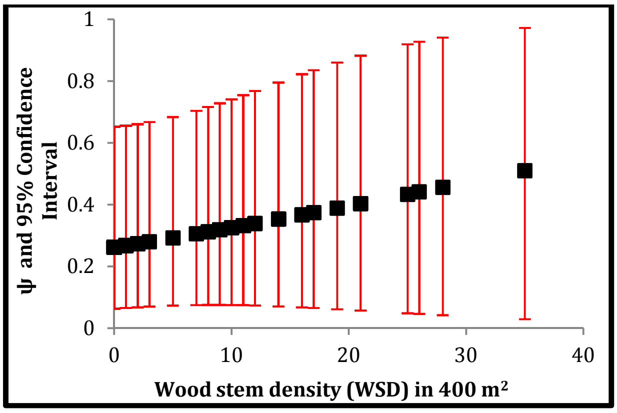
Top ranked model for occupancy estimation of Kondana Soft-furred Rat for winter data included the detection variability due to trapping occasions and trap response of the species. The evidence support for the top ranked models was low to lowest (w_{i} = 1 - 26%) (Table 4.4 2a). Plot of ψ vs POB, based on topmost model, showed gradual increase in occupancy with POB and after crossing value of 50 % almost all sampling units were occupied (Fig. 4.4 2a). Occupancy estimated with this model ranged between 0.15 - 0.99. POB and PHR had inverse and WSD had direct correlation with occupancy of the species.

In summer data top two models, with covariates POB and PGR, had 54 % of evidence support (Table 4.4 2b). Trap response (TR) of the individuals was removed from the models because of huge error in estimates, might be data was not adequate to fit TR models. Principle components were extracted from POB and PGR, PC1 accounts for 78 % of variations and negatively correlated with PGR. Graph of ψ against PC1 showed that occupancy was increasing with rising POB and decreasing with increasing PGR, however estimated had very large 95 % CI (Fig. 4.4 2b). Occupancy estimates were ranged between 0.0001 - 1.0.

Rajgad (A6)

Total trapping efforts were 450 trap nights (150/season) at Rajgad. Due to very low trapping success (naive occupancy = 10%) occupancy was not estimation for post-monsoon.





a) **b)**

Fig. 4.4 3- Occupancy estimation (ψ) and 95% confidence interval (red lines) versus predictor variable from best and simple occupancy models for Kondana Soft-furred Rat Rajgad data (a- winter, b -summer).

Except a model with detection variability in trapping occasion, all other models included models with constant detection probability. TR was dropped from analysis due to large error in estimates. First three models had model probability of 53% and along with remaining models they included POB, PHD and WSD as predictor covariates for occupancy estimation of *M. kondana* (Table 4.4 3a). I used second model to show the contrasting relationship between POB and WSD in occupancy model. Though PC 2 only explained 25% of variations in POB and WSD, it had positive correlation with POB and negative correlation with WSD, hence I used it for showing this relationship. The plot of ψ vs. PC2 showed that occupancy ascend steeply with increasing POB and dropped rapidly with increasing WSD (Fig. 4.4. 3a). Occupancy estimated with this model was ranged between 0.02 - 0.96.

In summer data, top ranked models for occupancy estimation of Kondana Soft-furred Rat included constant detection probability models. The model probabilities for the top ranked models were low to lowest (w_{i} = 0.3 - 17%) (Table 4.4 3b). Graph of ψ vs WSD, showed gradual and smooth increase in occupancy with WSD (Fig. 4.4. 3a). Occupancy estimated based on this model ranged between 0.21 - 0.51. POR and PHD had inverse and WSD had direct relationship with occupancy of the species.

4.5 POPULATION ESTIMATION

Sinhgad (A7)

In over all model selection process simplest models (Mo, Mb, and Mt) were chosen 60 % of times, followed by time variation and heterogeneity model (Mth) 20% of times and remaining models were selected < 7% of times.

In post-monsoon, 29 individuals of *M. kondana* were uniquely marked, trapped in 50 grids (each grid had 400m² of area, total area sampled ~ 2 ha) during 300 trap nights. Top most models (ΔAIC >3) had 89% of evidence support, they included null models, behavioural effect and heterogeneity models (Table 4.5. 1a). I used model averaging for estimation of population of the species, which resulted into weighted average of 54.97 (SE = 104.72) and 95 % of CI 1-260 individuals in 2 ha (Table 4.5. 1b). First two individuals heterogeneity models incorporated variations in recapture probabilities and had model probabilities of 67% (Table 4.5. 1c). Individual heterogeneity model population estimates, weighted average of 43.42 (SE = 9.31) and 95 % of CI 25.17- 61.67 individuals in 2 ha (Table 4.5. 1d), were less than closed population model estimates (Fig 4.5 1).

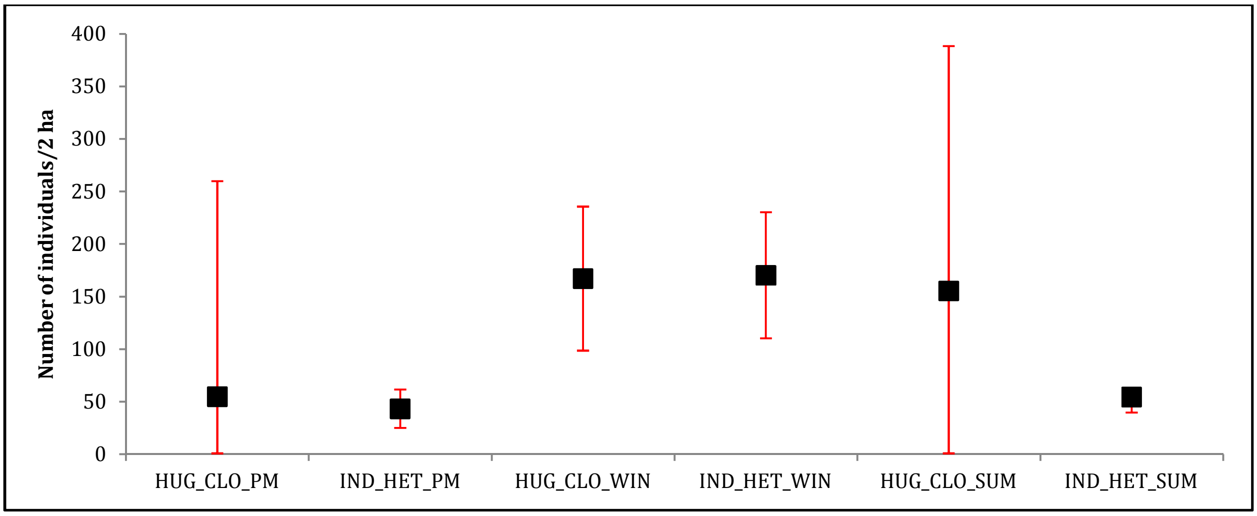


Fig 4.5 1 Population estimates based on Huggins' closed population model and individual heterogeneity model for Kondana Soft-furred Rat at Sinhgad (■-weighted average mean, red lines - 95% confidence interval, HUG- Huggins' closed population model, HET- individual heterogeneity model, PM-post-monsoon, WIN-winter, SUM- summer).

Total 81 individuals of Kondana Soft-furred Rat were uniquely marked in winter season. Null model was selected as top most model with evidence support of 80%. It followed by low model probability (w_i = 12%) heterogeneity model (Table 4.5. 1e). Model average estimate was 167.26 (SE=34.96) with 95% CI 98.74 - 235.78 individuals in 2ha (Table 4.5.

1f). In individuals heterogeneity models, topmost models had almost constant parameters except a model with variations in recapture probabilities, they had model certainty of 87% (Table 4.5. 1g). Population estimates based on individuals heterogeneity models, weighted average of 170.42 (SE = 30.64) and 95 % of CI 110.38 - 230.47 individuals in 2 ha (Table 4.5. 1h), were consistent with closed population model estimates (Fig 4.5 1).

In summer trapping, 39 individuals of *M. kondana* were uniquely marked. Model with heterogeneity in capture and recapture probabilities was selected as top model with moderate evidence support 48.5 %. Next two models, time variation and heterogeneity model and null model were equally competitive to topmost model (Table 4.5. 1i). Model averaging estimations resulted into weighted average of 155.56 (SE = 118.84) and 95 % of CI 1- 388.49 individuals in 2 ha (Table 4.5. 1j). Topmost individuals heterogeneity models including variations in recapture probabilities and had model probabilities of 57% (Table 4.5. 1k). The model average population estimated based on these heterogeneity model models, weighted average of 54.56 (SE = 7.51) and 95 % of CI 39.34 - 69.28 individuals in 2 ha (Table 4.5. 1l), seems more realistic than closed population model estimates (Fig 4.5 1).

Torna Fort (A8)

In total 22 individuals, in 150 trap nights, of Kondana Soft-furred Rat were uniquely marked in winter season at Torna Fort. Top most models with collective model probability of 75% included behavioural effect, time variation and heterogeneity in capture and recapture probabilities of the rats (Table 4.5. 2a). Model average estimate were weighted average 52.48 (SE=27.99) with 95% CI 1 - 107.35 individuals in 2ha (Table 4.5. 2b). In individuals heterogeneity models, topmost models had variation in capture and recapture probabilities (Table 4.5. 2c). Population estimates based on the model average, weighted average of 26.67 (SE = 4.14) and 95 % of CI 18.56-34.78 individuals in 2 ha (Table 4.5. 2d), were lower than closed population model estimates (Fig 4.5 2).

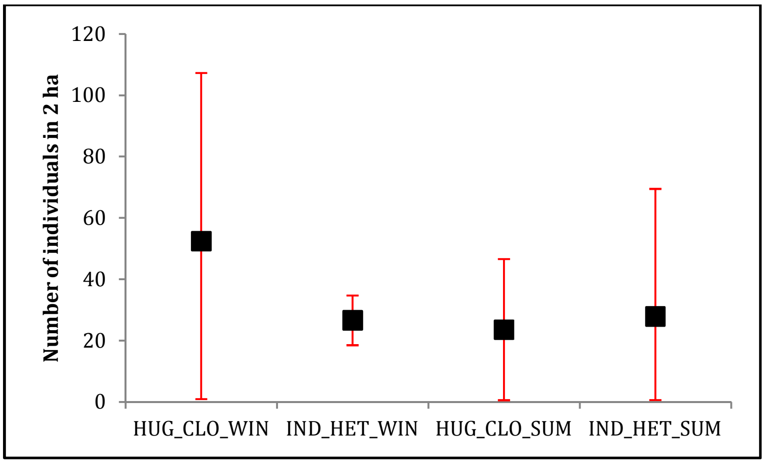


Fig 4.5 2 Population estimates based on Huggins' closed population model and individual heterogeneity model for Kondana Soft-furred Rat at Torna Fort (■-weighted average mean, red lines - 95% confidence interval, HUG- Huggins' closed population model, HET- individual heterogeneity model, PM-post-monsoon, WIN-winter, SUM- summer).

In summer trapping, 14 individuals of *M. kondana* were uniquely marked. Topmost models had 92.4 % of evidence support, they included null models, behavioural effect and heterogeneity models (Table 4.5. 2e). I used model averaging for estimation of population of the species, which resulted into weighted average of 23.62 (SE = 11.74) and 95 % of CI 0.62 - 46.62 individuals in 2 ha (Table 4.5. 2f). Top individuals heterogeneity models selected had constant capture and recapture probabilities with evidence support of 81% (Table 4.5. 2g). The population estimates, weighted average of 27.94 (SE = 21.22) and 95 % of CI 0.69 - 61.52 individuals in 2 ha (Table 4.5. 2h), were comparable with closed population model estimates (Fig 4.5 2).

Rajgad (A9)

In summer trapping, 16 individuals of *M. kondana* were uniquely marked, in 150 trap nights, at Rajgad. First two models with 64.9 % of evidence support were equally competitive, they included null and behavioural effect (Table 4.5. 3a). I used model averaging for estimation of population of the species, which resulted into weighted average of 18.26 (SE = 5.24) and 95 % of CI 7.99-28.53 individuals in 2 ha (Table 4.5. 3b). Top two individuals heterogeneity models incorporated variations in recapture probabilities and had model probabilities of 67% (Table 4.5. 3c). The population estimates, weighted average of 21.84 (SE = 5.96) and 95 % of CI 10.16- 33.52 individuals in 2 ha (Table 4.5. 3d), were comparable with those of closed population model estimates (Fig 4.5 3).

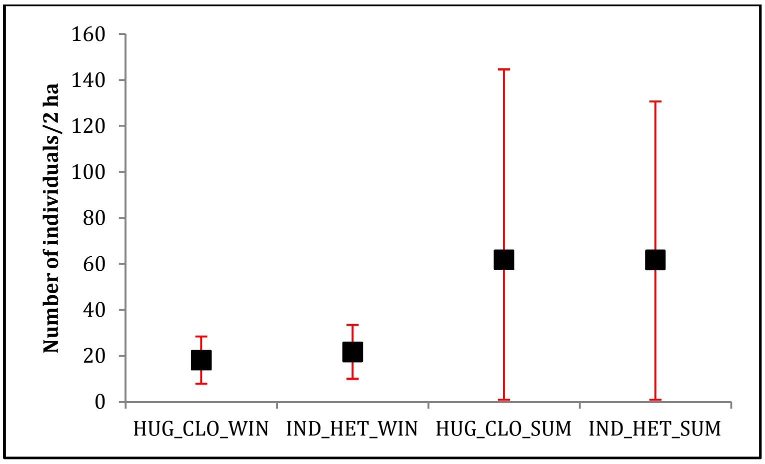


Fig 4.5 3 Population estimates based on Huggins' closed population model and individual heterogeneity model for Kondana Soft-furred Rat at Rajgad (■-weighted average mean, red lines - 95% confidence interval, HUG- Huggins' closed population model, HET- individual heterogeneity model, PM-post-monsoon, WIN-winter, SUM- summer).

Total 17 individuals of Kondana Soft-furred Rat were uniquely marked in summer season. Null model selected as top most model with evidence support of 70%. It followed by low model probability (w_i = 24%) heterogeneity model (Table 4.5 3e). Model average estimate was 61.91 (SE=42.24) with 95% CI 1 - 144.70 individuals in 2ha (Table 4.5. 3f). In individuals heterogeneity models, all were topmost models with constant and also varying capture and recapture probabilities (Table 4.5. 3g). Population estimates based on these models, weighted average of 61.83 (SE = 35.16) and 95 % of CI 1- 130.74 individuals in 2 ha (Table 4.5. 3h), were consistent with closed population model estimates (Fig 4.5 3).

5. DISCUSSION

The morphological characters, especially HB, weight, pelage and number of planter pads were consistent with original description of the species provide by Mishra and Dhanda (1975). While considering wide range of variations in HB and other quantities external characters and their overlapping with *M. meltada*, I would suggest to use planter pad number (6) as key character to differentiate *M. kondana* from *M. meltada*. Besides giving support to previous investigation, mainly morphological identity of the species, this study provided more details on external morphological characters and also improved reliability of the results through its spatio-temporal scale. Heterogeneity in non breeding group - mainly the grey and brown pelage forms and various age categories, should be resolved for proper understanding of morphology and ecology of the species. This issue can be elucidated through systematic collection of the dead sample or small number of live sample to examine their anatomy in order to correlate it with external morphology of the species such as HB, weight and pelage for determine various age categories. The advance molecular techniques can also be useful in this matter.

I have found that sex ratio skewed towards male at all sites - Sinhagd (1.60:1) , Torna Fort (3.25:1) and Rajgad (8:1). The investigation showed that males are more active and range over a greater area than females, which would increase probability of male biased catch (Tanton 1965, Wood 1971, Prakash 1977, Braun 1985). In contrast, alternative hypothesis suggested the females are dispersing and subjected to higher mortality rather than the males (Shanker & Sukumar 1998). Braun (1985) suggested that skewed sex ratio would be due to less activeness of female, seasonal variation in trapability, trapping methods and differential rates of mortality or dispersal. It is necessary to examine the movement pattern of males and females of *M. kondana* and also estimate the mortality rates using population models to test above hypotheses. Because studies demonstrated sex ratio influence population structure and dynamics (Gaines & McClenaghan 1980) which would have direct implication in conservation and management of population of the species.

The prevalence of breeding males and females of Kondana Soft-furred Rat in post-monsoon (October -November) season was not an unusual event because it was known phenomenon that most of animals in topical monsoon regions depend on monsoon for their breeding. The rats gained weight in post-monsoon, mainly of females, indicated increase in fats deposition in the body which was crucial for pregnancy and post-natal nourishment of the young ones. And occurrence of litter of the species in post- monsoon was further supported breeding season of the species. Chandrahas and Krishnaswami (1974) discussed in detail the breeding ecology of the Soft-furred Field Rat, *Millardia melatda,* sister species of *M. kondana*, in south India. They also mentioned the peak breeding season of *M. melatda* in October to January in synchronisation with crop harvesting season, however they noted the low breeding in February and March which was not observed in this investigation. This may be due to difference in species specific life history traits, geographic variations, habitats, trapping efforts and methods.

It would not be surprising that the topographic ruggedness index in 200m buffer (TRI_200) was a strongest predictor variable for the landscape level distribution of *M. kondana*. At least in three cases - Central Rock Rat *Zyzomys pedunculatus* in Australia (McDonald *et al*. 2013), Allegheny Wood Rat *Neotoma magister* in USA (Balcom & Yahner 1996) and Large Rock-rat *Cremnomys elvira* in India (Molur *et al.* 2005), rocky terrain is determine presence of these species. And all known sites of occurrence of *M. kondana* were situated in most rugged an rocky localities in the northern Western Ghat. However, ruggedness index computed in 200, 400 and 600 m buffer were highly significantly correlated ($t = 11.42$ & 13.24, $df=19$, $p>0.0001$) and therefore spatial importance of particular or all three variables on occupancy of the species was unclear. On the other hand, percentage of forest cover in 700m (Per_for_cov_700) buffer was selected as second most important predictor variable. It can be interesting phenomenon of variation in landscape level habitat preference of the species at different spatial scale. But weak positive response of the species towards forest cover at larger spatial scale was intriguing because it generally avoid forested areas. Although forest cover was not positively associated with the species directly, it might be plausible that forest cover indirectly through regulating or maintaining the other factors determined presence of the species.

In contrast to TRI and forest cover, percentage of grassland and agriculture cover in 400m buffer (Per_grs_cov_400, Per_agr_cov_400) had negative correlation with occupancy of the *M. kondana*. It is one of the well known facts that mainly habitat specialist species declined rapidly with human disturbance such as expansion of the agricultural fields and exploitation of grassland. It may be alarming that agricultural activates in such short distance (400m) will be negatively influence the occupancy of the species. Balcom & Yahner (1996) discussed impact of growing percentage of agricultural cover on local extermination of the *N. magister*, rock dwelling habitat specialist species, by increase in population of habitat generalist competitors such as commensal rats and wide ranging predator like owls. In addition to this, Prakash & Singh (2001) also reported a case in Rajasthan, India - Cutch Rock Rat *Cremnomys cutchicus* is outcompeted from its natural habitat by Roof Rat *Rattus rattus*, widespread and commensal species, due to spreading of agricultural fields. Though Kondana Soft-furred Rat prefer open habitat, it was unclear why occupancy decline with increasing percentage of grassland cover. It appears to be associated with loss of quality of the grassland habitat. Most of the grasslands I have sampled were completely open and almost lost their perennial herb, shrub and tree cover, which can otherwise provide good obscurity, due to intensive grazing, wood cutting and fire (Per. Observation). In microhabitat preference analysis also it was found that species avoid completely open habitat and need minimum amount of obscurity.

Area with RTI (>20) and Per_for_cov_700 (>40%) would seems to be the highly potential for occurrence of Kondana Soft-furred Rat. The known sites of presence the species and strongest evidence support for RTI in landscape level occupancy models indicated habitat specialist nature of the species. And at the same time also suggested the vulnerability of the species to habitat loss, which is evidenced in three threatened species of rats and they all are associated rocky habitat (McDonald *et al*. 2013, Balcom & Yahner 1996, Molur *et al.* 2005). I would suggest landscape level occupancy results should be used with caution due to small sample size (n=21 units, 4 unoccupied and 17 uncoupled units), however their importance in designing further systematic study was undoubtable. I recommend more extensive landscape level sampling design with spatial and temporal replicates of the various combination of land covers and ruggedness indices, which would provide deeper insight into factors influencing distribution and occupancy of the species at landscape level.

The pattern of habitat preference of *M. kondana* was coincide with seasonal dynamics of the herbaceous communities on the rocky outcrops (Watve 2013). In post-monsoon herb and grass are at peak of their productivity, food was available evenly and with abundance, and therefore it could be more likely that rats were selecting sites (here refer for grid) with high obscurity and giving less importance to PHD. Simonetti (1989) emphasized that food distribution, predation risk and vegetation structures are important factors for habitat choice for neo-tropical small mammals. As environment became more and more drier and hotter (as approaching towards summer) most of seasonal herbs and grasses were disappeared, which resulted into uneven food distribution and obscurity. And mainly obscurity confined around perennial herb patches, grasses, shrubs and trees this could be the reason for increasing importance of PHD, WSD and PGR towards summer. However, increasing evidence support for negative effect of grassy area on occupancy of the species in direction of the summer also suggested that more and more sites becoming completely open and losing their obscurity. It was further supported by increased importance of POR, which was negatively correlated with the species. These sites may not provide protection cover necessary for survival of the species and it would be appeared that the rats abandoned those open grassy areas and migrated to nearby perennial herb or woody patches with proper obscurity and food. Generally, small mammals select shrub microhabitat more frequently than the open areas between shrubs and this could be related to predator avoidance (Murúa & González 1982, Simonetti 1989, Chandrasekar-Rao & Sunquist 1996, Shenoy & Madhusudan 2006, Mohammadi 2010). The potential predator recorded at the study sites were - Domestic Cat *Felis catus*, Small Indian Civet *Viverricula indica*, Asian Palm Civet *Paradoxurus hermaphroditus*, Indian Gray Mongoose *Herpestes edwardsi,* Jungle Cat *Felis chaus* and Rusty-spotted Cat *Prionailurus rubiginosus*, owls and snakes.

I also found the spatial pattern in habitat preference of Kondana Soft-furred Rat. The predictive models suggested comparatively more importance of PHD at Sinhgad, than at Rajgad or Torna Fort. This could be due to human interference, at Sinhgad large proportion of the area was planted with *Furcraea foetida*, kind of ornamental agave, may be for aesthetic purpose. Its spiny leaves, perennial, shrubby and clusters forming nature made it excellent habitat creator for *M. kondana* with providing suitable obscurity. On the contrary, at Torna Fort and Rajgad, the other perennial herbs or woody species may be performing role of *Furcraea foetida,* and therefore PHD seems less important at these sites. WSD was relatively more importance and negative predictor at Torna Fort and Rajgad, however it was positive predictor and low evidence support at Sinhgad. This pattern might be due to difference in vegetation and murid communities at these sites. Different patterns of community structure and habitat preference among small mammal communities have been investigated in India (Shanker 2003, Chandrasekar-Rao & Sunquist 1996, Shenoy & Madhusudan 2006, Prakash & Singh 2001, Mudappa *et al*. 2001, Molur & Singh 2009). Sinhgad had deciduous and planted vegetation with less abundant forest rat such as White-tailed Wood Rat *Madromys blanfordii* and Sahyadri Rat *Rattus satarae*; on the contrary, Torna Fort and Rajgad had semi-evergreen forest with more abundant forest rat species (based on trapping data not included in this report). The negative correlation of the species with WSD at Torna Fort and Rajgad may be suggesting avoidance of woody areas to reduce the competition with forest rats. Shanker (2003) is reported similar pattern of competition exclusion, in south India, between Roof rat *R. rattus* (may be misidentified and description exactly matches with Sahyadri Rat *Rattus satarae*) found in shola forest and *M. melatada* in grasslands. Almost none to very low evidence support for PGR as predictor variable at Rajgad can also be related with vegetation distribution pattern. Sinhgad and Torna Fort had comparatively open and grassy areas, whereas Rajgad had woody and rocky areas which could be reason for spatial variations in response of the species to PGR. However, POB did not shown any distinct spatial pattern and generally strongly supported all sites, this may be indicating its critical importance for occurrence the species.

I have observed temporal trend in single season occupancy model fitted to Kondana Soft-furred Rat data at all three sites. The more parameterized and complex model were selected as best models in winter and they were replaced with less parameterized and simple models in summer. The pattern seems consistence with underlying temporal variations in habitat preference of the species found in microhabitat selection analysis and decrease in naive occupancy towards summer, ranged 30-6% difference between winter and summer. This dynamics in occupancy could also suggest changing pattern of distribution of the resources. They may be abundant and evenly distributed in winter while in summer restricted to some patches. Those patches can be distinctly discriminated using few microhabitat variable and it would appears to be supported thought selection of less parameterized and simple models in summer. There may be also possibility that no effect model simply selected because of their parsimonious nature which suggest that sample size was not sufficient to fit more complex models such as trap response and trapping occasion variation models (Shanker 2000).

In designing occupancy estimation studies spatial and temporal variation in habitat preference *M. kondana* must be considered. While looking at patterns and evidence support I suggest POB and PHD should be included as covariates at all sites and seasons. WSD was important negative predictor, mainly in forested areas, of occupancy of the species; therefore, it can be incorporated as covariate while sampling in comparatively woody areas like Torna Fort and Rajgad. All other important covariates such as PGR, PRO and PSO seems to be provide same piece of information i.e. openness of the site/sampling unit, while considering evidence support PGR can be included as indicator of openness of site and negative, generally, predictor of the species occupancy. I recommend winter as a best season for occupancy estimation due to highest naive occupancy of the species, 80 - 30% in this investigation. The occupancy estimates of winter season can be used for long term population monitoring of *M. kondana* through occupancy estimates as an population index or it combine with other population indices. Increasing trapping efforts through more sampling occasions and grids can be provide deeper insight into spatio-temporal dynamics of occupancy of Kondana Soft-furred Rat.

The population of the species had shown almost similar temporal trend at all sites, it was at peak in winter and collapse in summer. This patterns was exactly synchronise with productivity of the habitat which was highest at winter and decline towards summer. The studies conducted by Bindra & Sagar (1968), Chandrahas & Krishnaswami (1974) and Lathiya *et al*. (2003) on *M. meltada* revealed that the species mature in about three months, gestation period of 20 days and breed throughout the year; However, peak of population abundance and breeding is observed in winter followed by decline in summer. It would appears that, Although species breed in all seasons, the winter (a crop harvesting season) with its high productivity provides abundant food for survival and reproduction of the rats which may be resulted into the population peak in winter. While looking at early maturity and short gestation period of *M. meltada* it would be more likely that it has short life span, may be less than year. The shortage of food and physiological death might be driving factors for collapse in population of the species in summer. Similar pattern of population fluctuation for *M. kondana* seems more likely while considering population and habitat evidence and close relationship of *M. kondana* with *M. meltada*.

In most of cases the null or simple models were selected as best models which could be related with inadequate sample size. There were variations in population estimated with closed models with Huggins' estimator and individual heterogeneity model. Average population estimates of individual heterogeneity model were comparatively lower and with low confidence interval than that of closed model estimates. These estimates rather seems more realistic than closed model estimates while considering the number of uniquely marked individuals and knowing that ignoring individual heterogeneity in capture and recapture probabilities leads biased estimation of the population size (Norris & Pollock 1996, Pledger 2000), which appears true in this case.

Population of *M. kondana* estimated was highest at Sinhgad (44.73 rat/ha) than of Torna Fort (13.65 rats/ha) and Rajgad (20.92/ha). This could be actual pattern or mere result of double trapping efforts at Sinhgad. If the pattern was true, it might be human interference which besides negative impacts modified habitat suitable for the species. It included the plantation of the *F. foetida* and addition of the food in habitat. Sinhgad is well known tourist place and have considerable number of food stalls (about 15-20), they dump the food remains nearby and in addition to that tourist also disperse food all over the place. And increase in density of the small mammals with addition of the food has been well understood and strongly supported phenomenon (Boutin 1990, Banks & Dickman 2000, Prevedello *et al.* 2013). This food hypothesis and *F. foetida* plantation hypothesis would be worth testable with food supplementation and habitat manipulation experiments at Sinhgad and if possible incorporating spatial replicates at other sites of occurrence of the species. However, one can't overlook the role of variation in communities and abundance of murids, other competitors and predators among these sites in determining density of *M. kondana*.

In sampling design, I would suggest increase trapping efforts and maximize number of marked individuals in order to obtain higher capture and recapture probabilities which increases precision of population estimates (White & Burnham 1999). I also recommend use of large Sherman traps due to their higher trapping success for *M. kondana.* There should be more attention given towards marking methods - I used ear tags but removal rate was very high and tattooing was time consuming and marking fades gradually. Both methods seems unreliable in long term population studies. I recommend passive integrated transponder (PIT) tags, though cost was high it will be worth investing while considering reliability of the results and its durability. Winter will be good season for population estimation and monitoring of the species.

6. PUBLIC AWARENESS, CAPACITY BUILDING, POLICIES AND OUTREACH

I have conducted educational awareness programmes in two schools at each site of occurrence of *M. kondana* - Sinhgad, Torna Fort and Rajgad, in total six schools (Fig 6.1). Around 500 students from higher secondary schools were educated about the regional biodiversity and its conservation in general and Kondana Soft-furred Rat in particular. Talks on - natural history, economical and ecological importance of *M. kondana* in the ecosystem and conservation measures of the species and its habitat, were given using interactive power point presentation. Apart from the theoretical approach, the simple game was conducted for students for understanding the food wed and critical importance of its component. I collaborated with Centre for Environmental Education (CEE, Pune) for this programme and Mr. Suhas Waingankar, Educational Officer, CEE, was designed and implemented the education awareness programme. In addition to this public awareness was also created through exhibiting poster containing information about the project in local language, Marathi, at study site (Fig 6.1. d)

a)

b)

c)

d)

Fig. 6.1 Various activities carried out during Kondana Soft-furred Rat educational and public awareness programme - a) Mr. Suhas Wainganka r, Educational Officer, CEE, Pune conducting slide show on biodiversity of the northern Western Ghats, b) students playing food web game, c) students from higher secondary school at Torna Fort participated in this programme, d)CEPF- ATREE team visited the poster exhibiting information about the project in local language, Marathi.

Another important outcome of the project was related to capacity building - during this project total eight volunteers were trained in handing and sampling the habitat of the small mammals. The trainee included two post graduating students from Department of Zoology, University of Pune, Maharashtra; three under graduating student (in arts field) from college in Pune; a Assistant Professor from Zoology Department, Dr. Ghali College, Kolhapur, and his undergraduate student; and an field assistant, Natural History Collection Department, BNHS. One of the volunteers, Mr. Ganesh Mane, after training conducted the rodents survey in the Western Ghats under guidance of Dr. Uma Ramkrishnan, Faculty, National Centre for Biological Sciences (NCBS), Bangalore, a reputed and leading institute in field of advanced biological research in India.

During this project I have developed formal collaboration with Dr. Uma Ramkrishnan, NCBS for conducting the molecular investigation which reduced large amount of expenses on molecular analysis and those saved funds were used in other important field oriented activities of the project. In addition to this the informal collaboration was developed with Simon Poulton, Ph. D. Student, East Anglia University, UK. Simon Poulton is expert on ecology of the small mammals and actively helped in sampling design of the this study.

This was first relatively long duration and ecological study on very little known and critically endangered Kondana Soft-furred Rat and it will certainly help in developing the policies for conservation of the species. This report will be submitted to the Forest Department and State Board of Biodiversity of Maharashtra to take the necessary action at local scale for conservation of the species. I will submit this report to the IUCN small mammal specialist group to reassess the status of the species based on the population and distribution data collected during this study and also suggest to upgrade the information about the species in IUCN website. I will actively peruse these key policy making bodies for developing the appropriate policies for conservation of the species. In addition to this, the funding agency will be duly acknowledged in upcoming scientific and popular articles to increase outreach of this study and funding agency, in order to motivate young researchers to work on threatened and lesser known small mammals of the South Asia.

7. CONSERVATION AND MANAGEMENT RECOMMENDATIONS

It was not an easy task to suggest the conservation and management recommendations considering the paucity of the data on *M. kondana* and short duration of this study. Although I would propose the following recommendations for conservation of the species.

1. The gradual increase in number of sites of occurrence of the species may indicated under sampling of *M. kondana* at landscape level and it might be resulted into under estimated population and distribution of the species. The finding of this investigation suggested species had variation in response at different spatial scales. Therefore I would suggest detailed systematic study should be undertaken to understand the multi-spatial habitat preference and distribution pattern of the species. This will be useful in developing landscape level conservation management plan of the species.

2. The findings of this study indicated the strong preference of the species for rugged terrain and at presently these habitats are at high risk due to quarrying, mining, wind farms, developmental projects etc. (Watve 2013). Therefore initiates should be taken for identification, mapping, monitoring and conservation of such site.

3. Habitat preference analysis revealed that the percentage of obscurity of the microhabitat habitat was very strongly influence the occupancy of Kondana Soft-furred Rat. However, it avoided woodland as well as completely open grassland, these two habitats represent two extremities, and seems to prefer intermediate habitat characteristics. And activities such intensive grazing, wood cutting (clearing trees and shrubs) and burning, create habitat too open and afforestation made it too dense for the species, these activities should be strictly discouraged or minimized to prevent extirpation of the species.

4. Adaptive management system should be practiced considering great variations in spatial and temporal response of the species to microhabitat variables. Therefore site and season specific management plan will be developed and implemented in initial phase and through adaptive management system the generalisations can be made in later phases.

5. I strongly recommend, the policy making bodies must elevated protection status of

M. kondana - at present the species in Schedule V (vermin and pest), a lowest protection level given to the species, according to Indian Wildlife Protection Act, 1972. Besides that, four sites of occurrence of the species - Sinhgad, Torna Fort, Rajgad and Raireshwar are outside protected area, with almost no legal wildlife protection, and came under joint jurisdiction of the Forest Department and the Archaeological Department of Maharashtra. Therefore, the formal MoU between Forest Department and the Archaeological Department of Maharashtra will provide protection to the species through formal or informal approaches, especially maintaining the balance between habitat destruction and aesthetic value of the Forts.

6. The sites of occurrence of *M. kondana* are also rich in their floral an faunal diversity (Watve 2013). The necessary permissions and financial support from the Maharashtra Forest Department, Maharashtra State Biodiversity Board and Ministry of Environment, Forests and Climate Change (MoEFCC), would greatly facilitate networking, capacity building and monitoring the species and other floral and faunal diversity associated with it for long term conservation of biodiversity of this region.

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APPENDIX

Table 4.3. 1 Summary of the GLM (binomial) generated for examining microhabitat preference of the Kondana Soft-furred Rat (a=post-monsoon, c=winter, e=summer) and model average results (b=post-monsoon, d=winter, f=summer) at Sinhgad.

a)

	Model	-2*l*	k	AICc	Δ AICc	w_i	ER
1	POB	-30.1133	2	64.48	0.00	0.365	1
2	POB+PHD	-29.3387	3	65.20	0.72	0.255	1.43
3	POB+WSD	-30.0480	3	66.62	2.14	0.125	2.91
4	POB+WSD+ PHD	-29.3164	4	67.52	3.04	0.080	4.57
5	PRO+PSO	-30.8067	3	68.14	3.65	0.059	6.21
6	PRO+PSO+ PHD	-30.2317	4	69.35	4.87	0.032	11.42
7	PRO+PSO+ WSD	-30.5011	4	69.89	5.41	0.024	14.95
8	INTERCEPT	-34.6174	1	71.32	6.84	0.012	30.51
9	PRO+PSO+ WSD+PHD	-30.0646	5	71.49	7.01	0.011	33.3
10	PHD	-33.7634	2	71.78	7.30	0.009	38.48
11	WSD	-34.0050	2	72.27	7.78	0.007	49
12	PGR	-34.1971	2	72.66	8.18	0.006	59.62
13	PCA	-34.5281	2	73.31	8.83	0.004	82.67

b)

	Est.	SE	95 % CI (LL, UL)	Nm	w_p
INTERCEPT	-0.09	0.32	-0.71 , 0.53	17	1
POB	1	0.39	0.24 , 1.76	4	0.824
PHD	0.38	0.32	-0.25 , 1.01	7	0.392
WSD	0.13	0.33	-0.52 , 0.77	7	0.252
PSO	-0.56	0.37	-1.28 , 0.17	4	0.126
PRO	-0.76	0.48	-1.7 , 0.18	4	0.126
PGR	-0.22	0.3	-0.81 , 0.38	5	0.016
PCA	0.09	0.3	-0.49 , 0.67	2	0.006

Abbr. variable - PSO - Percentage cover of soil, PGR - Percentage cover of grass, PRO - Percentage cover of rock, PHR - Percentage cover of herb, POB - Percentage of obscurity, PCA - Percentage cover of canopy, WSD - woody stem density, PHD - Perennial herb density.
Abbr. table - 2*l* =-2 log-likelihood, k - No. of parameter, AICc -Akaike information criterion (small sample), Δ AICc-difference in AICc, , **w_i** - weight of model, ER -evidence ratio, Est. -Estimate, SE-Unconditional standard error, , 95 % CI-95 % confidence interval, Nm- No. of models, w_p - weight of predictor/variable

c)

	Model	-2*l*	k	AICc	Δ AICc	w_i	ER
1	PHD	-20.6994	2	45.67	0.00	0.178	1
2	PGR+PHD	-19.6940	3	45.93	0.27	0.156	1.14
3	POB+PHD	-19.8319	3	46.21	0.54	0.136	1.31
4	POB	-21.3637	2	46.99	1.33	0.092	1.94
5	POB+WSD+ PHD	-19.5085	4	47.95	2.28	0.057	3.13
6	PGR+WSD+ PHD	-19.6320	4	48.19	2.53	0.050	3.54
7	PGR	-21.9970	2	48.26	2.60	0.049	3.66
8	INTERCEPT	-21.7444	1	48.41	2.75	0.045	3.95
9	POB+WSD	-20.9355	3	48.42	2.75	0.045	3.96
10	PCA	-19.6940	2	48.75	3.09	0.038	4.68
11	PRO+PSO+ PHD	-19.9822	4	48.89	3.23	0.036	5.03
12	WSD	-22.369	2	49.01	3.34	0.034	5.31
13	PGR+PCA	-19.6320	3	49.72	4.06	0.023	7.61
14	PGR+WSD	-21.7444	3	50.03	4.37	0.020	8.89
15	PRO+PSO+ WSD+PHD	-21.9970	5	50.24	4.57	0.018	9.85
16	PRO+PSO	-21.2906	3	50.90	5.24	0.013	13.71
17	PRO+PSO+ WSD	-21.2906	4	51.51	5.85	0.010	18.6

d)

	Est.	SE	95 % CI (LL, UL)	Nm	w_p
INTERCEPT	1.75	0.49	0.79 , 2.71	22	1
PHD	1	0.57	-0.12 , 2.11	7	0.631
POB	0.77	0.66	-0.52 , 2.06	4	0.33
PGR	-0.6	0.49	-1.55 , 0.35	5	0.299
WSD	0.34	0.44	-0.52 , 1.2	7	0.234
PSO	-0.37	0.32	-1.01 , 0.26	4	0.076
PRO	-0.23	0.38	-0.96 , 0.51	4	0.076
PCA	0.61	0.61	-0.58 , 1.8	2	0.062

e)

	Model	-2*l*	k	AICc	Δ AICc	w_i	ER
1	PGR+PHD	-31.2439	3	69.01	0.00	0.196	1
2	PHD	-32.4516	2	69.16	0.15	0.182	1.08
3	POB+PHD	-32.3281	3	71.18	2.17	0.066	2.96
4	PSO+PHD	-32.3917	3	71.31	2.30	0.062	3.15
5	PHR+PGR+ PHD	-31.2306	4	71.35	2.34	0.061	3.22
6	INTERCEPT	-34.6574	1	71.40	2.39	0.059	3.3
7	PGR	-33.8193	2	71.89	2.88	0.046	4.23
8	WSD	-33.9731	2	72.20	3.19	0.040	4.93
9	POB	-34.1724	2	72.60	3.59	0.033	6.02
10	PHR	-34.2214	2	72.70	3.69	0.031	6.32
11	POB+WSD+ PHD	-31.9946	4	72.88	3.87	0.028	6.92
12	PSO+WSD+ PHD	-32.0030	4	72.89	3.89	0.028	6.98
13	PGR+WSD	-33.4540	3	73.43	4.42	0.022	9.12
14	PCA	-34.6059	2	73.47	4.46	0.021	9.29
15	PSO	-34.6492	2	73.55	4.54	0.020	9.7
16	PHR+WSD	-33.5490	3	73.62	4.61	0.020	10.02
17	PHR+PGR	-33.5527	3	73.63	4.62	0.019	10.06
18	PHR+PGR+ WSD+PHD	-31.1577	5	73.68	4.67	0.019	10.33
19	POB+WSD	-33.5860	3	73.69	4.68	0.019	10.4
20	PSO+WSD	-33.9730	3	74.47	5.46	0.013	15.32
21	PHR+PGR+ WSD	-33.1638	4	75.22	6.21	0.009	22.28
22	PHR+PGR+PCA	-33.5446	4	75.98	6.97	0.006	32.6

f)

	Est.	SE	95 % CI (LL, UL)	Nm	w_p
INTERCEPT	0.01	0.3	-0.57 , 0.58	22	1
PHD	0.67	0.34	0.01 , 1.33	8	0.643
PGR	-0.44	0.32	-1.07 , 0.19	8	0.378
WSD	0.28	0.31	-0.33 , 0.9	9	0.197
PHR	0.1	0.36	-0.6 , 0.81	7	0.165
POB	0.19	0.31	-0.41 , 0.8	4	0.146
PSO	0.08	0.31	-0.52 , 0.68	4	0.123
PCA	0.06	0.3	-0.53 , 0.65	2	0.027

Table 4.3. 2 Table 4.3. Summary of the GLM (binomial) generated for examining microhabitat preference of the Kondana Soft-furred Rat (a=post-monsoon, c=winter, e=summer) and model average results (b=post-monsoon, d=winter, f=summer) at Torna Fort.

a)

	Model	-2*l*	k	AICc	Δ AICc	w_i	ER
1	PHR+WSD	-9.0026	3	24.53	0.00	0.190	1
2	PHR	-10.2816	2	24.82	0.29	0.164	1.16
3	PHR+PGR+ WSD+PHD	-7.0169	5	25.40	0.87	0.123	1.55
4	PHR+PGR+ PHD	-8.4685	4	25.83	1.30	0.099	1.91
5	PHR+PGR+ WSD	-8.8170	4	26.52	2.00	0.070	2.71
6	PHR+PGR	-10.2659	3	27.05	2.53	0.054	3.54
7	PHD	-11.9752	2	28.21	3.68	0.030	6.29
8	POB+WSD+ PHD	-10.2580	4	29.40	4.88	0.017	11.46
9	PRO+WSD+ PHD	-10.3394	4	29.57	5.04	0.015	12.43
10	POB+PHD	11.5584	3	29.64	5.11	0.015	12.88
11	WSD	-12.8127	2	29.88	5.35	0.013	14.54
12	INTERCEPT	-13.9385	1	29.96	5.43	0.013	15.13
13	POB+WSD	-11.7986	3	30.12	5.59	0.012	16.38
14	PGR+PHD	-11.8149	3	30.15	5.62	0.011	16.65
15	PRO+PHD	-11.9314	3	30.38	5.86	0.010	18.7
16	PRO+WSD	-12.1634	3	30.85	6.32	0.008	23.59
17	POB	-13.3101	2	30.88	6.35	0.008	23.91
18	PRO	-13.3104	2	30.88	6.35	0.008	23.92
19	PGR+WSD	-12.3202	3	31.16	6.64	0.007	27.59
20	PGR	-13.6981	2	31.65	7.12	0.005	35.25

b)

	Est.	SE	95 % CI (LL, UL)	Nm	w_p
INTERCEPT	-3.6	1.27	-6.1 , -1.11	22	1.00
PHR	1.41	0.72	-0.01 , 2.82	6	0.70
PGR	-0.29	1.17	-2.58 , 2	7	0.37
WSD	-1.59	1.37	-4.27 , 1.1	9	0.33
PHD	0.91	0.53	-0.14 , 1.95	8	0.32
POB	-0.66	0.78	-2.18 , 0.87	4	0.05
PRO	0.11	0.65	-1.16 , 1.37	4	0.04

c)

	Model	-2*l*	k	AICc	Δ AICc	w_i	ER
1	POB	-27.0087	2	58.27	0.00	0.45	1
2	POB+ PHD	-26.3322	3	59.19	0.91	0.28	1.58
3	POB+ WSD	-26.9810	3	60.48	2.21	0.15	3.02
4	POB+ WSD+PHD	-26.3291	4	61.55	3.27	0.09	5.14
5	PCA	-31.2159	2	66.69	8.41	0.01	67.17

d)

	Est.	SE	95 % CI (LL, UL)	Nm	w_p
INTERCEPT	-0.71	0.34	-1.38, -0.03	22	1.00
POB	1.13	0.38	0.39, 1.88	4	0.946
PHD	0.42	0.37	-0.32, 1.15	8	0.375
WSD	0.08	0.37	-0.65, 0.81	9	0.245
PHR	-0.39	0.39	-1.15, 0.37	7	0.008
PCA	0.51	0.31	-0.09, 1.12	2	0.007
PGR	0.16	0.31	-0.46, 0.77	8	0.007
PRO	-0.38	0.33	-1.03, 0.27	4	0.007

Abbr. variable - PSO - Percentage cover of soil, PGR - Percentage cover of grass, PRO - Percentage cover of rock, PHR - Percentage cover of herb, POB - Percentage of obscurity, PCA - Percentage cover of canopy, WSD - woody stem density, PHD - Perennial herb density.

Abbr. table - 2*l* =-2 log-likelihood, k - No. of parameter, AICc -Akaike information criterion (small sample), Δ AICc-difference in AICc, , **w_i** - weight of model, ER -evidence ratio, Est. -Estimate, SE-Unconditional standard error, , 95 % CI-95 % confidence interval, Nm- No. of models, w_p - weight of predictor/variable

e)

	Model	-2*l*	k	AICc	Δ AICc	w_i	ER
1	POB	-27.7717	2	59.80	0.00	0.222	1
2	INTERCEPT	-29.6477	1	61.38	1.58	0.101	2.2
3	PGR	-28.6572	2	61.57	1.77	0.092	2.42
4	POB+PHD	-27.7087	3	61.94	2.14	0.076	2.92
5	POB+WSD	-27.7361	3	61.99	2.20	0.074	3
6	PRO	-29.4065	2	63.07	3.27	0.043	5.13
7	PHD	-29.4067	2	63.07	3.27	0.043	5.13
8	WSD	29.4406	2	63.14	3.34	0.042	5.31
9	PHR	-29.4834	2	63.22	3.42	0.040	5.54
10	PGR+PHD	-28.3551	3	63.23	3.43	0.040	5.57
11	PGR+WSD	-28.3924	3	63.31	3.51	0.038	5.78
12	PCA	-29.6361	2	63.53	3.73	0.034	6.45
13	PHR+PGR	-28.5326	3	63.59	3.79	0.033	6.65
14	POB+WSD+PH D	-27.6617	4	64.21	4.41	0.024	9.09
15	PRO+WSD	-29.2322	3	64.99	5.19	0.017	13.38
16	PRO+PHD	-29.3154	3	65.15	5.35	0.015	14.54
17	PHR+WSD	-29.3160	3	65.15	5.36	0.015	14.55
18	PHR+PGR+ PHD	-28.2526	4	65.39	5.60	0.014	16.41
19	PHR+PGR+ WSD	-28.3102	4	65.51	5.71	0.013	17.38
20	PHR+PGR+ PCA	-28.4293	4	65.75	5.95	0.011	19.58
21	PRO+WSD+ PHD	-29.0735	4	67.04	7.24	0.006	37.28
22	PHR+PGR+ WSD+PHD	-27.9092	5	67.18	7.38	0.006	40.11

f)

	Est.	SE	95 % CI (LL, UL)	Nm	w_p
INTERCEPT	-1.01	0.34	-1.67 , -0.34	22	1
POB	-0.72	0.43	-1.57 , 0.12	4	0.39
PGR	0.44	0.31	-0.17 , 1.06	8	0.24
WSD	-0.17	0.37	-0.89 , 0.55	9	0.23
PHD	0.17	0.32	-0.45 , 0.79	8	0.22
PHR	-0.19	0.39	-0.95 , 0.58	7	0.13
PRO	0.19	0.32	-0.43 , 0.81	4	0.08
PCA	0.07	0.32	-0.56 , 0.7	2	0.04

Table 4.3. 3 Summary of the GLM (binomial) generated for examining microhabitat preference of the Kondana Soft-furred Rat (a=post-monsoon, c=winter, e=summer) and model average results (b=post-monsoon, d=winter, f=summer) at Rajgad.

a)

	Model	-2*l*	k	AICc	Δ AICc	w_i	ER
1	POB+WSD	-13.5621	3	33.65	0.00	0.260	1
2	POB+WSD+PHD	-12.7742	4	34.44	0.79	0.175	1.49
3	PHR+WSD	-14.4381	3	35.40	1.75	0.108	2.4
4	WSD	-15.6320	2	35.52	1.87	0.102	2.55
5	POB+PHD	-14.6724	3	35.87	2.22	0.086	3.04
6	PHD	-15.8646	2	35.98	2.34	0.081	3.22
7	PHR	-16.2340	2	36.72	3.08	0.056	4.66
8	POB	-16.6232	2	37.50	3.86	0.038	6.88
9	PRO+PSO+WSD	-14.8824	4	38.65	5.01	0.021	12.23
10	PRO+PSO+WSD+PHD	-13.6729	5	38.71	5.06	0.021	12.58
11	PRO+PSO+PHD	-14.9307	4	38.75	5.10	0.020	12.83
12	INTERCEPT	-18.3463	1	38.78	5.13	0.020	13
13	PRO+PSO	-16.7105	3	39.94	6.30	0.011	23.3

b)

	Est.	SE	95 % CI (LL, UL)	Nm	w_p
INTERCEPT	-2.58	0.7	-3.96 , -1.2	13	1
WSD	-1.27	0.7	-2.63 , 0.1	6	0.688
POB	0.86	0.52	-0.16 , 1.87	4	0.559
PHD	0.61	0.39	-0.15 , 1.37	5	0.383
PHR	0.63	0.39	-0.13 , 1.39	2	0.164
PRO	-0.51	0.87	-2.23 , 1.2	4	0.074
PSO	-0.52	0.72	-1.94 , 0.89	4	0.073

c)

	Model	-2*l*	k	AICc	Δ AICc	w_i	ER
1	POB+WSD	-19.9459	3	46.43	0.00	0.520	1
2	POB+WSD+PHD	19.3612	4	47.63	1.21	0.284	1.83
3	POB+PHD	-21.2047	3	48.94	2.52	0.148	3.52
4	POB	-23.5182	2	51.30	4.87	0.045	11.43

d)

	Est.	SE	95 % CI (LL, UL)	Nm	w_p
INTERCEPT	1.75	0.49	0.79 , 2.71	13	1
POB	2.11	0.76	0.63 , 3.59	4	0.997
WSD	-1.16	0.55	-2.24 , -0.08	6	0.805
PHD	0.55	0.44	-0.3 , 1.41	5	0.434
PRO	0.14	0.36	-0.56 , 0.85	4	0.001
PSO	-1.06	0.59	-2.21 , 0.09	4	0.001
PHR	0.03	0.32	-0.61 , 0.66	2	0

Abbr. variable - PSO - Percentage cover of soil, PGR - Percentage cover of grass, PRO - Percentage cover of rock, PHR - Percentage cover of herb, POB - Percentage of obscurity, PCA - Percentage cover of canopy, WSD - woody stem density, PHD - Perennial herb density.

Abbr. table - 2*l* =-2 log-likelihood, k - No. of parameter, AICc -Akaike information criterion (small sample), Δ AICc- difference in AICc, , **w_i** - weight of model, ER -evidence ratio, Est. -Estimate, SE-Unconditional standard error, , 95 % CI- 95 % confidence interval, Nm- No. of models, w_p - weight of predictor/variable

e)

	Model	-2*l*	k	AICc	Δ AICc	w_i	ER
1	PRO	-23.8243	2	51.90	0.00	0.288	1
2	PRO+WSD	-23.3272	3	53.18	1.27	0.152	1.89
3	PRO+PHD	-23.6380	3	53.80	1.89	0.112	2.58
4	POB	-24.8320	2	53.92	2.02	0.105	2.74
5	INTERCEPT	-26.3454	1	54.77	2.87	0.069	4.2
6	PRO+WSD+PHD	-23.2511	4	55.39	3.49	0.050	5.72
7	POB+PHD	-24.5330	3	55.59	3.68	0.046	6.31
8	PGR	-25.9411	2	56.14	4.23	0.035	8.31
9	WSD	-25.9430	2	56.14	4.24	0.035	8.32
10	POB+WSD	-24.8308	3	56.18	4.28	0.034	8.5
11	PHD	-26.0523	2	56.36	4.46	0.031	9.28
12	PGR+WSD	-25.5724	3	57.67	5.76	0.016	17.84
13	POB+WSD+PHD	-24.5082	4	57.91	6.00	0.014	20.1
14	PGR+PHD	-25.7227	3	57.97	6.06	0.014	20.73

f)

	Est.	SE	95 % CI (LL, UL)	Nm	w_p
INTERCEPT	-1.5	0.45	-2.39 , -0.61	14	1
PRO	-1.29	0.72	-2.7 , 0.12	4	0.602
WSD	0.3	0.41	-0.51 , 1.1	6	0.302
PHD	-0.25	0.43	-1.1 , 0.6	6	0.267
POB	0.59	0.35	-0.11 , 1.28	4	0.199
PGR	-0.37	0.47	-1.29 , 0.56	3	0.065

Table 4.4. 1. Summary of the model selection statistics for single season occupancy models fitted to Kondana Soft-furred Rat data from Sinhgad (a=post-monsoon, b=winter, c=summer).

a)

	Model	-2*l*	k	QAIC	Δ QAIC	w_i
1	ψ(POB),*P*(.),*P*(.)	150.48	4	82	0	0.3956
2	ψ(POB+PHD),*P*(.),*P*(.)	148.09	5	82.86	0.86	0.2574
3	ψ(POB),*P*(Day),*P*(.)	148.22	6	84.92	2.92	0.0919
4	ψ(POB+PHD),*P*(Day),*P*(.)	145.8	7	85.76	3.76	0.0604
5	ψ(PHD),*P*(.),*P*(.)	158.59	4	85.88	3.88	0.0569
6	ψ(POB),*P*(.),*P*(TR)	150.3	6	85.91	3.91	0.056
7	ψ(POB+PHD),*P*(.),*P*(TR)	147.91	7	86.77	4.77	0.0364
8	ψ(PHD),*P*(Day),*P*(.)	155.86	6	88.57	6.57	0.0148
9	ψ(POB),*P*(Day),*P*(TR)	148.22	8	88.92	6.92	0.0124
10	ψ(POB+PHD),*P*(Day), *P*(TR)	145.79	9	89.76	7.76	0.0082
11	ψ(PHD),*P*(.),*P*(TR)	158.41	6	89.79	7.79	0.008
12	ψ(PHD),*P*(Day),*P*(TR)	155.86	8	92.57	10.57	0.002

b)

	Model	-2*l*	k	AIC	Δ AIC	wi
1	ψ(POB+PHD),*P*(.),*P*(.)	181.06	5	191.06	0	0.133
2	ψ(PHD),*P*(.),*P*(.)	183.25	4	191.25	0.19	0.121
3	ψ(POB),*P*(.),*P*(.)	183.47	4	191.47	0.41	0.108
4	ψ(WSD+PHD),*P*(.), *P*(.)	182.05	5	192.05	0.99	0.081
5	ψ(PHD),*P*(Day),*P*(.)	180.74	6	192.74	1.68	0.057
6	ψ(POB+WSD+PHD), *P*(.),*P*(.)	180.84	6	192.84	1.78	0.055
7	ψ(POB+PHD),*P*(Day), *P*(.)	178.99	7	192.99	1.93	0.051
8	ψ(POB+WSD),*P*(.), *P*(.)	183.19	5	193.19	2.13	0.046
9	ψ(WSD),*P*(.),*P*(.)	185.24	4	193.24	2.18	0.045
10	ψ(POB+PHD),*P*(.), *P*(TR)	179.68	7	193.68	2.62	0.036
11	ψ(PHD),*P*(.),*P*(TR)	181.87	6	193.87	2.81	0.033
12	ψ(POB),*P*(.),*P*(TR)	182.09	6	194.09	3.03	0.029
13	ψ(PHD),*P*(Day),*P*(TR)	178.29	8	194.29	3.23	0.027
14	ψ(POB+PHD),*P*(Day), *P*(TR)	176.58	9	194.58	3.52	0.023
15	ψ(WSD+PHD),*P*(.), *P*(TR)	180.67	7	194.67	3.61	0.022
16	ψ(POB),*P*(Day),*P*(.)	182.75	6	194.75	3.69	0.021
17	ψ(POB+WSD+PHD), *P*(.),*P*(TR)	179.46	8	195.46	4.4	0.015
18	ψ(WSD+PHD),*P*(Day) ,*P*(.)	181.61	7	195.61	4.55	0.014
19	ψ(POB+WSD),*P*(.), *P*(TR)	181.8	7	195.8	4.74	0.012
20	ψ(WSD),*P*(.),*P*(TR)	183.86	6	195.86	4.8	0.012
21	ψ(POB+WSD+PHD), *P*(Day),*P*(.)	180.09	8	196.09	5.03	0.011
22	ψ(POB),*P*(Day),*P*(TR)	180.38	8	196.38	5.32	0.009
23	ψ(WSD),*P*(Day),*P*(.)	184.41	6	196.41	5.35	0.009
24	ψ(POB+WSD+PHD), *P*(Day),*P*(TR)	176.52	1 0	196.52	5.46	0.009
25	ψ(POB+WSD),*P*(Day), *P*(.)	182.55	7	196.55	5.49	0.009
26	ψ(WSD+PHD),*P*(Day) ,*P*(TR)	179.45	9	197.45	6.39	0.006
27	ψ(WSD),*P*(Day), *P*(TR)	181.86	8	197.86	6.8	0.004
28	ψ(POB+WSD),*P*(Day), *P*(TR)	180.22	9	198.22	7.16	0.004

c)

	Model	-2*l*	k	QAIC	ΔQ AIC	wi
1	ψ(PHD),*P*(.),*P*(.)	151.6	4	47.67	0	0.330
2	ψ(PGR),*P*(.),*P*(.)	154.18	4	48.34	0.67	0.236
3	ψ(PGR+PHD),*P*(.),*P*(.)	149.78	5	49.19	1.52	0.154
4	ψ(PHD),*P*(.),*P*(TR)	148.16	6	50.77	3.1	0.070
5	ψ(PGR),*P*(.),*P*(TR)	150.74	6	51.44	3.77	0.050
6	ψ(PHD),*P*(Day),*P*(.)	150.98	6	51.5	3.83	0.049
7	ψ(PGR),*P*(Day),*P*(.)	153.55	6	52.18	4.51	0.035
8	ψ(PGR+PHD),*P*(.), *P*(TR)	146.34	7	52.29	4.62	0.033
9	ψ(PGR+PHD),*P*(Day), *P*(.)	149.16	7	53.03	5.36	0.023
10	ψ(PHD),*P*(Day),*P*(TR)	147.65	8	54.63	6.96	0.010
11	ψ(PGR),*P*(Day),*P*(TR)	150.18	8	55.29	7.62	0.007
12	ψ(PGR+PHD),*P*(Day), *P*(TR)	145.99	9	56.2	8.53	0.005

Abbreviations

-2*l* - -2 log-likelihood
k - No of parameters
QAICc -Quasi- Akaike information criterion
Δ QAICc -Difference in AICc value relative to the top model
w_i - Akaike weight
PHR - Percentage of herb cover
PGR - Percentage of grass cover
POB -Percentage of obscurity
WSD - Woody Stem Density
PHD-Perennial herb density
TR - Trap response
Day - Trapping occasion
(.) - Constant/ not variable

Table 4.4. 2. Summary of the model selection statistics for single season occupancy models fitted to Kondana Soft-furred Rat data from Torna Fort (a=winter, b=summer).

a)

	Model	-2*l*	k	QAICc	Δ QAICc	w_i
1	ψ(POB),p(.Day),p(.TR)	118.9	4	38.28	0	0.261
2	ψ(POB+PHR),p(.Day),p(.TR)	117.49	5	39.94	1.66	0.114
3	ψ(POB+WSD),p(.Day),p(.TR)	118.82	5	40.26	1.98	0.097
4	ψ(WSD),p(.Day),p(.TR)	127.53	4	40.33	2.05	0.094
5	ψ(PHR),p(.Day),p(.TR)	127.53	4	40.33	2.05	0.094
6	ψ(POB),p(Day),p(.TR)	116.27	6	41.65	3.37	0.049
7	ψ(POB+WSD+PHR),p(.Day),p(.TR)	117.49	6	41.94	3.66	0.042
8	ψ(POB),p(.Day),p(TR)	118.35	6	42.15	3.87	0.038
9	ψ(WSD+PHR),p(.Day),p(.TR)	127.32	5	42.28	4	0.035
10	ψ(POB+PHR),p(Day),p(.TR)	114.86	7	43.32	5.04	0.021
11	ψ(POB+WSD),p(Day),p(.TR)	116.19	7	43.63	5.35	0.018
12	ψ(PHR),p(Day),p(.TR)	124.63	6	43.64	5.36	0.018
13	ψ(WSD),p(Day),p(.TR)	124.63	6	43.64	5.36	0.018
14	ψ(POB+PHR),p(.Day),p(TR)	116.93	7	43.81	5.53	0.017
15	ψ(POB+WSD),p(.Day),p(TR)	118.27	7	44.13	5.85	0.014
16	ψ(WSD),p(.Day),p(TR)	126.98	6	44.2	5.92	0.014
17	ψ(PHR),p(.Day),p(TR)	126.98	6	44.2	5.92	0.014
18	ψ(POB+WSD+PHR),p(Day),p(.TR)	114.86	8	45.32	7.04	0.008
19	ψ(WSD+PHR),p(Day),p(.TR)	124.49	7	45.61	7.33	0.007
20	ψ(POB),p(Day),p(TR)	116.23	8	45.64	7.36	0.007
21	ψ(POB+WSD+PHR),p(.Day),p(TR)	116.93	8	45.81	7.53	0.006
22	ψ(WSD+PHR),p(.Day),p(TR)	126.76	7	46.15	7.87	0.005

b)

	Model	-2*l*	k	AIC	Δ AIC	w_i
1	ψ(PGR+POB),p(.)	101.37	4	109.37	0	0.380
2	ψ(POB),p(.)	105.06	3	111.06	1.69	0.163
3	ψ(POB+PHD),p(.)	104.79	4	112.79	3.42	0.069
4	ψ(POB+WSD),p(.)	104.85	4	112.85	3.48	0.067
5	ψ(PGR+POB),p(Day)	101.23	6	113.23	3.86	0.055
6	ψ(PGR+POB+PHD),p(.)	104.4	5	114.4	5.03	0.031
7	ψ(POB+WSD+PHD),p(.)	104.43	5	114.43	5.06	0.030
8	ψ(PGR),p(.)	108.89	3	114.89	5.52	0.024
9	ψ(WSD),p(.)	108.89	3	114.89	5.52	0.024
10	ψ(POB),p(Day)	104.91	5	114.91	5.54	0.024
11	ψ(PHD),p(.)	109.06	3	115.06	5.69	0.022
12	ψ(WSD+PHD),p(.)	107.86	4	115.86	6.49	0.015
13	ψ(PGR+POB+WSD+PHD),p(.)	104	6	116	6.63	0.014
14	ψ(PGR+WSD),p(.)	108.07	4	116.07	6.7	0.013
15	ψ(PGR+PHD),p(.)	108.12	4	116.12	6.75	0.013
16	ψ(POB+PHD),p(Day)	104.65	6	116.65	7.28	0.010
17	ψ(POB+WSD),p(Day)	104.7	6	116.7	7.33	0.010
18	ψ(PGR+WSD+PHD),p(.)	106.8	5	116.8	7.43	0.009
19	ψ(PGR+POB+PHD),p(Day)	104.26	7	118.26	8.89	0.005
20	ψ(POB+WSD+PHD),p(Day)	104.28	7	118.28	8.91	0.004

Table 4.4. 3 Summary of the model selection statistics for single season occupancy models fitted to Kondana Soft-furred Rat data from Rajgad (a=winter, b=summer).

a)

	Model	-2*l*	k	QAICc	Δ QAICc	wᵢ
1	ψ(POB),p(.)	103.22	3	34.57	0	0.233
2	ψ(POB+WSD),p(.)	98.53	4	35.36	0.79	0.157
3	ψ(POB+PHD),p(.)	99.38	4	35.58	1.01	0.141
4	ψ(PHD),p(.)	110.38	3	36.41	1.84	0.093
5	ψ(POB+WSD+PHD),p(.)	96.87	5	36.94	2.37	0.071
6	ψ(WSD),p(.)	112.95	3	37.08	2.51	0.066
7	ψ(POB),p(Day)	98.21	5	37.28	2.71	0.060
8	ψ(POB+WSD),p(Day)	93.59	6	38.09	3.52	0.040
9	ψ(POB+PHD),p(Day)	94.32	6	38.28	3.71	0.036
10	ψ(WSD+PHD),p(.)	110.23	4	38.38	3.81	0.035
11	ψ(PHD),p(Day)	105.38	5	39.13	4.56	0.024
12	ψ(POB+WSD+PHD),p(Day),p(TR)	91.84	7	39.64	5.07	0.019
13	ψ(WSD),p(Day)	107.94	5	39.79	5.22	0.017
14	ψ(WSD+PHD),p(Day)	105.23	6	41.09	6.52	0.009

	Model	-2*l*	k	QAICc	Δ QAICc	wᵢ
1	ψ(WSD),p(.),p(.)	94.29	4	31.38	0	0.170
2	ψ(PHD),p(.),p(.)	94.62	4	31.45	0.07	0.164
3	ψ(PRO),p(.),p(.)	94.71	4	31.47	0.09	0.162
4	ψ(PRO+WSD),p(.),p(.)	94.22	5	33.36	1.98	0.063
5	ψ(WSD+PHD),p(.),p(.)	94.26	5	33.37	1.99	0.063
6	ψ(PRO+PHD),p(.),p(.)	94.57	5	33.44	2.06	0.061
7	ψ(WSD),p(Day),p(.)	89.55	6	34.3	2.92	0.039
8	ψ(PRO),p(Day),p(.)	90.41	6	34.5	3.12	0.036
9	ψ(PHD),p(Day),p(.)	91.41	6	34.73	3.35	0.032
10	ψ(WSD),p(.),p(TR)	93.1	6	35.11	3.73	0.026
11	ψ(PHD),p(.),p(TR)	93.44	6	35.19	3.81	0.025
12	ψ(PRO),p(.),p(TR)	93.52	6	35.2	3.82	0.025
13	ψ(PRO+WSD+PHD),p(.),p(.)	94.18	6	35.35	3.97	0.023
14	ψ(WSD+PHD),p(Day),p(.)	88.67	7	36.1	4.72	0.016
15	ψ(PRO+WSD),p(Day),p(.)	89.23	7	36.23	4.85	0.015
16	ψ(PRO+PHD),p(Day),p(.)	90.41	7	36.5	5.12	0.013
17	ψ(PRO+WSD),p(.),p(TR)	93.04	7	37.09	5.71	0.010
18	ψ(WSD+PHD),p(.),p(TR)	93.08	7	37.1	5.72	0.010
19	ψ(PRO+PHD),p(.),p(TR)	93.38	7	37.17	5.79	0.009
20	ψ(PRO+WSD),p(Day),p(.)	88.25	8	38.01	6.63	0.006
21	ψ(PRO+WSD+PHD),p(Day),p(.)	88.25	8	38.01	6.63	0.006
22	ψ(WSD),p(Day),p(TR)	88.93	8	38.16	6.78	0.006
23	ψ(PRO),p(Day),p(TR)	89.78	8	38.36	6.98	0.005
24	ψ(PHD),p(Day),p(TR)	90.78	8	38.58	7.2	0.005
25	ψ(PRO+WSD+PHD),p(.),p(TR)	93	8	39.09	7.71	0.004
26	ψ(WSD+PHD),p(Day),p(TR)	88.05	9	39.96	8.58	0.002
27	ψ(PRO+WSD),p(Day),p(TR)	88.61	9	40.09	8.71	0.002
28	ψ(PRO+PHD),p(Day),p(TR)	89.78	9	40.36	8.98	0.002

Abbreviations

-2*l* - -2 log-likelihood
k - No of parameters
QAICc -Quasi- Akaike information criterion
Δ QAICc -Difference in AICc value relative to the top model
wᵢ - Akaike weight
PHR - Percentage of herb cover
PGR - Percentage of grass cover
POB -Percentage of obscurity
WSD - Woody Stem Density
PHD-Perennial herb density
TR - Trap response
Day - Trapping occasion
(.) - Constant/ not variable

b)

Table 4.5. 1 Results of model selection and model average derived parameter N (a,b=post-monsoon, e,f=winter, i,j=summer) and individual heterogeneity models (head and body length as covariate) with respective model average derived parameter N (c,d=post-monsoon, g,h=winter, k,l=summer) for closed models with Huggins' estimator fitted to Kondana Soft-furred Rat data from Sinhgad .

a)

	Model	k	AIC	Δ AIC	w_i	D
1	Mo	1	95.11	0.00	0.529	125.35
2	Mb	2	96.83	1.71	0.225	124.95
3	Mh	3	97.72	2.61	0.143	123.69
4	Mbh	4	99.43	4.31	0.061	123.17
5	Mt	4	101.04	5.93	0.027	124.78
6	Mtb	5	103.30	8.19	0.009	124.75
7	Mth	6	103.99	8.88	0.006	123.09

b)

	Model	N	SE	w_i	95 % CI
1	Mo	41.07	8.77	0.529	
2	Mb	34.10	5.36	0.225	
3	Mh	144.91	254.11	0.143	
4	Mbh	36.31	0.00	0.061	
5	Mt	40.87	10.41	0.027	
6	Mtb	66.00	23.98	0.009	
7	Mth	145.38	184.76	0.006	
	Wt. avg.	54.97	43.93		(1, 260)
	Uncon. SE		104.72		

c)

	Model	k	AIC	Δ AIC	w_i	D
1	P(.),C()	5	98.96	0.00	0.370	88.127
2	P(.),C(.)	3	99.39	0.43	0.299	93.061
3	P(),C()	6	100.36	1.40	0.184	87.177
4	P(),C(.)	4	100.80	1.84	0.147	92.256

d)

	Model	N	SE	w_i	95 % CI
1	P(.),C()	42.45	7.97	0.370	
2	P(.),C(.)	41.07	8.77	0.299	
3	P(),C()	47.91	11.96	0.184	
4	P(),C(.)	45.05	7.29	0.147	
	Wt. avg.	43.42	8.84		(25.17, 61.67)
	Uncon. SE		9.31		

e)

	Model	k	AIC	Δ AIC	w_i	D
1	Mo	1	271.49	0.00	0.803	571.45
2	Mh	3	275.23	3.74	0.124	571.11
3	Mt	4	276.54	5.05	0.064	570.35
4	Mth	6	280.38	8.89	0.009	570.00

f)

	Model	N	SE	w_i	95 % CI
1	Mo	163.52	27.87	0.803	
2	Mh	191.45	42.35	0.124	
3	Mt	162.88	32.22	0.064	
4	Mth	198.33	151.54	0.009	
	Wt. avg.	167.26	31.10		(98.74, 235.78)
	Uncon. SE		34.96		

g)

	Model	k	AIC	Δ AIC	w_i	D
1	P(.),C()	4	273.26	0.00	0.666	265.09
2	P(.),C(.)	3	275.57	2.31	0.209	269.47
3	P(),C()	6	277.16	3.90	0.095	264.80
4	P(),C(.)	5	279.43	6.17	0.030	269.18

h)

	Model	N	SE	w_i	95 % CI
1	P(.),C()	172.64	31.29	0.666	
2	P(.),C(.)	163.52	27.49	0.209	
3	P(),C()	172.40	30.90	0.095	
4	P(),C(.)	163.30	27.53	0.030	
	Wt. avg.	170.42	30.35		(110.38-230.47)
	Uncon. SE		30.64		

i)

	Model	k	AIC	Δ AIC	w_i	D
1	Mh	3	146.54	0.00	0.485	219.41
2	Mth	6	147.80	1.26	0.258	214.12
3	Mo	2	147.81	1.27	0.257	222.79

j)

	Model	N	SE	w_i	95 % CI
1	Mh	199.18	93.96	0.485	
2	Mth	172.48	156.10	0.258	
3	Mo	56.16	8.48	0.257	
	Wt. avg.	155.56	88.04		(1, 388.49)
	Uncon. SE		118.84		

k)

	Model	k	AIC	Δ AIC	w_i	D
1	P(.),C()	4	147.86	0.00	0.572	139.51
2	P(.),C(.)	3	149.92	2.05	0.205	143.70
3	P(),C()	6	150.39	2.52	0.162	137.62
4	P(),C(.)	5	152.34	4.47	0.061	141.80

l)

	Model	N	SE	w_i	95 % CI
1	P(.),C()	54.00	7.12	0.572	
2	P(.),C(.)	56.16	8.23	0.205	
3	P(),C()	53.94	7.30	0.162	
4	P(),C(.)	56.08	8.06	0.061	
	Wt. avg.	54.56	7.43		(39.94, 69.28)
	Uncon. SE	7.51			

Table 4.5. 2 Results of model selection and model average derived parameter N (a,b=winter, e,f=summer) and individual heterogeneity models (head and body length as covariate) with respective model average derived parameter N (c,d=winter, g,h=summer) for closed models with Huggins' estimator fitted to Kondana Soft-furred Rat data from Torna Fort.

a)

	Model	k	AIC	Δ	w_i	D
1	Mb	3	86.21	0.00	0.458	101.07
2	Mbh	4	88.48	2.27	0.147	101.07
3	Mt	5	88.55	2.34	0.142	98.80
4	Mtb	6	89.63	3.42	0.083	97.46
5	Mo	2	89.76	3.55	0.077	106.83
6	Mth	6	90.91	4.70	0.044	98.74
7	Mh	3	91.95	5.74	0.026	106.81
8	Mtbh	7	92.14	5.93	0.024	97.46

b)

	Model	N	SE	w_i	95 % CI
1	Mb	65.36	23.88	0.458	
2	Mbh	65.36	27.17	0.147	
3	Mt	24.37	2.77	0.142	
4	Mtb	54.00	25.33	0.083	
5	Mo	25.52	2.71	0.077	
6	Mth	25.24	3.23	0.044	
7	Mh	26.12	5.74	0.026	
8	Mtbh	54.00	40.38	0.024	
	Wt. avg.	52.48	18.87		(1, 107.35)
	Uncon. SE		27.99		

c)

	Model	k	AIC	Δ	w_i	D
1	P(.),C()	4	87.99	0.00	0.662	79.339
2	P(),C()	6	90.25	2.25	0.215	76.821
3	P(.),C(.)	3	91.96	3.96	0.091	85.572
4	P(),C(.)	5	94.06	6.07	0.032	83.062

d)

	Model	N	SE	w_i	95 % CI
1	P(.),C()	25.47	3.04	0.662	
2	P(),C()	30.30	4.85	0.215	
3	P(.),C(.)	25.52	2.71	0.091	
4	P(),C(.)	30.46	5.44	0.032	
	Wt. avg.	26.67	3.47		(18.56, 34.78)
	Uncon. SE		4.14		

e)

	Model	k	AIC	Δ AIC	w_i	D
1	Mo	2	54.70	0.00	0.558	58.42
2	Mb	3	56.84	2.14	0.191	58.24
3	Mh	3	57.02	2.32	0.175	58.42
4	Mbh	4	59.29	4.59	0.056	58.24
5	Mt	5	61.91	7.21	0.015	58.28
6	Mth	6	64.64	9.95	0.004	58.28

f)

	Model	N	SE	w_i	95 % CI
1	Mo	21.73	6.64	0.558	
2	Mb	29.36	10.50	0.191	
3	Mh	21.73	12.97	0.175	
4	Mbh	29.36	28.20	0.056	
5	Mt	21.67	6.85	0.015	
6	Mth	21.67	40.31	0.004	
	Wt. avg.	23.62	9.83		(0.62, 46.62)
	Uncon. SE		11.74		

g)

	Model	k	AIC	Δ	w_i	D
1	P(.),C(.)	2	54.51	0.00	0.816	50.21
2	P(.),C()	4	58.16	3.65	0.132	49.08
3	P(),C(.)	5	60.81	6.29	0.035	49.14
4	P(),C()	6	62.23	7.72	0.017	47.83

h)

	Model	N	SE	w_i	95 % CI
1	P(.),C(.)	29.36	23.07	0.816	
2	P(.),C()	21.62	6.14	0.132	
3	P(),C(.)	21.66	5.78	0.035	
4	P(),C()	21.55	5.56	0.017	
	Wt. avg.	27.94	19.94		(0, 69, 52)
	Uncon. SE		21.22		

Table 4.5.3 Results of model selection and model average derived parameter N (a,b=winter, e,f=summer) and individual heterogeneity models (head and body length as covariate) with respective model average derived parameter N (c,d=winter, g,h=summer) for closed models with Huggins' estimator fitted to Kondana Soft-furred Rat data from Rajgad Fort.

Abbreviations-Mo - Null model, Mb-behavioural effect model, Mh- heterogeneity model, Mt-time variation model, Mtb- time variation and behaviour effect model, Mbh- behaviour effect and heterogeneity model, Mth-time variation and heterogeneity model, Mtbh-time variation, behaviour effect and heterogeneity model, k- no of parameters, AIC- Akaike Information Criterion, Δ AIC - difference in AIC values, w_i-model weight, D- deviance, N-estimated population size, SE- standard error, Uncon. SE-unconditional standard error, 95 % CI- 95% confidence interval, P-capture probability, C-recapture probability, (.)=constant/no variation and () =variation.

a)

	Model	k	AIC	Δ	w_i	D
1	Mb	3	66.14	0.00	0.335	63.76
2	Mo	2	66.27	0.13	0.314	66.17
3	Mbh	4	68.33	2.19	0.112	63.57
4	Mh	3	68.48	2.35	0.104	66.11
5	Mt	5	68.87	2.73	0.086	61.61
6	Mth	6	71.27	5.13	0.026	61.39
7	Mtb	6	71.48	5.34	0.023	61.60

b)

	Model	N	SE	w_i	95 % CI
1	Mb	16.57	0.87	0.335	
2	Mo	19.13	2.71	0.314	
3	Mbh	16.94	0.99	0.112	
4	Mh	20.83	12.84	0.104	
5	Mt	18.53	2.86	0.086	
6	Mth	21.87	12.16	0.026	
7	Mtb	20.71	5.03	0.023	
	Wt. avg.	18.26	3.26		(7.99, 28.53)
	Uncon. SE		5.24		

c)

	Model	k	AIC	Δ	w_i	D
1	P(),C()	6	66.91	0.00	0.351	52.86
2	P(.),C()	4	67.19	0.28	0.305	58.26
3	P(),C(.)	5	68.14	1.23	0.190	56.71
4	P(),C()	3	68.55	1.64	0.155	62.00

d)

	Model	N	SE	w_i	95 % CI
1	P(),C()	24.56	7.55	0.35	
2	P(.),C()	19.67	3.21	0.30	
3	P(),C(.)	22.51	5.62	0.19	
4	P(.),C(.)	19.13	2.71	0.15	
	Wt. avg.	21.84	5.11		(10.16, 33.52)
	Uncon. SE		5.96		

e)

	Model	k	AIC	Δ AIC	w_i	D
1	Mo	1	51.91	0.00	0.704	70.11
2	Mb	2	54.07	2.16	0.239	70.10
3	Mt	4	58.21	6.30	0.030	69.62
4	Mbh	4	58.69	6.78	0.024	70.10
5	Mth	6	63.25	11.34	0.002	69.62

f)

	Model	N	SE	w_i	95 % CI
1	Mo	57.98	42.24	0.704	
2	Mb	73.01	37.68	0.239	
3	Mt	57.36	37.28	0.030	
4	Mbh	73.01	62.16	0.024	
5	Mth	57.36	63.96	0.002	
	Wt. avg.	61.91	41.53		(1, 144.70)
	Uncon. SE		42.24		

g)

	Model	k	AIC	Δ	w_i	D
1	P(),C()	3	56.34	0.00	0.480	49.832
2	P(),C(.)	5	57.87	1.53	0.224	46.537
3	P(.),C(.)	4	58.69	2.35	0.148	49.823
4	P(.),C(.)	4	58.69	2.35	0.148	49.823

h)

	Model	N	SE	w_i	95 % CI
1	P(),C()	57.98	25.64	0.480	
2	P(),C(.)	55.25	55.72	0.224	
3	P(.),C(.)	73.01	0.00	0.148	
4	P(.),C(.)	73.01	34.15	0.148	
	Wt. avg.	61.83	29.83		(1, 130.74)
	Uncon. SE		35.16		