SUMMARY

Biodiversity losses are rampant at the global, regional, national and local levels. Tropical deforestation, habitat conversion and biological invasions are major threats to the biologically rich tropical forest ecosystems which are little understood, particularly with respect to Community dynamics. Community ecology is the key science to understand the underlying ecological interactions that make biotic communities to organize and evolve in the face of ever changing environment, particularly the human-mediated activities in forested landscapes. Understanding of these ecological interactions across forest landscapes having human induced disturbance gradient not only provides, an insight on the changes in biotic communities in response to disturbance, but also enable to evolve conservation strategies for sustainability of ecosystem health.

The ecological dynamics of avian communities are well-worked out and these communities are widely used as bio-indicators for assessing the health of forest ecosystems, spatio-temporal changes in the biodiversity of the landscapes and in formulating conservation priorities. Nahargarh Wildlife Sanctuary is located in Aravalli range of Rajasthan and is about 22 kms from Jaipur. Aravallis are the oldest mountains in the world and are highly degraded due to anthropogenic activities. The forests of the Sanctuary have been utilized by local communities for their livelihood and there has been increase in human population in and around the area resulting in enhanced pressures on the forests. The consequence of these human pressures on the forests is the alteration of vegetation structure and composition which in turn has impact on wildlife. To
sustain the biodiversity through effective management of the Sanctuary, the following issues need to be addressed: (i) what is the extent of human induced disturbance across the landscape? (ii) how plant and animal communities are changing in response to disturbance gradient across the landscape? (iii) what is the relationship between plant and animal communities across the disturbance gradient of the landscape? and; (iv) how bird nest predation is influenced by biotic factors in an Aravalli forest? The answers to these questions are critical for the management of sanctuary and sustainable utilization of its resources. The information on the above mentioned issues is lacking. The present investigation on ‘Avifauna and Community Dynamics in Aravallis’ was, therefore, undertaken with the following objectives: (i) to assess the extent of human induced disturbance across the landscape; (ii) to study the changes in plant and bird communities across the disturbance gradient of the landscape; (iii) to understand the interactions between plant and bird communities across the disturbance gradient of the landscape; and (iv) to investigate the effects of biotic factors on nest predation in a typical Aravalli forest.

The field site selected for investigation was Nahargarh Wildlife Sanctuary situated at 22 kms from Jaipur. It spreads over an area of 85 sq km in Aravalli ranges of Rajasthan, and has semi arid climate with mean annual precipitation of 250 mm and annual temperature variation of maximum (47.8°C) and minimum (2.2°C) across the seasons. The landscapes of the sanctuary support dry deciduous to thorn forest of different degraded states with *Anogeissus pendula* as the dominant tree. Based on the intensity of 6 different disturbance factors of anthropogenic origin (agriculture, human habitation, grazing, lopping, road
construction and dumping of wastes), the landscape was divided into 3 regions—Nahargarh Biological Park (NBP), Jal Mahal Forest (JMF) and Kukas Forest (KF). The disturbance factor was measured in terms of: (i) distance of human settlement from the forest border; and (ii) relative impact factor (RIF) which was calculated from the arbitrary scores assigned to each of the 6 activities on the scale of 0 to 3 depending upon their intensities. Kukas Forest was the closest to the forest border, whereas the Nahargarh Biological Park is far away from the forest border; Jal Mahal forest is closer to the forest border as compared to Kukas Forest but away from the forest border as compared to Nahargarh Biological Park. The RIF values varied from 4 to 16, with the highest value (16) recorded for Kukas Forest and lowest value (4) for Nahargarh Biological Park; Jal Mahal Forest showed RIF of 10. These results suggest that Kukas Forest is highly disturbed, Nahargarh Biological Park is least disturbed and Jal Mahal Forest is moderately disturbed. In other words, the landscape selected has disturbance gradient.

To assess the presence of edaphic gradient across the landscapes having disturbance gradient, soil pH, percent organic matter and NPK levels were estimated following the methods outlined by Allen et al (1974). The soils belong to sandy or sandy loam, and the pH varied from 6.6 to 6.8. The pH range suggests that the soils are slightly acidic to nearly neutral. The soils showed high percent organic matter ranging from 7.52 to 7.77 across the habitats, and this might be due to dumping of wastes of biological origin by humans and defecated matter by grazing livestock and bird droppings. Inspite of high organic matter, the soil pH is slightly acidic to alkaline suggesting that the soils are highly buffered.
The NPK levels varied from 56.28 to 69.78 µg/g, 8.1 to 10.38 µg/g and 16.02 to 19.2 ppm, respectively across the habitats indicating that soils are nutritionally rich. The edaphic gradient observed is independent of disturbance gradient as well as of vegetation composition, structure and diversity. This is evident from the relationships of soil characteristics analysed with the disturbance gradient (distance of human settlement from forest border and RIF). In other words the edaphic gradient is patchy and does not influence the plant community patterns across the habitat.

Plant community composition, structure and diversity were analysed in the three regions as well as for the Sanctuary using line transects and quadrats of varying sizes. The floristic composition and the distribution of plant species among three regions were enumerated. The total number of plant species recorded for the Sanctuary was 175, out of which 142 were found in Nahargarh Biological Park, 133 were found in Jal Mahal Forest and 139 were observed for Kukas Forest. These species were distributed among 57 families, suggesting high taxonomic diversity. Although Poaceae and Fabaceae were dominant families in all the three regions, the percent of species found in each of the families varied among different regions suggesting region specific patterns. The ratio of species of trees: shrubs: herbs varied among three regions suggesting region specific spectrum of life forms. For example, herbs were most abundant in highly disturbed region (Kukas Forest) as compared to least disturbed region (Nahargarh Biological Park).
Quantitative phytosociological characters were used to characterize the communities. DBH and foliage height diversity were estimated to study the structure of the community. The diversity was assessed using different diversity indices. The density, DBH and IVI values were calculated for tree species and these values showed marked variation among the three regions; although *Anogeissus pendula* was dominant tree in all the three regions, the species showed marked variation in its density among three regions; the highest density value (8.463) was recorded for Nahargarh Biological Park and lowest for Kukas Forest, and the value for Jal Mahal Forest was higher than that of Kukas Forest.

Similarly, the most ecological successful species also varied among the three regions. This is evident from the variation in IVI values of tree species among the regions. For example, the most successful species in Nahargarh Biological Park were *Dalbergia sissoo* (3.773) and *Balanites roxburghii* (3.252); in Jal Mahal Forest the most successful species were *Commiphora wightii* (8.43), *Boswellia serrata* (6.985) and *Ailanthes excelsa* (6.45); and in Kukas Forest the most successful species were *Acacia leucopholea* (5.792) and *Azadirachta indica* (5.433). These observations suggest that the region specific community patterns and reflect ecological differentiation of communities across the disturbance gradient of the landscape. The community patterns observed are perhaps evolved as a result of ecological sorting across the disturbance gradient of the landscape. For example, the density of *Anogeissus pendula* decreases with increase in disturbance, while the density of *Prosopis juliflora* increases with the increase in disturbance. Similar patterns were shown by different tree species with respect to IVI values.
Although the percent of trees belonging to different DBH classes was similar among the three regions with highest number of trees under 20-50m DBH class and lowest number of trees under >200 cm class, but the number of trees under each DBH class was markedly different among three regions; and the decrease in the number of trees was prominent with the increase in disturbance suggesting that disturbance gradient generates region specific structure of plant communities across the landscape. Similar pattern of variation in foliage height diversity – a measure of community structure – was observed among three regions.

The species richness and diversity indices and evenness/heterogeneity indices were estimated for three regions. These indices showed marked differences among three regions and the patterns are region specific. For example, the number of species was highest (142) for Nahargarh Biological Park; and for Jal Mahal it was lowest (133); and the Kukas Forest showed slightly higher number of species (139). However, the tree density, and Simpson’s diversity index were highest for Nahargarh Biological Park and low for both Jal Mahal Forest and Kukas Forest; ‘J’ values (0.160) was lowest for Nahargarh Biological Park and highest (0.207) for Kukas Forest; and Jal Mahal Forest showed higher value than that of Nahargarh Biological Park. These observations suggest that the Nahargarh Biological Park, which is least disturbed, has high tree density, high plant diversity and greater heterogeneity as compared to moderately and highly disturbed regions. This is further confirmed when the indices of species richness and diversity, and tree density were correlated with the distance from human settlement from forest border. For example, the distance of human settlement
from forest border showed statistically significant (at \( P<0.05 \)) negative relationships with Shannon’s diversity and ‘J’, but statistically significant (at \( P<0.05 \)) positive relationships with Simpson’s diversity and tree density. These observations also indicate that the plant communities are ecologically differentiated in response to the disturbance gradient across the landscape.

To study the avian community, both primary and secondary data were used. The primary data was collected using species - effort curves, all out search for birds and variable width transects. To understand avian community dynamics across the habitats, composition of the community, species richness and diversity, breeding seasons of species, distribution of species among three regions, conservation status and feeding guilds and relationships of species richness and diversity to distance of human settlement from forest border were investigated.

A total of 104 species were recorded for the sanctuary and these were distributed among 42 families. The dominant families in the sanctuary were Corvidae, Sylvinidae and Passeridae. Most of the families were represented by 1 percent to 2 percent of the total species. This pattern of distribution of species among families indicates the presence of high taxonomic diversity in the Sanctuary. Of the total species, 70 percent were resident and 20 percent were migratory. Except \textit{Sarcogyps calvus} and \textit{Gyps bengalensis}, which are critically endangered, all other species fall under Least Concern conservation category of IUCN. The predominant breeding season was monsoon. Most of the species were common to all the three regions, some of the species were restricted to two regions and
few were confined to single region. These results suggest the region specific patterns of avian community composition across the landscape.

Two critically endangered species (*Sarcogyps calvus* and *Gyps bengalensis*) were sighted in the sanctuary. These were rare in the Nahargarh Biological Park which is least disturbed; only one of these two species (*Sarcogyps calvus*) was sighted very rarely in Jal Mahal Forest which is moderately disturbed; and both species were absent in Kukas Forest which is highly disturbed. These observations suggest that the disturbance led to local extinction of species and both the species may become extinct in the Sanctuary if the present anthropogenic activities are continued at the present rate in the area.

The three regions showed variations in the number of bird species and dominant families and the percent of species belonging to dominant families, the relative proportion of resident, migratory and endemic to Indian subcontinent. For example, the Nahargarh Biological Park showed highest number of species (92) with *Corvidae* and *Muscicapididae* as dominant families having 12 percent and 5 percent of the total species, respectively and ratio of 75 percent resident: 16 percent migratory: 9 percent endemic to Indian subcontinent; Kukas Forest recorded the lowest number of bird species (57) with *Corvidae* and *Sylviinidae* as dominant families having 12 percent and 10 percent, respectively and ratio of 80 percent resident: 12 percent migratory: 8 percent endemic to Indian subcontinent; the bird community profile of Jal Mahal Forest was close to that of Nahargarh Biological Park with 62 number of total species and *Corvidae*, *Sylviinidae* and *Sturnidae* as dominant families having 13 percent, 10 percent and 7 percent of
total species, respectively; and ratio of 76 percent resident: 18 percent migratory: 6 percent endemic Indian subcontinent. These observations suggest that the disturbance gradient across the landscape influences the avian community dynamics resulting in their ecological differentiation. Further, this is also evident by the region specific profiles of species richness and diversity indices profiles. For example, the highest HR and lowest ‘J’ values were recorded for Nahargarh Biological Park as compared to Jal Mahal Forest and Kukas Forest regions suggesting high heterogeneity in the community of least disturbed area as compared to disturbed areas. The high H and Simpson’s diversity values in Jal Mahal Forest and Kukas Forest, respectively, might be due to agriculture in disturbed areas. When these indices were correlated with the distance of human settlement from forest border, the ‘r’ values for combinations with ‘H’ and ‘J’ were weak, negatively correlated, and statistically insignificant (at P<0.05), but relationships with HR and number of species were strong, positive and statistically significant (at P<0.05). These observations suggest that bird species richness and diversity and heterogeneity decreases with the increase in disturbance level.

The seasonal distribution of species among the three regions in different years was assessed. In all the three regions showed pronounced seasonal and annual variations in number of bird species sighted were observed. Maximum number of bird species was sighted during monsoon and a minor peak was observed during summer months; and there was a decline in the numbers during winter months. This pattern of seasonal variation is common to all the three regions. However, the three regions showed region specific pattern in different seasons and years...
suggesting microclimatic conditions also influences the avian community dynamics. The number of species sighted in each seasons varied among the regions. These variations can be explained in terms of food availability and the seasonal changes in phenology of vegetation such as leaf shedding, leaf flushing, flowering and fruiting and decomposition of litter by arthropods.

The number of bird species also showed annual variations among three regions. For example, in the year 2003 the number of bird species sighted was 21 at Nahargarh Biological Park during monsoon but in the monsoon of 2004 it was 15; similar patterns were observed at other regions. This can be explained on the basis of variation in weather patterns, particularly precipitation level and temperature regime, both of which influence the phenology of the vegetation in the area.

The number of feeding guilds and their composition among three regions were assessed. The maximum number of feeding guilds (15) was recorded for Nahargarh Biological Park and lowest number (11) was recorded for Kukas Forest suggesting reduction in food web size in highly disturbed areas as compared to least disturbed areas. The sizes of feeding guilds varied markedly among three regions. For example, in all three regions the dominant feeding guild was insectivore, but its size was large with 23 species in Nahargarh Biological Park in contrast to its small size with 16 species in Kukas Forest.

The different regions showed variation in the top 5 dominant feeding guilds. For example, the feeding guild insectivore-nectarivore occupied second dominant
position in Nahargarh Biological Park, but it was fourth dominant guild in Jal Mahal Forest and Kukas Forest; in Kukas Forest granivore occupies the second dominant feeding guild; similarly, the feeding guild carnivore was the fifth dominant feeding guild in Jal Mahal Forest, but it was fourth dominant feeding guild in Nahargrah Biological Park; in the Kukas Forest region omnivore was the third dominant feeding guild. These results can be explained on the basis that the abundant food base such as insects and flowers and ideal canopy structure and microclimatic conditions of intact forests found in Nahargarh Biological Park might have contributed to enhanced sizes of insectivore and insectivore-nectarivore guilds; on the other hand disturbed forest with more open space and less tree density and fragmentation of habitat found in Jal Mahal Forest and Kukas Forest are perhaps associated with dominance of granivore, omnivore and carnivore guilds.

The omnivore birds are generalist birds and are more in disturbed regions as compared to undisturbed regions. The insectivore, insectivore-nectarivore and frugivore are specialist birds, all of which showed decline in disturbed regions as compared to undisturbed habitat.

The patterns of variation observed in the number and size of feeding guilds among three regions might be associated with the variations in plant composition and structure and species richness and diversity observed across the disturbance gradient of the landscape. In other words, ecological sorting of biotic communities might have taken place across the disturbance gradient of the landscape leading to evolution of communities. This is also amply evident from the patterns of
interactions between plant and bird communities among three regions and also the replacement of native species by *Prosopis juliflora* and loss of endangered bird species in highly disturbed Kukas Forest.

The extent of mutualism between avian community and plant community was assessed using correlation analysis. Relationships of bird species diversity and number of birds (species richness) in all the four seasons with plant community characteristics such as plant species diversity, number of species (richness), tree density and foliage height diversity were studied for each region. For Nahargarh Biological Park, the bird species diversity and richness (number of species) was strongly correlated with foliage height diversity, plant species diversity and richness and tree density and the ‘r’ values were statistically significant (at P<0.05), except for some combinations. For Kukas Forest, these correlations were broken down except for few combinations of bird diversity and richness with plant species richness, tree density and foliage height diversity. For example, bird species diversity in summer season only showed statistically significant ‘r’ values (at P<0.05) with foliage height diversity, tree density and number of plant species (in spring also). For Jal Mahal Forest, the patterns of relationships of bird diversity and richness with plant community characteristics are similar to that observed for Nahargarh Biological Park except for break down of correlations in one or two combinations. These patterns of relationships between avian community and plant community characteristics across the disturbance gradient of landscape demonstrate that: (i) plant community composition and structure, diversity and richness influence avian community dynamics, and (ii) disturbance
breaks the relationship between plant and bird communities due to loss of biotic integrity leading to degradation of ecosystem from one state to another state.

To understand the territory size of Type A birds, which are highly territorial, the territory size of Magpie Robin (Type A bird) was mapped using spot marking. The number of territories mapped was high for Nahargarh Biological Park and Jal Mahal Forest, and it was low (1) for Kukas Forest; the size of territory was highest in Kukas Forest (1846.5 ± 85.56 sq m) but lowest in Nahargarh Biological Park (1400.667 ± 249.16 sq m); the territory size of Jal Mahal Forest (1667.67 ± 94 sq m) was higher than that of Nahargarh Biological Park but lower as compared to that of Kukas Forest. These observations indicate that disturbance increases the territory size because of the need for birds to move longer distances in search of food such as insects/fruits/nectar in disturbed areas where the food base for birds is scarce or limited due to changes in vegetation structure and composition.

Spot-mapping is widely used in ornithological studies and it has been used for the first time to study territorial birds in Aravallis. It is useful in understanding the area requirement of bird species, spatial patterns of plot occupancy or diversity and intra and interspecific territoriality and bird distribution in relation to resource distribution.

To assess the extent of nest predation, which is critical in avian community dynamics, the role of biotic factors (disturbance and edge effects) on the nest predation was studied using artificial nests with artificial eggs. The experiments
were conducted not only at three regions, but also at the Delhi Ridge which is also a part of Aravallis and is highly disturbed. The nest predation was highest (180) at Delhi Ridge; within the Sanctuary Kukas Forest showed highest (140) nest predation; the nest predation was lowest (60) in Nahargarh Biological Park. These results suggest that disturbance enhances nest predation because of loss of vegetation cover and more openness, both of which make it easier for predators to move and also enhance the visibility of the predator for spotting the nest. On the other hand, dense vegetation with closed canopy cover conceals nests. This is true for Nahargarh Biological Park where lowest nest predation was observed.

To understand whether colour of egg has effect on nest predation, an experiment was conducted using white and blue coloured eggs. No difference was observed in the level of nest predation between white and blue eggs suggesting that the colour of eggs does not effect nest predation in Aravalli forests. To assess the forest edge effect on the nest predation, an experiment was conducted by placing the artificial nests at the forest interior and edge. The relative proportion of intact nests to nests attacked varied between the forest interior and forest edge, with higher proportions of nests attacked for nests placed at the edge as compared to that of forest interior. The differences in the relative proportion of intact nests to nests attacked were statistically significant between forest interior and edges suggesting that the edge effect enhances nest predation because of fragmentation and patchy distribution of forests, both of which make more visibility to the predators. To find out the extent of the spread of edge effect on nest predation, experiments were conducted by placing nests at different
distance interval classes ranging from 0-10 to 81-100 m from the forest edge. The nests depredated were maximum (75) at 0-10m distance interval class and depredation decreased with the increase in distance interval class, and lowest (20) depredation of nests was observed at 81-100m distance interval class. The differences in nest depredation among different distance interval class was statistically significant ($\chi^2=111.84$, d.f. =6, $P \leq 0.05$). When the nests were placed within 50m distance from the edge and beyond 50m distance from the edge, the depredation of nests was maximum (252) within 50m distance as compared to the nests placed beyond 50m distance, and the differences between the two sites were statistically significant ($F_{1,19}=36.97$, $P \leq 0.05$). In other words the nest predation is least in intact forests than in the fragmented forests with many small patches where the edge effect enhances nest predation.