Executive summary

Frequent extraction of plant biomass in the form of timber, firewood, fodder, and non-timber forest produce (NTFP), by rural populations, are the most widespread disturbances in the forests of developing countries including India. Such small-scale extractive pressures or chronic disturbances modify structure and composition of habitat. These disturbances alter not only habitat characteristics but also affect use, survival and fitness of biotic communities. Despite their prevalence, very few studies have actually investigated relationships between these disturbances and biotic communities. This may be because of the correlated and interactive nature of such disturbances, and their gradual effects on habitat characteristics, which impede their quantification. However, it becomes difficult for managers to control or use remedial measure in the absence of any analytical study on the nature and effects of these disturbances. Apart from mere investigation of effects of these disturbances on biodiversity it becomes essential to identify “ecological indicators” which could be easily used by managers to monitor such pressures.

Birds have been found to be highly sensitive to modification in their habitat and therefore act as best model taxa to examine and monitor impacts of these cryptic disturbances. In order to understand the dynamics of small-scale extractive disturbances and their effects on floral and faunal community we undertook a study in Shiwalik landscape of Northern India. One of the most important reasons for selecting this landscape for this study was its significance for conservation of large mammals as well for various resident and migrant bird communities. At the same time, it has a strong gradient of anthropogenic disturbances from near pristine to highly disturbed areas as it is situated in the midst of one of the most populated areas of the world. Realizing the conservation significance of this landscape, government has provided special protection to some of these forested areas by creating protected areas. However, protected areas also suffer from extractive practices by local communities residing within and around their boundaries. Our main objectives in this study were as follows

1) Identification of various small-scale extractive disturbances and their causative agents in major forest type of this landscape.

2) Quantification of impacts of these disturbances on different layers of vegetation to examine the possible changes in structure and composition of the habitat.
3) To investigate the response of overall bird community as well as different foraging guilds to habitat degradation in different forest types during breeding and non-breeding season

4) Identification of indicator bird species which could be utilized for monitoring small-extractive disturbances in this landscape and documentation of simple protocols to monitor these species in field.

We selected a contiguous patch (29° 57' to 31°20' N and 77°35' to 79°20'E coordinates) of forest in Shiwalik landscape between river Yamuna in the west and river Ganga in the east. We selected three major forest types namely, Dry plain Sal forest, Dry and Moist Shiwalik Sal forest. We choose a total of 30 sampling sites with 10 sites in each forest type. Sampling units of both dry and hill forests were largely located in the western part of Rajaji National Park and Shiwalik Forest Division, while that of moist Shiwalik Sal forest were located in the Dehradun Forest Division and Rajaji National Park. We identified potential sampling sites with the help of satellite imageries, topographic sheets and forest management plan and finalized the sampling sites after a reconnaissance survey. At each site, we delineated an area of 1kmx1km as sampling plot, leaving a buffer of >250m from forest boundary to negate edge effects. Within each plot, we laid nine systematic intensive sampling points with 250m distance between two points. At each point (n=269, since one plot in dry forest had 8 sampling points), we quantified vegetation structure, composition, anthropogenic disturbances and birds in nested circular plots. Each site was surveyed at least six times covering one breeding and one non-breeding season to understand the seasonal changes in disturbance regimes and bird communities. Two sites from each forest types were surveyed during both the years so as to understand within site variation in bird community. At each sampling point, concentric 10m and 5m radius circular plots were laid to quantify vegetation structure and composition for tree and shrub layers respectively. Whereas disturbance indicators viz. % of lopped trees, intensity of lopping on each tree, number and width of human/cattle trails, number of trees showing signs of firewood collection, signs of fire, number of cut stumps (indicating timber extraction, primarily in the past) etc. were quantified in 20 m radius circular plots around intensive sampling points. Similarly intensive sampling points were used for quantification of bird community though point-transect (variable radius circular plot) method.
We compared disturbance variables across forest types using multiple comparisons after Kruskal-Wallis test. Principal Component Analysis (PCA) was used to examine the degree of segregation of disturbance variables between forest types. We did a spearman’s rank correlation test to investigate the relationship between proximity of human settlements and various disturbances. We used conditional modeling approach to examine the response of *Lantana camara* to various disturbances among forest types. Overall bird densities were estimated using distance analysis while correcting for detection bias. Birds were categorized into guilds at coarser and finer levels based on their food requirements. Point specific densities were estimated by post-stratification function of DISTANCE software. Densities of all species and guilds were estimated by pooling species with similar detections distances together and categorizing them into three detection groups based on their behavior. We used generalized linear mixed effect models to examine the response of vegetation and birds to various habitat variables owing to the hierarchical sampling design. Candidate models were constructed based on information available in literature and our personal observations. Best model was selected using information theoretic approach. Due to vast seasonal changes in bird community composition separate models were built for breeding and non-breeding season.

We found a strong positive correlation among various disturbances at landscape level which indicate their synergistic behavior. Disturbances in dry forest were mostly caused by *Gujjar* population residing within Rajaji NP and villages adjoining the park while in the hill forest it was mostly caused by *gujar* population inside Rajaji NP. On the other hand, moist forest was surrounded by small towns, villages, and agricultural areas, which were the major source of disturbance. Human proximity and protection level influenced the disturbance levels to some extent. Dry and hill forests faced higher lopping and livestock grazing pressures compared to less diverse moist forest with very few palatable species. Although village densities explained lopping and grazing disturbance, they barely explained firewood and timber extractions.

Small-scale extractive disturbances have significantly modified the vegetation structure at both shrub and tree layer in all forest types. It especially resulted in decline in percentage canopy cover and stunted shrub height. Native shrub cover declined with timber extraction in both dry and moist and with livestock grazing in hill forest. These disturbances have not influenced tree species diversity in any forest type but native shrub diversity was significantly
influenced. Frequent perturbations in ecosystem due to these disturbances have led to invasion and spread of, one of the world’s worst invasive species, *Lantana camara* in the understory of all forest types. Such changes in vegetation structure and invasion of exotic species are expected to cause change in vegetation composition in future.

Over two years of sampling period, a total of 173 bird species were recorded from the study area through 19184 observations. Bird communities in all these forest types change remarkably during breeding and non-breeding season with the arrival of altitudinal, local, long-distance and passage migrants. Bird species richness and densities across all forest types were usually higher during breeding than non-breeding season. We did not find any pattern in overall bird richness and density across a disturbance gradient at plot level. This could be accounted to the inherent properties of sampling points which were being masked on averaging the response and predictors at plot level. Year round availability of food resources and cover of invasive shrub *Lantana camara* positively influenced the bird richness and density during breeding and non-breeding season across all forest types. It also increased similarity in bird composition across sampling plots within dry forest. Coefficient of variation of tree crown cover, an index of canopy patchiness, was another important variable which positively influenced bird species richness during breeding season. Fire during the breeding season in hill forest led to decrease in bird richness. Out of disturbance variables, firewood collection resulted in low species richness across seasons. In our study, we did not found a strong association of bird composition with either overall vegetation structure or composition. Small-scale extractive disturbances led to increased similarity in bird composition among sampling plots. For instance, grazing in hill forest and firewood collection in dry & moist forest had resulted in increased similarity among sampling plots. All these disturbances adversely affect the specialist species (e.g., ground dwelling, trunk-bark feeder) and attract generalist species.

We observed that insectivore and nectarivore-insectivore guild experienced negligible change in density across seasons. Densities of frugivorous and omnivorous guilds, on the contrary, increased considerably during breeding season. Granivorous guild appeared in the forest during breeding season only. At plot level we did not observe any trend in guild densities across disturbance gradient. However, increase in densities of frugivorous, nectarivorous and omnivorous birds were noticed in hill forest during breeding season. Guilds with different sensitivities to small-scale extractive disturbances were identified. Fine foraging guild with
insect diet exhibited high sensitivity to disturbances. Canopy and understory insectivores decreased in abundance with increasing disturbances but trunk bark foraging guild did not show any relationship. Birds with fruit diet were benefitted by lantana cover. Abundance of granivorous and omnivorous birds increased with increasing disturbances.

A total of 66 species of birds emerged as indicators of overall disturbance in three forests during two seasons. Highly disturbed areas were preferred by generalist species whereas specialist species preferred less disturbed habitats. Jungle babbler *Turdoides striata*, Spotted dove *Streptopelia chinensis*, Jungle crow *Corvus macrorhynchos* emerged as indicator of high disturbance area whereas species specialized in their foraging or nesting demands such as Jungle prinia *Prinia sylvatica*, Emerald dove *Chalcophaps indica*, Great tit *Parus cinereus* indicated less disturbed areas. Species specialized in foraging from trunk-bark such as Great tit and Nuthatches decreased in abundance with increasing disturbance due to firewood and small-timber extraction. Increasing pressure due to livestock grazing led to decline in abundance of understory birds such as Jungle prinia *Prinia sylvatica* and Red-jungle fowl *Gallus gallus*. Understory generalist species such as Himalayan bulbul and Red-vented bulbul, increased with increasing lopping pressure. Benefits to such species could be attributed to high density of *Lantana camara* in such areas. Highly degraded areas of all forest types were indicated by similar set of bird species pointing toward homogenization of biotic communities. Interestingly, some of the migrant species were also found to be highly sensitive to extractive disturbances. Hume’s leaf warbler decreased significantly with increasing timber extraction whereas Pied bushchat *Saxicola caprata* and Slaty-blue flycatcher *Ficedula tricolor* increased with increasing lopping pressure.

Species responding significantly to disturbances were later ranked for characteristics essential for their use in monitoring program. We surveyed literature on the qualities required for a good indicator species. Apart from their sensitivity to disturbance, detection in field, seasonal availability in the landscape and cross-forest distribution were the important criteria used for selecting the final set of top indicators. A total of 15 species emerged as top indicators for monitoring high and low-level of disturbances. Ecological reasons for selection and simple methods for sampling top indicator species were provided in an order to monitor small-scale extractive disturbances in Shiwalik landscape.