Executive Summary

Frequent extraction of plant biomass in the form of timber, firewood, fodder, and non-timber forest products (NTFP) by rural populations, is the most widespread disturbances in the tropical forests. These disturbances not only alter habitat characteristics but also affect habitat use, survival and fitness of biotic communities. Despite being a major cause of forest degradation, very few studies have actually investigated the relationships between these disturbances and biotic communities. It becomes difficult for natural resource managers to control or manage these disturbances in the absence supporting evidence and studies. Additionally it is essential to identify ecological indicators that could be easily used by managers to monitor such pressures.

Birds are highly sensitive to modification in their habitat and therefore amongst the 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, I undertook a study in Shiwalik landscape of northern India. One of the most important reasons for selecting this landscape was its significance for conservation of various large mammals and diverse assemblages of resident and migrant bird communities. At the same time, the landscape experiences 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 regions of the world. Realizing the conservation significance of this landscape, special protection has been provided to forested areas by designating them as protected areas. However, protected areas also suffer from biomass extraction carried out by local communities residing within and along the fringes.

My main research aims were to:

1. Identify the major causes of disturbance in three main forest type of this landscape and assess if disturbance depends on degree of protection.

2. Quantify impacts of disturbances on different layers of vegetation (tree and shrub) and examine changes in structure and composition of the habitat, if

any.

3. Investigate the response of birds community and foraging guild levels to habitat degradation in different forest types during breeding and non-breeding seasons.

4. Identify indicator bird species suitable for future monitoring of small-scale extractive disturbances in this landscape.

A contiguous stretch of the Shiwalik landscape between river Yamuna in the west and river Ganga in the east was selected to carry out this study. Within this area sampling sites were selected in three major forest types namely, Dry Plain Sal forest, Dry Shiwalik Sal forest and Moist Shiwalik Sal forest. I identified potential sampling sites, across a disturbance gradient. Later, in each forest type, I selected 10 sampling grid, totaling to a 30 grids across the landscape. Each grid had an area of 1 km^2 and a surrounding buffer of at least 250 m on each side. In each grid, I laid nine systematic intensive sampling points with inter-point distance of 250 m.

At each intensive sampling point, I quantified vegetation structure and composition, anthropogenic disturbances and birds. Each site was visited at least six times covering one breeding and one non-breeding season to understand the seasonal changes in disturbance regimes and bird communities. Sampling grids of both dry Shiwalik sal forest and dry plain sal forest were largely located in the western part of Rajaji National Park and Shiwalik Forest Division, while that of the moist Shiwalik Sal forest were located in the Dehradun Forest Division and Rajaji National Park.

I compared disturbance variables and also examined their degree of segregation across forest types. Relationship between proximity of human settlements and various disturbances was analyzed. I used conditional modeling approach to investigate the disturbance variables responsible for the (i) presence and (ii) abundance of an exotic invasive shrub *Lantana camara* in the study area. Bird density for grids and sampling points were estimated using Distance sampling approach. Birds were categorized into feeding guilds at coarser and finer scales. I used generalized linear mixed effect models to examine the response of vegetation and birds to various habitat variables. Due to vast seasonal changes in bird community composition separate models were built for breeding and non-breeding season.

I found a strong positive correlation among disturbance variables at land-

scape scale which indicate synergistic behavior of small-scale extractive disturbances. Dry Shiwalik Sal forest and Dry Plain Sal forest faced higher lopping and livestock grazing pressures compared to Sal *Shorea robusta* dominated moist forest. Village density explained lopping and grazing disturbance but level of protection (national park *vs* forest division) governed firewood and timber extraction.

Small-scale extractive disturbances have significantly modified the vegetation structure at both shrub and tree layer across forest types. It especially resulted in the decline of (i) canopy cover and (ii) shrub height. The major causative agent for native shrub cover loss in the Dry Plain Sal forest and Moist Shiwalik Sal forest was past timber extraction whereas in the Dry Shiwalik Sal forest it is the livestock grazing. Small-scale extractive disturbances have not modified the tree species composition as yet but has significantly altered the native shrub composition. These disturbances have led to invasion and spread of, one of the world's most invasive species, *L. camara* in the understory of all forest types. Such changes in vegetation structure and invasion of exotic species are expected to modify vegetation composition in future.

Over two years of sampling period a total of 173 bird species was recorded from the study area through 19184 observations. Bird communities in all these forest types are different during breeding and non-breeding seasons 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.

L. camara cover increased the overall bird richness and density across all forest types and seasons. It also increased similarity in bird composition across sampling plots within Dry Plain Sal forest. Coefficient of variation of tree crown cover, an index of horizontal heterogeneity, was another important variable which positively influenced bird species richness during breeding season. Out of disturbance variables, firewood collection resulted in low species richness across seasons. 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 and moist forest had resulted in increased similarity in bird community composition among sampling plots.

At the plot level, I did not observe any trend in guild densities across disturbance gradient. 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 disturbance. Guilds with fruit diet were benefited by *L.camara* cover. Granivorous and omnivorous birds increased with increasing disturbances.

A total of 66 species of birds emerged as indicators of overall disturbance in three forests. Highly disturbed areas were indicated by generalist species whereas specialist species were associated with less disturbed habitats. Jungle babbler *Turdoides striata*, Spotted dove *Streptopelia chinensis*, Jungle crow *Corvus macrorhynchos* indicated highly disturbed areas whereas species specialized in foraging strategy or substratum such as Jungle prinia *Prinia sylvatica*, Emerald dove *Chalcophaps indica*, Great tit *Parus cinereus* indicated less disturbed areas.

Species specialized in foraging from bark of tertiary branches such as Great tit *Parus cinereus* and Nuthatches decreased in abundance with increasing disturbance due to firewood and small-timber extraction. Livestock grazing led to decline in abundance of understory birds such as Jungle Prinia *Prinia sylvatica* and Red Junglefowl *Gallus gallus*. However, understory generalist species such as Himalayan Bulbul *Pycnonotus leucogenys* and Red-vented Bulbul*Pycnonotus cafer* increased with increasing lopping pressure. Increment in density of such species could be attributed to high density of *L.camara* in disturbed areas. Highly degraded areas of all forest types were indicated by similar set of bird species indicating homogenization of bird community. Interestingly, few migrant bird species were also responded strongly to extractive disturbances. Hume's Leaf-warbler *Phylloscopus humei* 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 utility in monitoring program. With the help of literature, I identified four parameters for increasing the robustness of indicator species. In addition to the sensitivity to disturbance, detection in field, seasonal availability in the landscape and cross-forest distribution were the criteria used for ranking and selecting the final set of top indicators. A total of 15 species emerged as top indicators for monitoring high and low-level of disturbances.