FINAL TECHNICAL REPORT

EFFECTS OF FOREST USE ON BIODIVERSITY CONSERVATION VALUES AS SEEN IN BIRD COMMUNITIES OF SARISKA TIGER RESERVE, RAJASTHAN

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1. Abstract

A study was carried out in a tropical dry forest in India, to investigate the effects of extractive activities such as fodder and firewood collection, on native bird communities and to study the relative influences of altered vegetation composition and structure on them. The study was based on comparison between five 'disturbed' (extracted) and five 'undisturbed' (non-extracted) sites in the riparian habitat, that were delineated using quantitative disturbance indicators. Birds were sampled eight times over a period of 6 months (summer & monsoon) utilising the fixed radius point count method. Six different variables related to vegetation structure (canopy cover, basal area, average tree height, tree density, tree height diversity and tree species richness) were quantified as also tree species composition. There was no significant difference in number of recorded species, bird abundance or bird diversity index between disturbed and undisturbed sites. However, bird species composition differed significantly between disturbed and undisturbed sites. Eight of 45 (18%) locally abundant bird species showed significant selection for either disturbed or undisturbed habitats. Of these eight species, four chose undisturbed habitats and four, disturbed. All four species adversely affected by disturbance are primarily insectivorous. Canopy cover, tree basal area and tree species richness were significantly lower in disturbed sites in comparison to undisturbed sites. In both habitats, bird species composition was significantly dependent on these components of altered vegetation structure. Tree species composition was not significantly altered by disturbance in riparian forest. Also, tree species composition did not significantly affect bird species composition. Partial Mantel's tests confirmed that there were no significant residual effects of tree species composition on bird composition after the effects of vegetation structure were accounted for. Our study indicates that rural biomass extraction can have significant effects upon bird species composition of tropical scrub forest which is caused principally by alteration of vegetation structure, rather than by changes in forest tree composition.

2. Introduction

Biomass extraction, in the form of grazing, fuelwood and non-timber forest product (NTFP) collection, may be the most widespread pressure on forests in developing countries, where rural populations depend significantly on them for their sustenance as well as livelihoods (e.g. Hegde and Enters, 2000; Harris and Mohammed, 2003). In some ecosystems, the contribution of NTFP to rural income may be as much as fifty percent leading to high levels of extractive pressure on forest resources (Hegde et al., 1996).

There is evidence that the long-term extractive use of forests may cause significant changes in both vegetation structure and composition of forests (e.g. Murali et al., 1996; Shankar et al., 1998; Tilman and Lehman, 2001; Sagar and Singh, 2004). Changes in vegetation attributes caused by anthropogenic disturbances, in turn, have the potential to influence native forest fauna, particularly species that are rare, resource-specialised or habitat-restricted (Bawa and Seidler, 1998; Terborgh, 1998; Shahabuddin and Prasad, 2004). Yet the consequences of rural biomass extraction for forest fauna have been scantily studied despite the fact that such information is essential for effective conservation planning in developing countries (but see Du Plessis 1995, Laiolo 2003). Studies on the influence of biomass extraction in tropical dry forest ecosystems are, in particular, very limited, despite the fact that this biome comprises nearly half of all tropical forests and faces heavy pressure for subsistence extraction (Sagar and Singh 2004; Sagar et al 2003; Sanchez-Azofeifa et al 2005).

Avifaunal communities are highly sensitive to changes in habitat caused by human use and modification (Raman et al., 1998; Thiollay, 1999; Lohr et al., 2002). Studies show that most changes in bird communities in degraded habitat are caused by changes in forest vegetation structure such as in the density of trees, density of bamboo understorey, tree size class variation, densities of old trees and snags, and amount of woody litter (Du Plessis, 1995; Lohr, Gauthreaux and Kilgo, 2002; Raman et al., 1998). However, in some cases, bird communities are also impacted by changing tree species composition because bird species may depend on specific nectar or fruit sources or on breeding habitat whose spatial occurrence is influenced by disturbance (Raman, 2006). Tree composition may also influence vegetation structure due to varying canopy architectures across species or changed dominance of plant groups having distinct architectures. For instance, increased abundance of bamboo or cane within tropical forests can considerably alter forest structure.

In this research project, we quantify effects of anthropogenic disturbance caused specifically by altered vegetation structure and composition, on bird species assemblages of a tropical dry forest, located in Sariska Tiger Reserve in northern India.

3. Objectives

The questions that are addressed in the present study are: (1) does anthropogenic disturbance caused by biomass extraction affect the diversity and composition of forest avifaunal communities and if so, in what ways? and (2) what is the relative importance of altered forest vegetation structure and composition through which the changes in avifaunal community (if any) are mediated? Effects on the bird community are studied with respect to diversity, abundance and species composition while changes in vegetation structure and composition are studied with respect to attributes of the tree layer (see schematic of study questions in Figure 1).

4.Methodology

Study Area

Sariska Tiger Reserve (henceforth referred to as Sariska), a protected area located in the Indian state of Rajasthan in north-western India, was one of the important areas for conservation of the endangered tiger (*Panthera tigris*) in India until its recorded local extinction in late 2004 (Johnsingh et al., 1997; Mazoomdar, 2005; see Figure 2). Sariska covers an area of 866 km^2 and is located in the semi-arid zone delineated as biogeographic province 4A (semi-arid Gujarat-Rajputana) (Rodgers et al., 2000). The area is seasonally dry, experiencing an average annual rainfall of 650 mm and extremes of temperature with cold winters and extremely hot summers (April through June) (Government of Rajasthan, 2002). Sariska has an extremely diverse flora and fauna typical of the tropical dry forest biome of India. The Reserve has been designated as an Important Bird Area as it harbours as many as 183 bird species. Additionally, as many as 50% of the Indian bird species that are endemic to Indo-Malayan tropical dry forest realm of Asia, have been reported from here (Shahabuddin, Kumar and Verma, 2006; Jhunjunwala et al., 2001).

Sariska is covered by tropical deciduous and tropical thorn forests (Champion and Seth, 1968) found in three distinct associations. Hill slopes are covered by dry deciduous forests dominated by Anogeissus pendula. Rocky valleys with seasonal streams or perennial springs, harbour diverse semi-deciduous forest (referred to as riparian forest) of Ficus glomerata, Dendrocalamus strictus and Phoenix sylvestris among other species. In drier and flatter terrain without permanent water sources, scrub forest habitat occurs widely, dominated by tree species of short stature such as Ziziphus mauritiana, Butea monosperma and Acacia leucophloea. The understorey is diverse having a wide variety of grasses and thorny shrubs such as Capparis decidua, Capparis sepiaria and Grewia flavescens. A number of exotic invasive species have become common in the intensively used areas of the Reserve such as the annual shrub Cassia tora and the short-statured tree Prosopis juliflora, a species of Central American origin.

Sariska formed part of the game preserves of the Maharajah of Alwar, who closed off this area to public access, during the early twentieth century (Johari, 2003). After Indian independence, when the Alwar principality was annulled, Sariska Wildlife Sanctuary was notified comprising an area of 195 km^2 in 1955. Inside the sanctuary, there was extensive felling between 1955 and 1968 according to working plan prescriptions, after which commercial felling ceased (Johari, 2003). In 1979, Sariska was declared a Project Tiger Reserve, which today covers a total area of 866 km^2. The Tiger Reserve, however, still has scattered human settlements of local graziers who mainly live off livestock rearing, living in 27 hamlets.

It is thus important to note that Sariska has been subject to varying degrees of biomass extraction including timber-extraction, grazing, and collection of non-wood forest produce since recorded history is available. However, during the last twenty-five years since declaration as a Tiger Reserve (1982), parts of the Reserve have been strictly protected from anthropogenic disturbance enforced by patrolling and frequent compounding of cattle. Areas close to villages and on the periphery of the Reserve, however, continue to undergo grazing and other biomass extraction to varying extents (see also Yadav and Gupta, 2006). Our study is limited to studying the impacts of relatively *recent* (over approximately 25 years) anthropogenic disturbance that has been caused by subsistence-level biomass extraction activities.

Being primarily livestock herders, the main source of income for local residents is the production of milk, for which they graze their livestock inside the Reserve. Several villages outside the Reserve boundaries also depend on the forests inside for fodder and grazing. Mostly goats and buffaloes are kept but some people also keep sheep and cattle. Apart from grazing their livestock, people commonly lop leaves and branches from trees and shrubs for stall-feeding. People also collect deadwood and tree branches from the Sariska forests to meet their fuelwood requirements (pers. obs.). Trees and woody shrubs are felled occasionally for firewood. Additionally, a number of fruits and other plant parts are locally used as food (Shahabuddin et al., 2005).

Study Design

We quantitatively compared avifauna and forest vegetation between areas facing high pressure of biomass extraction and those that are better protected and currently face little or no anthropogenic pressure (henceforth referred to as 'disturbed' and 'undisturbed' sites, respectively). Ten sites for this study were selected in areas visually varying in disturbance levels, all of which were located in riparian forest. (see Figure 2 for location of study sites). The riparian habitat was chosen for detailed study because it is one of the three most widespread forest types inside the Reserve and possesses a distinctive floral and faunal assemblage (Shahabuddin and Verma, 2003). Native riparian forest has also become rare in northwestern India due to the fact that this habitat occurs in well-watered sites that also attract livestock and settlers. The selection of sites in riparian forest habitat was based on detailed discussions with park staff, village people and tourist guides in addition to our visual assessments of patterns of human use. Once the sites were selected, quantitative descriptors of anthropogenic disturbance were measured at each of the ten sites, for the purpose of grouping them into two distinct levels of disturbance (see 'Data Analysis' below). We emphasise that, for the purposes of this study, the terms 'disturbed' and 'undisturbed' only imply differential intensities of biomass extraction rather than a watertight distinction between used and unused zones.

For quantifying disturbance indicators, a randomly-oriented, a 500m-long, line transect was established at each site. Three circular plots, each of 10m-radius, were established along each transect: one each at the start, centre and the end, with the inter-point distance of 150–300 m. Thus, a total of thirty circular plots were marked inside the Reserve equally distributed over the designated ten study sites. The starting points of the ten study sites were located at a minimum distance of 650 m from each other. Additionally, using a GPS, it was ensured that the circular plots in adjacent line transects were no closer than 250 m.

Data Collection

Four distinct indicators of disturbance due to biomass extraction were recorded for each circular plot: proportion of trees showing signs of lopping, average scale of lopping of trees, number of human trails traversing the plot and number of piles of livestock dung.

These variables were chosen to reflect the intensity of use of the site for grazing, fodder-collection and fuel wood extraction by local people. While average scale of lopping of trees reflects the frequency of fodder- and fuel wood collection by people, livestock dung indicates the degree of usage by grazing livestock including goats, buffalo and cattle. The number of human trails traversing the plots also indicates the intensity of use by people for grazing as both people and livestock tend to use regular paths through the forest.

In each circular plot, we enumerated all the trees having girth at breast height (GBH) >20 cm (or DBH of 6.4 cm). The proportion of total number of trees showing signs of lopping was recorded. Lopping score for each tree was additionally measured on a scale of 0–4, as follows – 0: no lopping; 1: rudimentary signs of lopping; 2: up to half of the main branches lopped; 3: more than half of main branches lopped and 4: tree reduced to a stump. Intensity of lopping was calculated as the total lopping score divided by the total number of trees present. In each plot, the total number of dung pats of livestock was also recorded as an indicator of usage of the habitat by livestock. The number of distinct foot-trails running through each 10m-radius circular plot was also counted. Each of these four variables indicating disturbance was then averaged over a site's three circular plots to give a representative value for each site (see Table 1). We emphasise here that each of the measured disturbance indicators represent the combined effect of various anthropogenic activities on the forest including biomass extraction activities such as grazing, fodder-collection, wood-cutting, collection of fruit, trampling as well as simply physical disturbance, since these different forms of human use cannot be separated from one another. Table 1 lists the average value of the disturbance indicators in each of the ten study sites.

We studied vegetation structure of the tree layer in terms of 6 distinct variables at all of the same plots that had been studied for disturbance indicators: canopy cover, basal area, tree density, average tree height, tree height diversity and tree species richness. Canopy cover and basal areas can be substantially reduced by human use due to the prevalent practice of lopping tree branches and leaves for livestock fodder (pers. obs.). Extractive activities also affect height of forest over the long term because continual use for fodder does not allow trees to grow to their maximal heights (see also Kumar and Shahabuddin, 2005). Preferential use of certain tree species has resulted in highly diminished species richness (Kumar and Shahabuddin 2005) and vertical stratification (pers. obs.), which was sought to be measured through tree height diversity.

Within each 10m-radius circular plot, we assessed canopy cover at every 1m interval along its two mutually perpendicular diameters with the help of an improvised densitometer. At each of a total of forty points located thus, a hollow pipe with cross-wires at the end was used to look up at the canopy and the presence or absence of overhead vegetation at the cross-wire was recorded as '1' or '0' respectively. The proportion of points where overhead vegetation was recorded gave us the quantitative proportion of canopy cover for that plot. Tree density was quantified as the total number of trees occurring inside the plot, that had GBH >20 cm (or DBH >6.4 cm). We measured GBH of individual trees using a tape measure, which was used to calculate the tree basal area for the plot. Height of trees was calculated with the help of tape measure and shypsometer, and averaged over the total number of trees inside the plot as average height of trees. In addition, tree height diversity was calculated as a Shannon Diversity Index based on the number of woody stems in each height class (defined as 0-3 m, 3-6 m, 6-9 m, 9-12 m and 12-15 m).

Each of the six measured variables related to vegetation structure was averaged across the three circular plots in each site. It was this average value for each of the ten study sites in scrub vegetation that was utilised in all subsequent analyses (see Table 2).

We used fixed-radius point counts, located at each of the ten sites, for collecting data on avifaunal species abundance, diversity and composition (Bibby et al., 1992; Raman, 2003). At each of the sites, point counts were centred on the same circular plots as were used for sampling disturbance and vegetation structural characteristics (see above). We sampled each of the sites repeatedly, in all, eight times during the course of the study, i.e., from April 2007 through September 2007. These periods covered the well-demarcated monsoon and summer seasons in the Reserve, respectively. Thus a total of 240 point counts were undertaken across the ten study sites during the course of the study.

On a given day, we recorded all the birds occurring within a 30m-radius of a particular site for ten minutes, after a 2-minute waiting period. Birds were identified using Ali and Ripley (1983) and Grimmett et al. (1998). We did not record birds observed to be flying over the 30m-radius of the study point or soaring overhead. However, flying birds were recorded if they were flushed out from within 30m-radius of the study point by the observer or observed to be flying into or out of the transect area during the ten-minute duration of the count. Calling birds were also recorded if the observer was sure that they were calling from within the fixed radius of 30 m.

We started counts half-an-hour after sunrise and continued for two hours after that, usually between 7.30 AM and 9.30 AM, each morning. We sampled either one or two sites on each sampling day. The order of the two sites taken on a particular day was permuted for the following sampling round to take into account the possible diurnal variation in detection of bird species. All bird counts were undertaken by same pair of observers throughout the period of the study. No bird counts were undertaken during cloudy or foggy weather.

At each of the ten sites, we calculated abundance of each bird species by totalling all the records over the seven temporal and three spatial replicates at each site. This calculation thus represents frequency of observation and is thus an indicator of habitat utilisation. The cumulative number of species recorded at a given site was used as a surrogate of species richness. Species diversity was quantified using the Shannon Diversity Index. The cumulative number of individual birds recorded at a given site was used as an indicator of total bird abundance.

Statistical analyses

A Principal Components Analysis (PCA) was carried out with the four disturbance indicators to separate the sites into two clusters-one that represented high degree of use and extraction and the other that represented relatively low level of biomass extraction. For the PCA, each of the disturbance indicators was first relativised on a scale of zero to one, following Jongman et al. (1995) so that no single variable was weighted more in comparison to the others.

Effect of disturbance on bird community diversity and composition (see Figure 1)

Rank bird abundance (of all species), number of species recorded and diversity were compared between disturbed and undisturbed sites using non-parametric two-tailed Kruskal-Wallis tests for difference in means (Sokal and Rohlf, 1994). Being based on ranked data, Kruskal-Wallis tests do not require the assumptions of homogeneity of variances within groups and normality of data points, assumptions that are often difficult to meet in the case of biological community data.

To test if bird species composition differed significantly between disturbed and undisturbed sites, multi-response permutation procedure (MRPP) was used (McCune and Grace, 2002). This statistical test, based on randomisation, has been specially designed to assess similarity in species composition amongst two or more groups of sites. It tests the hypothesis that groups of sites differ more from each other in terms of species composition than expected by chance and yields a probability value that is statistically interpreted as a parametric significance level (McCune and Grace, 2002). MRPP is based on calculation of similarity indices calculated between pairs of sites. The similarity measure used in this case was Sorensen's index, also known as Bray-Curtis index (Krebs, 1999; McCune and Grace, 2002). MRPP can also be used to assess differences in any other given variable between two or more groups, based on randomizations.

To see which bird species, if any, specifically respond to disturbance regimes, frequencies of sightings of each species across ten sites, was subjected to indicator species analysis, a randomization-based technique used to describe the value of different species for indicating environmental conditions (Dufrene and Legendre, 1997, McCune and Grace, 2002). Being based on concepts of abundance and frequency, it combines both 'fidelity' and 'exclusivity' of a species to a group of sites. In the present case, it is ideal for assessing adherence of a species to a particular disturbance regime, based on our initial grouping of 'disturbed' and 'undisturbed' sites. Indicator values range from zero (no indication) to 100 (perfect indication) and are associated with a probability value, which is interpreted similarly to a P-value in parametric assessments. The P-value specifically represents the proportion of randomised trials with indicator value equal to or exceeding the observed indicator value of the given species. Indicator species analysis was carried out only for species seen more than 5 times during the course of the study.

Effect of disturbance on vegetation structure and that of vegetation structure on bird community (see Figure 1)

Each of the six structural variables were compared between disturbed and undisturbed sites using MRPP tests of difference to investigate the effects of disturbance on specific attributes of forest vegetation structure. The values of these attributes for the ten sites are listed in Table 2.

Mantel's tests were used to study effects of various vegetation structural variables on bird species composition. Mantel's test is a method that tests for associations amongst two or more variables using randomisation procedures rather than parametric methods (McCune and Grace, 2002). Variables to be tested are first converted to similarity matrices that are based on the degree of likeness between pairs of sites, based on the attributes that are recorded. Thus a similarity matrix for each structural variable tested, was composed of ten rows and ten columns with each item representing the degree of likeness between two sites in terms of the given variable. Species composition matrices were constructed of similarity indices calculated between all possible pairs of sites, again formed of ten rows and ten columns. In the present case, the similarity measure used for quantifying similarity of species composition among sites was the Bray-Curtis similarity index (Krebs, 1999). Mantel's test calculates the degree of association between the two distance matrices using simple correlation but tests the significance of the correlation coefficient by comparing it to values generated by randomising the matrix many times (10,000 times, in this case). The alternative hypothesis in a Mantel's test is that the observed value of the correlation between two distance matrices is greater than values that may be observed by chance.

The advantage of using Mantel's tests is that randomisation allows inference without assumptions of normality and much greater power than parametric tests (Manly, 1991). Additionally, Mantel's tests allow the incorporation of species composition into the analysis along with other variables through use of similarity indices, which is not possible otherwise.

Effect of disturbance on tree species composition and that of tree species composition on bird species composition (see Figure 1)

Mantel's tests were also used to study the effect of disturbance on tree species composition using similarity matrices and the effect of tree species composition on bird species composition, in the same manner as described for the bird species composition - vegetation structure analysis.

Relative importance of vegetation structure and vegetation composition

The relative importance of vegetation composition and vegetation structure, on bird species composition was analysed using partial Mantel's tests (McCune & Grace 2002). While simple Mantel's test compares two matrices, partial Mantel's test calculates the association between two distance matrices while taking into account a third. We therefore used partial Mantel's tests to explore the association between (1) bird species composition with vegetation structure while accounting for vegetation composition, and (2) bird species composition with vegetation composition while accounting for vegetation structure.

Software used

PCA, Mantel's tests, MRPP and indicator species analysis was carried out using PC-ORD, a statistical software specifically designed for analysing ecological community data (McCune and Mefford, 1999). Kruskal-Wallis tests were done with the help of S-PLUS statistical software.

5. Results/Findings

Grouping sites on basis of disturbance levels

Figure 3 shows the ordination of 10 sites based on PCA of the four relativised disturbance indicators: per cent trees lopped, scale of lopping, number of livestock dung piles and number of human trails. The first PCA axis accounted for 99.35% of variance in the data matrix while the second PCA axis accounted for an additional 0.65% of variance. The results of the PCA show that almost all of the variation in the set of disturbance indicators is accounted for by the first PCA axis. From this it can be inferred that different elements of anthropogenic disturbance, such as leaf collection, firewood collection and grazing, tend to occur together. This result is also borne out by our observations of the way in which local villagers use the forest habitat.

The plotting of the sites along the two PCA axes shows that sites are clustered into two groups along Axis 1. Consequently this classification of sites into two groups (5 in disturbed and 5 in undisturbed habitat) was then used for all further analysis in comparisons of disturbed and undisturbed sites (also refer to Table 1 for details on disturbance indicators of each site).

Effects of disturbance on bird community attributes and species composition

MRPP using the bird species-site matrix indicates that bird species composition differs significantly between disturbed and undisturbed sites (P=0.03).

Kruskal-Wallis tests indicate that disturbed and undisturbed sites do not differ significantly in terms of net bird abundance (χ^2=0, P=0.1, df=1) or total number of species recorded (χ^2=0.93, P=0.33, df=1) (see Figures 4a,b). Bird diversity index as measured by Shannon-Wiener's Diversity Index was not significantly different between undisturbed and disturbed sites (χ^2=0.01, P=0.91, df=1) (Figure 4c).

Of the 74 species recorded during transect counts, 45 were abundant enough to be analysed having been observed 5 times or more (refer to Table 3). Of these species, 8 species (18%) showed significant selection for either disturbed or undisturbed habitat at a significance level of 5 per cent (Table 4). While four species, such as, laughing dove (*Streptopelia senegalensis*) and Eurasian collared dove (*Streptopelia decaocto*) showed significant selection for disturbed habitats, four others such as Tickell's blue flycatcher (*Cyornis tickelliae*) and painted spurfowl (*Galloperdix lunulata*) showed significant selection for undisturbed sites. The remaining species did not show significant selection for either disturbance regime. Indicator values of the species showing significant selection ranged from 77% in great tit to 100% in painted spurfowl (refer to Table 4).

Disturbance-vegetation structure-bird species composition relationship

Kruskal-Wallis tests carried out to investigate the effect of disturbance on vegetation structural attributes showed that percentage canopy cover, tree species richness and tree basal area were significantly lower in disturbed sites in comparison to undisturbed sites (percentage canopy cover χ^2=6.32, P=0.01; tree species richness: χ^2=5.06, p=0.02; tree basal area: χ^2=3.94, P= 0.01). However, tree density, tree average height and tree height diversity were not significantly different between disturbed and undisturbed sites.

Simple Mantel's tests for impacts of single structural variables on bird species composition indicated that bird species composition is strongly linked to canopy cover (Mantel's R=0.3438, P=004.) and basal area (Mantel's R= 0.3213, p=0.04), but not to mean tree height (Mantel's R=0.2619, P=0.09), tree density (Mantel's R=-0.2099, P=0.07), tree height diversity (Mantel's R= -0.2254, P=0.08) or to tree species richness (Mantel's R= 0.0550, P=0.32). Taken together, the vegetation structural variables had a significant effect on bird species composition (Mantel's R=0.3361; p=0.05).

Disturbance-vegetation composition-bird species composition relationship

MRPP tests showed that tree species composition was not significantly different between disturbed and undisturbed sites (P=0.6423); see Kumar and Shahabuddin (2005) for details of altered tree species composition in the study sites). Also, there was no significant relationship between bird species composition and tree species composition (Mantel's R=0.2753; P=0.0967).

Combined model: Effects of tree species composition and vegetation structure on bird species composition

Partial Mantel's tests carried out for testing association between bird species composition and vegetation structure, accounting for vegetation composition, yielded a Mantel's correlation coefficient (R) of 0.36 which was significant at the alpha of 0.05 ($p<0.0326$). On the other hand, partial Mantel's test carried out for correlation between bird species composition and vegetation composition, accounting for vegetation structure, yielded a Mantel's R 0.2706 for scrub forest, which was insignificant ($p<0.0608$). These results indicate that there are no significant residual effects of vegetation composition on bird species composition over and above that caused by altered vegetation structure. In other words, altered vegetation structure accounts for most observed changes occurring in bird species composition due to disturbance.

6. Discussion

The current study shows that there can be significant impacts of biomass extraction on vegetation structure, and in turn, on native avifaunal communities of tropical dry forests. However, forest vegetation composition is not significantly altered by disturbance, nor does vegetation composition have any additional impacts on avifauna. The results of the current study are significant because the present ambiguity in conservation policy (see also Adams and Hulme, 2001; Schwartzman et al., 2000), regarding the possible ecological impacts of rural biomass extraction, has remained largely unresolved due to the paucity of quantitative studies in various extractive regimes. The current study represents a significant addition to our quantitative knowledge of ecological impacts of rural forest use in the tropical region, particularly the threatened riparian forest habitat.

Canopy cover, tree basal area and tree species richness were found to decline significantly with disturbance in Sariska. All these structural features are potentially important for fauna, particularly birds, in any forest ecosystem. Similar trends were seen in tree density, mean tree height and tree height diversity, though the differences were not statistically significant (see Kumar and Shahabuddin, 2005 for details). In the present study, bird species composition was found to respond, though weakly, to these elements of disturbance-altered vegetation structure. Bird–habitat relationships similar to those found in the present study have been found in numerous instances in both the tropical and temperate zones (Thiollay, 1999; Raman and Sukumar, 2002; Skowno and Bond, 2003). Reduction in canopy cover of trees, as seen in the present study, have the potential to affect the nesting and foraging of bird species because birds exhibit great selectivity of habitat with respect to forest structure (MacArthur and MacArthur, 1961; Wiens, 1989; Raman & Sukumar, 2002). In particular, reduction in canopy cover, woody debris and numbers of snags produces dramatic effects on breeding bird communities (Du Plessis, 1995; Beese and Bryant, 1999; Lohr et al., 2002; Poulsen 2002). In southern Indian rainforests and plantations, bird community structure was related to woody plant and cane densities (Raman and Sukumar, 2002).

Tree species composition was not found to be altered significantly by disturbance in the riparian forests of Sariska. Our earlier study on vegetation of Sariska (Kumar and Shahabuddin 2005) found that there do occur certain tree species that are favoured by local graziers for fodder (such as *Dendrocalamus strictus* and *Ficus glomerata*). These species tend to disappear in heavily utilised sites, leaving unpalatable species such as date palm (*Phoenix sylvestris*). It is possible that the scale of sampling used in the present study was not large enough to capture spatial variation due to anthropogenic activities.

In this study, the bird species adversely affected by disturbance were found to be primarily insectivorous, such as the great tit (*Parus major*) and painted spurfowl (*Galloperdix lunulata*). Insectivorous birds have been found to be particularly sensitive to forest alteration, fragmentation and degradation in a number of other sites in the tropics as well (Johns, 1991, Canaday, 1997, Sekercioglu et al., 2002). In a study in Papua New Guinea, flycatcher species were found to be most affected by conversion of primary forest to small scale agricultural fields in relation to other bird taxa (Marsden et al., 2006). Insectivorous birds are possibly more vulnerable to habitat change due to their dependence on arthropods, which in turn, require specific microclimatic conditions in the forest vegetation. A recent study showed that the density of insects in tropical forest canopies shows a strong positive correlation with leaf area and a negative relationship with vapour pressure deficit, an indicator of dryness (Dial et al. ,2006). It is therefore very likely that microclimatic conditions in forest canopy and understorey, and consequently, insect prey, are altered by activities such as logging, conversion to plantations, shifting cultivation and in the present case, intensive biomass extraction.

While bird species composition changes significantly due to disturbance, net numbers of species and overall bird abundances are not significantly affected. Therefore it may be argued that anthropogenic disturbance may result in greater landscape-level bird diversity than if there were no human use at all, due to artificial creation of patches that support different assemblages of birds. However, in the context of Sariska, it is important to note that the species that tend to be encouraged by disturbance, such as laughing dove, are those that can also survive in the larger human-modified landscape including sites such as crop-fields, urban parks and gardens (Ali and Ripley 1983; Grimmett et al 1998). On the other hand, the species found to be adversely affected by disturbance, such as the great tit and painted spurfowl, are at risk of becoming locally extinct due to their preference for relatively dense forest, a habitat that is already highly restricted in extent in the semi-arid province of Rajasthan (Shahabuddin and Verma, 2003).

A relatively small proportion of species was adversely impacted at the scale of disturbance investigated in this study (9%). The small number of bird species found vulnerable to disturbance can partially be attributed to the small scale nature of disturbance that was investigated. Disturbed vegetation over a radius of 500 m to 3 km, was typically surrounded by protected patches in Sariska. Landscape context can be extremely important for bird species occurrence, because movements of birds may be coarse-grained in relation to the size of disturbed patches in the landscape (e.g. Raman, 2006; Pearman, 2002). A recent study in Amazonian rainforest found that species composition of the guild of shrub-layer insectivores responds to forest structure at relatively smaller scales (200-600 m) in comparison to other guilds of birds such as omnivores and shrub-layer frugivores (Pearman, 2002).

The study shows that even subsistence-level biomass extraction, if carried out continuously over several years, may cause a small proportion of vulnerable bird species to decline or even disappear locally. The results therefore indicate the need for a proportion of natural habitat to be strictly protected where the entire range of faunal diversity can be conserved. However, in order to ensure strict nature protection, there is an urgent need to develop alternatives to the household and livelihood needs for plant products, of people living in and around protected areas as also sustainable extraction plans for those forest products that cannot be substituted immediately.

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Table 1: Mean values of selected disturbance indicators in the 10 study sites in Sariska and the allotted disturbance regime based on ordination (see Figure 2).

Site	*Disturbance regime*	*% of trees lopped*	*Average scale of lopping*	*Average no. dung clusters*	*Average no. of trails*
R1	Disturbed	100.00	2.79	4.33	1.33
R10	Disturbed	100.00	3.60	17.33	1.33
R5	Disturbed	100.00	3.61	8.33	0.67
R9	Disturbed	97.78	2.98	2.67	0.67
R2	Disturbed	96.49	2.33	3.33	0.67
R6	Undisturbed	4.44	0.07	0.00	0.00
R3	Undisturbed	13.64	0.14	0.33	0.00
R4	Undisturbed	0.00	0.00	0.00	0.00
R7	Undisturbed	0.00	0.00	0.00	0.00
R8	Undisturbed	7.14	0.14	1.00	0.00

Table 2: Values of structural variables related to the tree layer for the 10 study sites in Sariska Tiger Reserve, Rajasthan

Site	Cnpy % (%)	Tr nos	Tr sp no	Tr ba (sq.m.)	Tr av ht (m)	Tr ht dv
Disturbed Sites						
R1	44.16667	19	3	3.901286	9.407383	1.767378
R10	3.333333	25	7	2.574936	6.608	1.488274
R2	63.33333	57	4	13.01494	13.4138	1.670356
R5	25	18	4	3.226978	13.16667	1.611158
R9	74.16667	45	4	3.662903	9.653333	1.751263
Undisturbed Sites						
R3	76.66667	22	10	6.227542	13.04545	1.495884
R4	74.16667	31	7	9.755354	12.16129	1.648031
R6	79.16667	45	6	9.224955	12.56667	1.554281
R7	95	29	7	63.5361	13.86207	1.770363
R8	88.33333	14	8	15.76508	11.89286	1.94591

Key to vegetation structural variables:

Cnpy %	Average % canopy cover
Tr nos	Total number of trees in 942 sq.m
Tr sp no	Cumulative number of tree spp recorded
Tr ba	Total basal area of trees
Tr av ht	Average height of trees
Tr ht dv	Diversity of tree heights

(All values refer to those measured in 942 sq.m. area)

Table 3. Bird abundances recorded in the ten study sites located in riparian forest, Sariska Tiger Reserve, Rajasthan

S.No.	Bird Species		Disturbed Sites					Undisturbed Sites				
	Scientific name	Common Name	R1	R10	R2	R5	R9	R3	R4	R6	R7	R8
1	-	Flycatcher (unidentified)	0	0	0	0	0	0	0	0	1	0
2	*Actitis hypoleucos*	Common Sandpiper	0	0	0	1	0	0	0	0	0	0
3	*Acridotheres tristis*	Common Myna	0	11	3	13	3	0	3	1	0	0
4	*Alcedo atthis*	Common Kingfisher	1	0	1	0	0	0	0	1	0	0
5	*Amaurornis phoenicurus*	White-breasted Waterhen	1	0	0	0	0	0	0	0	0	0
6	*Anthus trivialis*	Tree Pipit	1	0	2	0	0	0	0	0	4	2
7	*Ardeola grayii*	Indian Pond Heron	0	0	0	0	0	0	0	2	0	0
8	*Athene brama*	Spotted Owlet	0	0	0	5	0	0	0	0	0	0
9	*Butastur teesa*	White-eyed Buzzard	0	0	0	0	0	1	0	0	0	0
10	*Carpodacus erythrinus*	Common Rosefinch	0	0	0	0	0	1	0	0	1	0
11	*Cercomela fusca*	Brown Rock-chat	0	4	0	0	0	0	0	0	2	1
12	*Centropus sinensis*	Greater Coucal	0	0	0	0	0	0	1	0	0	1
13	*Columba livia*	Yellow-eyed Babbler	0	0	0	0	0	0	0	1	0	3
14	*Copsychus saularis*	Oriental Magpie Robin	3	3	2	5	0	3	0	3	5	2
15	*Corvus splendens*	House Crow	1	0	1	8	0	0	1	0	0	0
16	*Culicicapa ceylonensis*	Grey-headed Canary Flycatcher	0	0	1	0	0	1	2	0	4	4
17	*Cyornis tickelliae*	Tickell's Blue Flycatcher	0	0	4	0	0	2	5	5	7	5
18	*Dendrocopos mahrattensis*	Yellow-crowned Woodpecker	0	1	0	0	0	0	0	0	0	0
19	*Dendrocopos nanus*	Brown-capped Pygmy Woodpecker	0	0	0	1	0	0	0	0	1	0
20	*Dendrocitta vagabunda*	Rufous Treepie	12	3	11	0	4	1	8	5	4	10
21	*Dinopium benghalense*	Black-rumped Flameback	1	4	0	2	0	0	0	0	0	0
22	*Dicrurus caerulescens*	White-bellied Drongo	0	0	2	0	0	0	2	0	1	7
23	*Dicrurus macrocercus*	Black Drongo	0	0	0	2	4	0	0	1	0	2
24	*Egretta garzetta*	Little Egret	3	0	1	0	0	0	0	1	0	0
25	*Emberiza stewarti*	White-capped Bunting	2	1	4	3	0	0	3	2	4	5
26	*Eudynamis scolopacea*	Asian Koel	1	0	0	0	0	0	0	0	0	0
27	*Ficedula parva*	Red-throated Flycatcher	2	1	13	0	1	3	7	1	3	7
28	*Galloperdix lunulata*	Painted Spurfowl	0	0	0	0	0	1	2	2	2	1
29	*Halcyon smyrnensis*	White-throated Kingfisher	1	0	5	2	0	0	2	0	0	0

S.No.	Bird Species		Disturbed Sites					Undisturbed Sites				
	Scientific name	Common Name	R1	R10	R2	R5	R9	R3	R4	R6	R7	R8
30	*Ketupa zeylonensis*	Brown Fish Owl	1	0	0	0	0	0	0	0	0	0
31	*Lanius schach*	Long-tailed Shrike	1	4	0	0	1	0	0	0	0	0
32	*Lanius vittatus*	Baybacked Shrike	0	0	0	1	0	2	0	0	0	0
33	*Lonchura malabarica*	Indian Silverbill	0	2	0	0	2	0	0	0	0	0
34	*Melophus lathami*	Crested Bunting	0	0	0	3	0	0	0	1	0	0
35	*Merops orientalis*	Green Bee-eater	0	0	0	6	1	0	0	0	0	0
36	*Motacilla cinerea*	Grey Wagtail	0	0	0	0	0	0	0	1	0	0
37	*Motacilla flava*	Yellow Wagtail	1	0	0	0	0	0	0	0	0	0
38	*Muscicapa ruficauda*	Rusty-tailed Flycatcher	0	0	0	0	0	2	0	0	0	0
39	*Nectarinia asiatica*	Purple Sunbird	1	1	1	0	9	6	5	1	0	1
40	*Oriolus oriolus*	Golden Oriole	0	2	0	0	0	4	0	0	2	3
41	*Orthotomus sutorius*	Common Tailorbird	9	1	5	2	0	4	3	5	2	3
42	*Pavo cristatus*	Indian Peafowl	1	3	8	6	1	1	11	7	1	4
43	*Parus major*	Great Tit	5	2	7	0	0	7	7	15	12	6
44	*Pericrocoteus cinnamomeus*	Small Minivet	0	0	3	0	2	1	0	1	6	4
45	*Pernis ptilorhynchus*	Oriental Honey-Buzzard	1	0	0	0	0	0	0	0	0	0
46	*Petronia xanthocollis*	Chestnut-Shouldered Petronia	1	0	0	5	10	5	1	0	0	0
47	*Phalacrocorax fuscicollis*	Indian Cormorant	2	0	1	0	0	0	0	2	0	0
48	*Phylloscopus griseolus*	Sulphur-bellied Warbler	3	0	2	0	0	2	2	1	6	2
49	*Phylloscopus humei*	Hume's Warbler	16	1	12	2	1	24	10	15	18	17
50	*Phoenicurus ochruros*	Black Redstart	2	6	7	12	3	0	0	0	4	1
51	*Prinia hodgsonii*	Grey-breasted Prinia	0	1	2	0	2	7	0	2	2	0
52	*Prinia inornata*	Plain Prinia	0	2	0	2	1	2	0	0	0	0
53	*Prinia socialis*	Ashy Prinia	0	0	0	0	0	1	0	0	0	0
54	*Psittacula cyanocephala*	Plum-headed Parakeet	0	0	0	0	5	2	2	0	0	4
55	*Psittacula krameri*	Rose-ringed Parakeet	13	6	47	13	7	10	36	16	0	29
56	*Pycnonotus cafer*	Red-vented Bulbul	0	19	1	17	14	14	2	9	14	21
57	*Rhipidura aureola*	White-browed Fantail	1	5	0	3	2	8	3	0	7	8
58	*Saxicoloides fulicata*	Indian Robin	2	26	1	22	21	5	0	0	0	1
59	*Spilornis cheela*	Crested Serpent Eagle	0	0	2	0	0	0	0	1	0	0
60	*Streptopelia chinensis*	Spotted Dove	0	1	1	1	1	0	0	0	0	0
61	*Sturnus contra*	Asian Pied Starling	0	0	0	1	0	0	0	0	0	0

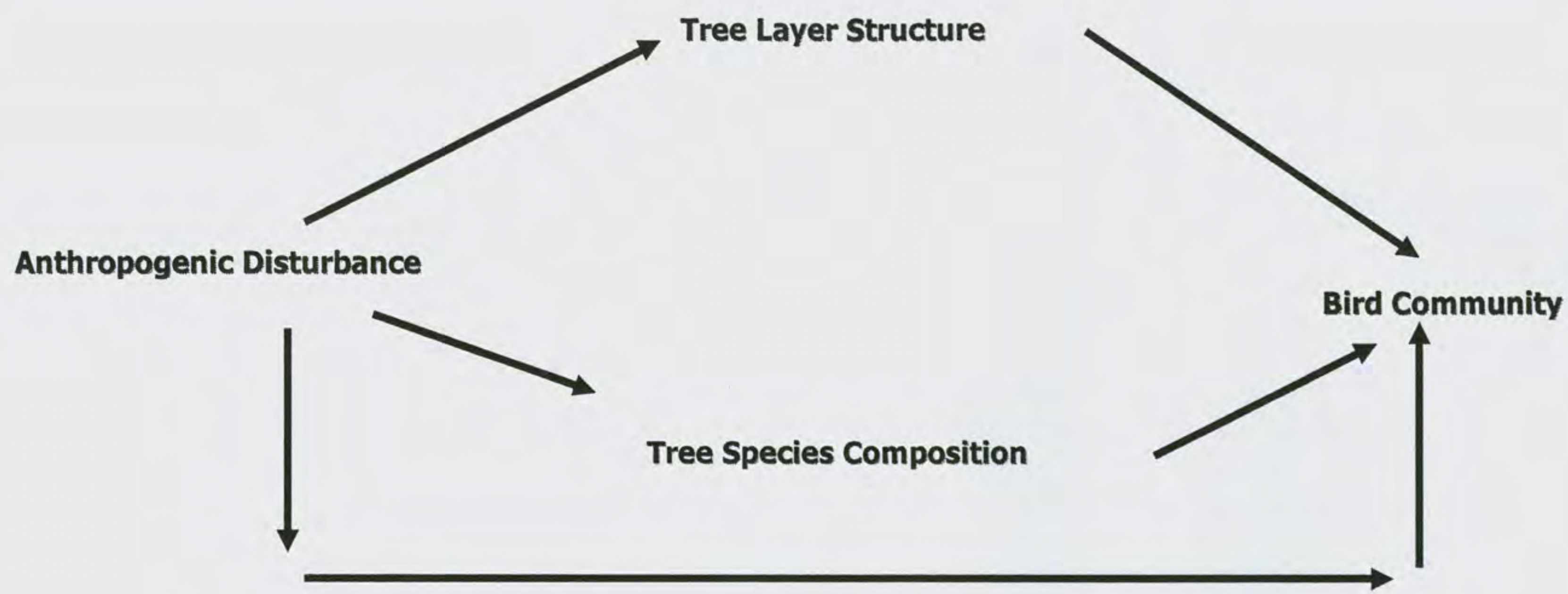
S.No.	Bird Species		Disturbed Sites					Undisturbed Sites				
	Scientific name	Common Name	R1	R10	R2	R5	R9	R3	R4	R6	R7	R8
62	*Streptopelia decaocto*	Eurasian Collared Dove	0	0	0	6	7	0	0	0	0	0
63	*Sturnus pagodarum*	Brahminy Starling	0	7	0	8	2	1	0	0	0	0
64	*Streptopelia senegalensis*	Laughing Dove	0	2	2	3	3	0	0	0	0	0
65	*Sylvia curruca*	Lesser Whitethroat	1	7	4	6	17	3	5	0	4	1
66	*Terpsiphone paradisi*	Asian Paradise-Flycatcher	0	0	0	0	0	3	0	0	1	0
67	*Tephrodornis pondicerianis*	Common Woodshrike	0	0	0	0	1	0	0	0	1	2
68	*Tringa ochropus*	Green Sandpiper	2	0	0	1	0	0	0	0	0	0
69	*Treron phoenicoptera*	Yellow-footed Green Pigeon	0	0	8	4	0	0	1	1	0	3
70	*Turdoides malcomi*	Large Grey Babbler	0	1	0	1	10	0	0	0	0	0
71	*Turdoides striatus*	Jungle Babbler	4	5	4	3	0	1	1	2	2	9
72	*Upupa epops*	Common Hoopoe	0	0	0	1	0	0	0	0	0	0
73	*Vanellus indicus*	Red-wattled Lapwing	6	0	3	0	0	0	0	0	0	0
74	*Zosterops palpebrosus*	Oriental White-eye	0	0	7	0	2	10	12	14	10	11

Table 4: Results of bird indicator species analysis through comparison between disturbed (n=5) and undisturbed sites (n=5). Only species showing significant indication value ($p < 0.05$) are shown.

Bird Species (Common Name)	Scientific name	Preferred Disturbance Regime	Indication Value (%)	P-Value
Tickell's blue flycatcher		U	85.7	0.0186
Painted spurfowl		U	100	0.009
Great tit		U	77	0.0364
Black redstart		D	85.7	0.0341
Indian robin		D	92.3	0.0458
Spotted dove		D	80	0.0482
Laughing dove		D	80	0.0482
Oriental white-eye		U	86.4	0.009

Note: D: disturbed sites; U: undisturbed sites

Figure 1. Schematic of inter-relationships between bird species composition, vegetation structure and vegetation composition being investigated.



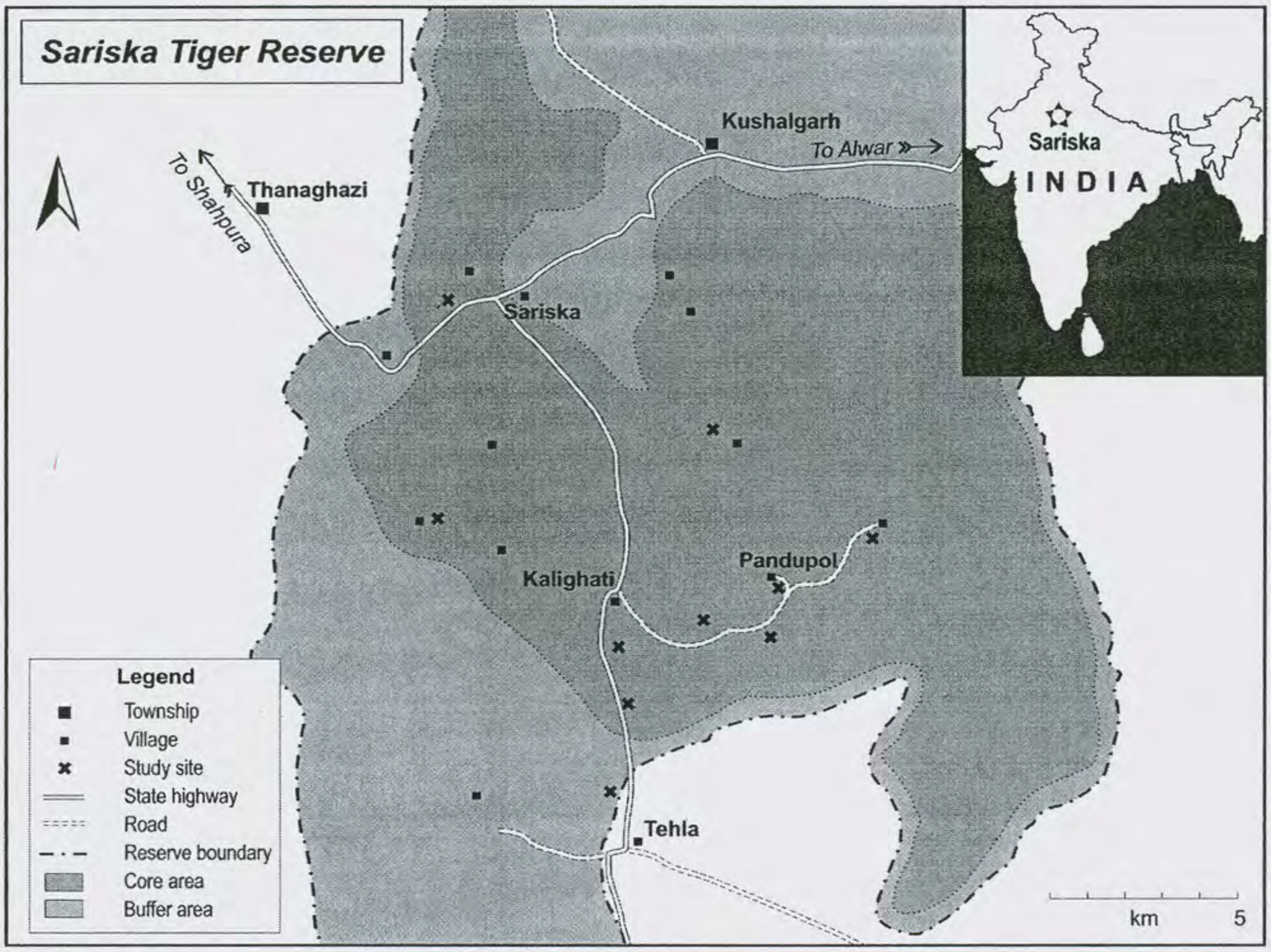


Figure 2. Map of Sariska Tiger Reserve in Rajasthan, India, showing administrative boundaries and the location of ten study sites in riparian forest habitat.

Figure 3. Ordination of study sites in riparian forest based on 4disturbance indicators

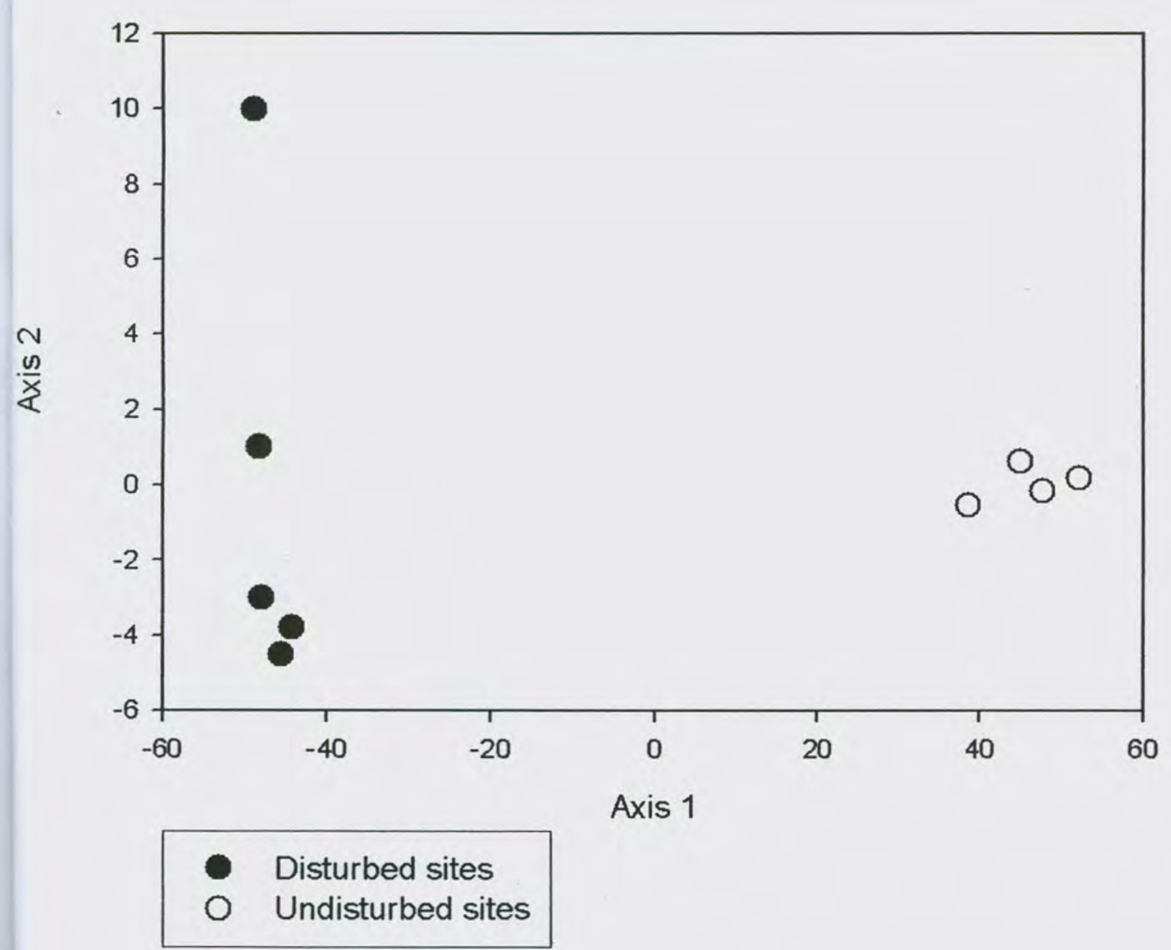
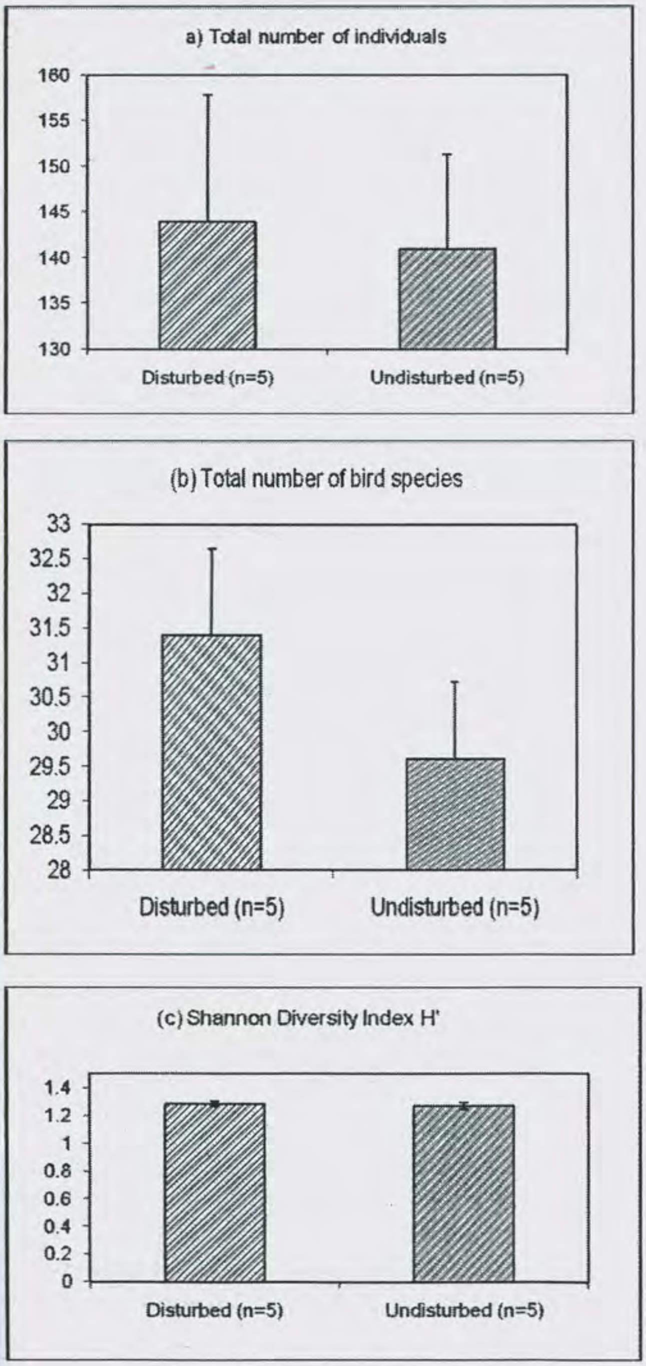


Figure 4. Differences in bird community characteristics between disturbed and undisturbed sites in Sariska Tiger Reserve in terms of (a) bird abundance (number of individuals recorded over the three spatial and temporal replicates in each site); (b) cumulative number of species recorded over the three spatial and temporal replicates in each site; and (c) diversity as measured by Shannon Diversity Index. Bars show mean values along with standard errors.



FINAL TECHNICAL REPORT OF RESEARCH PROJECT

PART III

1. **Recommendations including remedial measures relevant to the environmental problems studied under the Project**

a. Development of inviolate areas for biodiversity conservation should be an essential part of any forest management scheme so the entire range of organisms is preserved.

b. Development of alternative fuelwood and fodder resources for forest-dependent villagers

c. Restoration of tropical dry forest with naturally occurring species for conservation of biodiversity

2. **Utility of the findings of the project for industry/other organnizations**

The government can use the results of the study in formulating policy on wildlife conservation such as the amendments to the Wildlife Protection Act (1972) and Recognition of Rights of Tribals (and other Forest Dwellers) (2006).

3. **Whether any patents have been filed or are likely to be filed on the basis of the results**

None

4. **List of research papers published/accepted in the research work**

None

5. **Whether any research fellow associated with the scheme has been awarded PhD or any other higher degree**

None