Chapter Five

Ecological Change Along a Gradient of Forest Use

Abstract

I investigate changes in woody plant and small animal communities that result from forest resource harvest - specifically fuelwood, timber, tree fodder, bamboo, pollarded stems, leaf litter, and pasturage - at an isolated village in the Temperate Sikkim-East Nepal Himalaya (Chitre, Sankhuwasabha District, northeastern Nepal). I estimate the intensity of resource harvest across three progressively disturbed habitat zones, and assess the effects of harvest on wildlife habitats and the abundance, diversity, and composition of woody plant and small animal communities.

Most resource harvests occur in a zone of disturbed forest (DF) 300-600 m from the center of Chitre Village. Only pollarded stems are harvested primarily in village environments ≤300 m away (VE), and only bamboo is harvest exclusively in closed-canopy forest ≥600 m away (CF). Past harvest pressure has caused two-thirds of high-value woody plant species to decrease in abundance with proximity to the village, and all but a few low-value, disturbance-tolerant, woody species to increase. Among 51 woody plant species: 1) diversity (H') is highest in CF and no different between DF and VE, 2) basal area declines 17% from CF to DF and 36% from DF to VE, 3) the proportion of canopy volume contributed by large trees drops from 77-79% in CF and DF to 46% in VE, and 4) canopy heterogeneity, shrub cover, and shrub edge increase with proximity whereas bamboo cover decreases.

Among 70 small animal species, uncommon habitat- and dietary-specialists tend to decline with proximity, whereas regionally widespread habit- and dietary-generalists adapted to xeric habitats increase. Fifty-one percent are more abundant in DF than either CF or VE, 31% are

more abundant in CF than in either DF or VE, and habitat specialists are most diverse in DF and least diverse in CF. Bird diversity (H') is highest in DF and no different between CF and VE, whereas small mammal diversity does not differ significantly across zones.

Guild abundance (total detections of member species) varies across habitat zones more than guild richness (number of member species). Guilds that fare worse with increasing disturbance are avian strict frugivores and nectarivores, small mammals that are occasional carnivores, and birds that nest or forage strictly in the mid-canopy, nest strictly in the shrub canopy, or forage occasionally in the high canopy. Guilds that fare better with increasing disturbance are birds with a mixed diet of insects and leaves or buds, that forage strictly in the high canopy or occasionally on the ground, build open cup nests, nest strictly on the ground or occasionally in ground-level cavities, birds that nest occasionally in the high canopy or occasionally build domed nests, and fossorial small mammals.

Fuelwood and timber harvest directly decrease canopy cover, canopy volume, leaf fall, basal area of targeted late-successional tree species, and log abundance, and indirectly increase shrub cover and frequency of woody pioneer species, negatively affecting avian strict frugivores, avian strict shrub canopy foragers, and avian strict dome nesters, and positively affecting avian facultative granivores, avian omnivores, avian high canopy foragers, avian strict open cup nesters, avian strict tree cavity nesters, avian brood parasites, and avian strict ground nesters.

Tree fodder harvest reduces abundance and canopy volume of tree fodder species, negatively affecting avian strict frugivores and positively affecting mammalian facultative structure foragers, avian omnivores, avian ground and high canopy foragers and nesters, avian brood parasites, and birds that use open cup, dome, and tree cavity nests.

Pasturage reduces the frequency and basal area of palatable late-successional tree species and increases shrub cover and frequency of unpalatable pioneer species, negatively affecting avian strict frugivores and nectrivores, avian strict dome nesters, avian hanging nest builders, and mammalian facultative insectivores, and positively affecting avian facultative nectarivores, avian facultative shrub canopy foragers, avian facultative mid-canopy foragers, avian facultative depression nesters, mammalian facultative frugivores, mammalian facultative shrub canopy foragers, and mammalian strict fossorial foragers.

Introduction

Ecological succession of forest faunas has long been recognized (Adams 1908, Odum 1950, Shugart and James 1973), but species succession resulting from indigenous forest use has seldom been studied with quantitative rigor. When forests are heavily impacted by humans, microclimates become altered and habitat elements get redistributed, affecting the dispersal ability, physiological condition and home range size of animals, potentially reducing their survival and reproductive fitness (Wiens et al. 1985, Picket and White 1985, Pulliam 1988, Robertson and Hutto 2006).

In South Asia, quantitative study of anthropogenically-disturbed faunas is relatively recent (Gaston 1983, Beehler et al. 1987, Daniels et al. 1992, Daniels et al. 1995, Sundriyal and Sharma 1996, Baral 2001, Raman 2001, Chettri et al. 2002, Chettri et al. 2005). Most studies have addressed anthropogenic disturbance in general terms, without explicitly addressing cause and effect. Many studies have simply applied established principles of community ecology in novel landscapes. Sundriyal and Sharma (1996) conducted perhaps the most quantitative study relating household resource consumption to the structure and composition of temperate Himalayan forest. Chettri et al. (2001, 2002, 2005) advanced this research further by quantifying both fuelwood extraction and the structure and composition of avian habitats, but also did not establish or assess specific cause-and-effect linkages between harvested resources and the characteristic features, or "niche gestalt" (James 1971), of species' habitats.

The objective of this chapter is to analyze quantitative changes that occur in plant and animal communities as a result of specific resource harvest practices in the Temperate Sikkim-East Nepal Himalaya (TSENH). I analyze differences in the composition of plant and small animal communities across three progressively disturbed habitat zones around Chitre Village, using distance as a surrogate for duration and degree of anthropogenic disturbance. Such concentric zones of disturbed habitat commonly occur around remote settlements (Wagner 1960, Moench and Bandyopadhyay 1986, Whitney 1987). In Chapter 3, I provided evidence from relict stumps and trees that prior to settlement the entire study area was covered in mixed broadleaved forest. Recent research has shown that the composition of animal communities can be used to effectively assess and monitor the ecological condition of disturbed landscapes (Canterbury et al. 2000, O'Connel et al. 2000).

I begin by assessing the relative intensity of resource harvest in three progressively disturbed habitat zones. I then assess the effects of resource harvest on animal habitats by comparing the composition and structure of vegetation across zones. I test the response of selected bird and non-volant small mammal species to zonal habitat differences by contrasting species abundance, species diversity, and guild richness across zones. Finally, I assess the role of specific resource harvest practices in altering habitat features that are correlated with animal species abundance.

Among ecological studies in the temperate Himalaya, this is the first to directly link the harvest of specific forest resources to compositional changes in plant and animal communities, the first to attain credible estimates of passerine breeding densities, and the first to assess the local diversity of non-volant small mammals.

Methods

Study Area

The location and physical features of the Chitre study area are described in Chapter 1. Vegetation associations of the area are described in Chapter 3, and wildlife habitats are described in Chapter 4.

Data Collection

Data on resource harvest were gathered through interviews and observation, and by monitoring household resource consumption (Chapter 2). Plant and animal data were collected at ten 9-ha plots distributed along a distance/disturbance gradient extending out from the center of the village (Chapters 3 and 4). Plant, animal, and habitat data were collected at, or in reference to, sampling points on a 50 m x 50 m sampling grid within each 9-ha plot (36 points/plot, Fig. 3.1). Habitat variables were measured at each sampling point using a combination of point-centered-quarter, line intercept, fixed-area plots, and a shrub-edge diversity index. Descriptions and codes for habitat variables are provided in Appendix 4.1. Bird species occupancy was assessed with presence/absence surveys, and small mammal occupancy by trapping with box and pitfall traps. Breeding densities were estimated for selected passerine species by territorial spot-mapping. Methods for collecting animal and habitat data are described in detail in Chapter 4.

Data Analysis

My overall approach is to compare abundance and diversity of animal species across progressively disturbed habitat zones, then test whether abundance or diversity covary with zonal values for high-value forest resources (species ranked “good” by local informants for fuelwood, timber, or tree fodder). I treat zones as separate *macro*habitats, with each being represented by two 9-ha plots where general faunal surveys were conducted in 1993. The response variable is the sum of occupied sampling points per zone, which is an *index* of abundance. I use an index of abundance rather than raw counts because raw counts can be biased by group detections and variation in detectability (see Chapter 4 for additional animal sampling considerations).

Secondarily, I assess whether the breeding densities of selected understory passerines covary with values for high-value forest resources at the *micro*habitat scale. I treat individual occupied sampling sites as microhabitats, and I use data from all ten 9-ha plots in order to maximize sample size (it was unnecessary to balance sampling across zones for microhabitat analysis because no zonal comparisons were made). I do not use general survey detection locations for microhabitat analysis here because not all sites where individuals are observed accurately reflect the micro-scale resources necessary for successful reproduction (Van Horne 1983, Wiens 1989a); many detections are of non-breeding individuals or of individuals using a site for non-reproductive purposes. I conduct all statistical tests with STATISTICA software (StatSoft, Inc., Tulsa, OK). All tests are considered significant at $P \leq 0.05$, and all Mann-Whitney U tests include continuity correction for small sample size (Zar 1996).

Ranging distances for resource harvest

I assess relative harvest intensity across zones by comparing the number of harvest sites reported by each household for each zone. The principal resources I investigate are felled fuelwood (as opposed to woody debris collected from the ground), timber, tree fodder (lopped from trees by people), leaf litter, pollarded stems, bamboo, and pasturage. Harvest methods, species preferences, and common uses of these resources are described in Chapter 2.

Effects of resource harvest on habitat

I evaluate the effects of resource harvest on the *composition* of habitats by testing for differences in abundance and diversity of woody plant species across progressively disturbed zones (in Chapter 3, I compared the diversity of woody plants at plots that represent different vegetation associations without *a priori* consideration of their proximity to the village). I assess the relative abundance of woody species by comparing species frequencies with Mann-Whitney *U* tests. I use chi-square tests (Zar 1996) to compare relative species richness and relative effective diversity between zones (expected values being the observed value in an adjacent zone), and Hutcheson's *t* test (Zar 1996) to compare relative species diversity. I use standard formulae to calculate species diversity (H'; $-\sum p_i \ln p_i$, where p_i = proportion of the *i*th species, Shannon and Weaver 1949, Barbour et al. 1987), effective diversity (D; equal to $\exp(H')$, the number of equally-abundant species needed for the average proportional abundance of species to equal that observed in the dataset), and species equitability (J'; $H'/H'_{\max}$, where $H'_{\max} = \log_n$ of the number of species, Pielou 1969). Equitability is the distribution of individuals among species, and is highest when species abundances are equal. Species diversity is species richness weighted by species evenness, and increases with increasing species richness or increasing equitability. Effective diversity (D) is an index for comparing proportional differences in diversity.

To assess turnover of woody species across zones (β-diversity), I calculate: 1) Bray and Curtis coefficients of similarity ($BC_{ab} = 2C_{ab}/(N_a+N_b)$), where N_a = individuals sampled in habitat a, N_b = individuals sampled in habitat b, and C_{ab} = sum of the lesser values for species common to both habitats; Bray and Curtis 1957), and 2) the Horn-Morisita index of similarity ($C_{HM} = 2\sum n_{1i}n_{2i}/(\lambda_1+\lambda_2)N_1N_2$, where $\lambda_j = \sum n_{ji}^2/N_{j2}$, n_{ji} = individuals of a species *i* in a sample *j*, and N_j = total individuals in a sample *j*). I assess disproportionate species abundances across zones with Mann-Whitney *U* tests.

I assess the effects of resource harvest on habitat structure by testing for zonal variation in canopy volume, tree basal area, tree height, tree DBH (diameter at breast height), understory cover, and evidence of human disturbance (e.g., footpaths, stumps, lopped branches; Mann-Whitney *U*). I use basal area as a proxy for the available volume of fuelwood and timber species.

Effects of resource harvest on animal community structure

In Chapter 4, I explored the habitat associations of animal species and assemblages, and analyzed covariation of species abundances with habitat variables. Here, I assess the effects of harvesting specific forest resources on animal species abundance, diversity, and guild richness, from the perspective of anthropogenic influences on habitat. I use data for 61 bird species and 9 non-volant small mammal species, 11 more than I considered in Chapter 4 (rarely-encountered species are included for assessing diversity). I conduct guild-level habitat analyses at the macrohabitat (zonal) scale, using general faunal survey data and a subset of habitat variables that are indicative of forest resource extraction, listed in Appendix 4.1.

I compare animal species diversity and turnover across zones as I did for plant species (see above). Because my animal detection methods were unavoidably biased toward certain taxa, and my detection data constitute systematic samples rather than complete counts, my estimates of abundance and diversity must be considered relative rather than absolute (inventory data for all animal species encountered in the study area are provided in Appendixes 1.3 and 1.4).

To assess the effects of resource harvest on guild representation, I use chi-square tests to compare guild richness (number of member species) and guild abundance (number of sampling points where member species were detected, summed for all member species) across habitat zones, where expected values are the observed number of species or occupied sampling points in an adjacent zone, respectively. For brevity, I use the term guild representation to indicate either guild richness or guild abundance. I constitute ecological guilds subjectively according to natural history accounts by Ali and Ripley (1987) and Mitchell (1977), and my own field observations, and I distinguish between strict and facultative guild membership (e.g., consumes only insects versus consumes insects as well as fruit). Guild designations for bird species are given in Table 5.1, and for small mammal species in Table 5.2. I use the term *ecological guild* here where other authors might use *ecological association* (Morrison et al. 1992), not on ideological grounds, but because I reserve the term association for plant species associations and statistical associations between species and habitat variables. Ecological guilds are groups of species that exploit the same class of environmental resources in similar ways (Root 1967, Terborgh and Robinson 1986), and have been shown to have great utility in investigating environmental disturbance (Terborgh and Robinson 1986, Canterbury et al. 2000).

Effects of specific harvest practices

In order to assess the ecological effects of particular harvest practices, I first assess how a subset of habitat variables strongly affected by those activities varies across progressively degraded habitat zones (Mann-Whitney *U* tests). The harvest-affected response variables I use for this analysis are frequency, basal area (TBA/H), and canopy volume (CV/M) of high-value (Table 5.3) and pioneer plant species (Table 5.4), density of trees >61 cm DBH (VL_DENS), bamboo and shrub cover (BAM_COV, SRB_COV), and the abundance of cut stumps, lopped branches, and logs (STUMP, CUT, LOG). Detailed descriptions of these variables are given in Appendix 4.1. I exclude other habitat variables indicative of resource harvest from this analysis because the effects of multiple harvest types on those variables are difficult or impossible to distinguish (e.g, CANCOV, TBA/HA). Even the selected harvest-affect response variables are affected to some degree by multiple harvest types but, where strong correlations exist between them and species abundances, I infer substantial causation. The selected response variables can be affected both directly (immediately) and indirectly (gradually); tree felling, for example, has direct and immediate effects on tree density, whereas the increased frequency of pioneer species after timber harvest (ecological release) is an indirect and gradual effect.

Finally, I assess how harvest-affected response variables covary with animal species abundances and the richness and abundance of ecological guilds. At the macrohabitat scale, I use Pearson *r* correlation (Zar 1996) to test for covariation of species abundance and guild representation with mean zonal values of harvest-affected habitat variables. At the microhabitat scale, I compare values of harvest-affected habitat variables at occupied versus unoccupied sampling points, for spot-mapped passerines only. Covariance is not absolute proof of cause-effect relationships between resource harvest and species abundances or guild diversity, however (Wiens and Rotenberry 1981b). More likely, animals are responding to more fundamental, unmeasured, conditions or phenomena correlated with the harvest-affect variables, such as food resources or microclimates (Cody 1981, Block and Brennan 1993).

Results

Species accumulation curves confirm five repetitions of bird censuses (Fig. 5.1) and six nights of trapping for small mammals (Fig. 5.2) detected most breeding species, and were sufficient to compare relative diversity of breeding species across habitat zones. On average, detections of bird species peaked by the fifth count, and a sixth count increased the number of detected species by only 1.3% (~1 sp.). Similarly, the first four nights of small mammal trapping revealed 96% of the species detected by 6 nights of trapping, and the sixth night increased the number of mammal species by only 3.9% (<1 sp.).

There was no significant variation in 1993 and 1994 spot-mapped density data (U, $z_{0.05} = 0.192$, Appendix 4.7), so I pooled density data from both years.

Ranging distances for resource harvest

Pollarded stems are the only woody plant resource harvested primarily in VE (≤300 m from village center, Fig. 5.3.1). Fuelwood felling and pasture use occur primarily in DF (300-600 m from village center), secondarily in VE, and least in CF (≥600 m from village center; Figs. 5.3.2 and 5.3.3, respectively). Leaf litter harvest occurs predominantly in DF (Fig. 5.3.4), and tree fodder and timber harvests increase incrementally with distance (Figs. 5.3.5 and 5.3.6, respectively). Malingo bamboo (*Yushania maling*) is the only resource harvested exclusively in CF (Fig. 5.3.7).

Effects of resource harvest on habitat

The effects of resource harvest on habitat *composition* are apparent in the distributions of plant species across zones. Abundances of 19 out of 51 woody plant species (37%) differ significantly between zones (Table 5.5). Eight out of twelve high-value species are either incrementally abundant with distance from the village, disproportionately abundant in CF, or disproportionately sparse in VE (Table 5.5). Pioneer species are disproportionately abundant in VE or DF, or increase incrementally with proximity to the village (Tables 5.4 and 5.5, Figs. 3.6 and 3.7).

The relative diversity (H') of woody species appears to be affected by resource harvest, whereas other diversity indexes do not ($\bar{s}$, D, J'; Table 5.6). H' is significantly higher in CF than in DF or VE (t_H, $P < 0.001$), but no different between DF and VE. More woody species occur in VE than either DF of CF (18-21%), but the differences are not statistically significant ($X^2_{\ 0.05}$). Effective diversity (D) is 92% higher in CF than in DF ($P = 0.006$, $X^2_{\ 0.05}$), and 13% higher in VE than in DF, but these differences are also not significant).

Similarity indexes indicate 31% of woody species in CF do not occur in DF (69%

similarity), and 52% in CF do not occur in VE (48% similarity, Table 5.7). Woody species that decline >50% in the transition from CF to DF are ACECAM, ALACHI, FICNER, LINASS, LINPUL, LITELO, MICKIS, PERCLA, QUEOXY, RHOARB, and TETFRA. Half of these are high-value species. Species that increase >50% across the CF-DF transition, or occur only in DF, are BERARI, DAPBHO, HYDHET, LYOOVA, MAGCAM, and SYMTHE. Species that decline >50% in the transition from DF to VE are ACECAM, HYDHET, ILESIK, LINASS, LINPUL, LITELO, PERCLA, PERDUT, PRUNAP, QUELAM, QUEOXY, RHOARB, SARWAL, SYMTHE, and TETFRA, whereas ALNNEP, BERARI, CASHYS, EURACU, JUNREC, LYOOVA, MYRSEM, PRUCER, RHUCHI, and SYMRAM increase >50% or occur only in VE.

The proportion of pioneer species in different canopy layers differs with increasing proximity to the village. Overall, pioneer species are less frequent in CF (34-59%) than in DF or VE (74-89%, Fig. 5.4). In CF, pioneer species are most abundant in the mid-canopy (trees 3-8.5 m tall), whereas in DF and VE they are equally abundant in the mid-canopy and understory (Fig. 5.4). With increasing proximity to the village, the high canopy (trees >8.5 m tall) transitions from equally small proportions of mesic and xeric pioneers in CF (<20%), to a high proportion of mesic-habitat pioneers in DF (60%), to moderate and equal frequencies of mesic- and xeric-habitat pioneers in VE (Fig. 5.4). In the mid-canopy (trees 3-8.5 m tall), mesic species are approximately twice as abundant as xeric species in CF and DF, and approximately equal in VE. In the understory (trees <3 m tall), mesic species are approximately three times as abundant as xeric species in CF and DF, whereas the proportions are approximately equal in VE.

Among woody plant species: 1) diversity (H') is highest in CF and no different between DF and VE, 2) basal area declines 17% from CF to DF and 36% from DF to VE, 3) the proportion of canopy volume contributed by large trees drops from 77-79% in CF and DF to 46% in VE, and 4) canopy heterogeneity, shrub cover, and shrub edge increase with proximity whereas bamboo cover decreases.

Effects of resource harvest are also apparent in zonal differences in habitat *structure*, as indicated in Table 5.8. Total basal area of woody species declines 17% from CF to DF and 36% from DF to VE, and basal area of high-value species declines even more precipitously, 54% from CF to DF and 57% from DF to VE. Features of the forest canopy, including canopy cover and canopy volume, diminish significantly with proximity to the village. The proportion of canopy volume contributed by trees >25 cm DBH drops from 77-79% in CF and DF to 46% in VE (Fig. 5.5). Canopy heterogeneity (standard deviation, SD_CC) increases with proximity to the village. Furthermore, the pioneer species that replace late-successional species in the canopy after disturbance lack the massive, open-interior, crowns of late-successional species (Boojh and Ramakrishnan 1982), diminishing thermal and foraging microenvironments that certain late-successional animal species are adapted to (e.g., pygmy blue flycatcher *Muscicapella hodgsoni* , black-headed shrike babbler *Pteruthius rufiventer*).

Understory features that result from resource harvest activities, such as CUT, STUMP, PATH, PAST, SRB_COV, and SRB_EDG, increase markedly with proximity to the village, whereas bamboo (BAMCOV), a high-value resource, decreases 93% from CF to DF and 96% from DF to VE (Table 5.8).

Effects of resource harvest on animal community structure

There is significant turnover of animal species across habitat zones (Table 5.9). Among the animal species systematically surveyed, 31% are more abundant in CF than in either DF or VE. Ten of those are disproportionately abundant in CF, 2 decline incrementally with proximity to the village, and 15 are disproportionately sparse in VE. Another 51% are more abundant in DF than either CF or VE. Thirteen of these are disproportionately abundant in DF, 8 are disproportionately sparse in CF, 3 increase incrementally with proximity to the village, and 12 are disproportionately abundant in VE, including 7 detected exclusively in VE (Table 5.9). A final 9% is equally abundant across all habitat zones. If habitat specialists are defined as species detected at $\geq$3 sampling sites solely in one zone or $\geq$3 times as many sampling sites as in other zones (Raman 2001), the number of habitat specialists is highest in DF (10 sp.), intermediate in VE (8 sp.), and least in CF (5 sp.; Table 5.9). Zonal associations of additional rarely-encountered species are provided in Appendixes 1.3 and 1.4.

Among the seven understory passerine species whose breeding densities were determined, densities of scaly-breasted wren babbler (*Pnoepyga albiventer*), white-browed shortwing (*Brachypteryx montana*), and chestnut-headed tesia (*Tesia castaneocoronata*) are highest in DF, whereas densities of pygmy wren babbler (*Pnoepyga pusilla*) and grey-bellied tesia (*Tesia cyaniventer*) decline with proximity to the village and densities of Indian blue robin (*Luscinia brunnea*) and grey bushchat (*Saxicola ferrea*) increase with proximity (Table 5.10). Raw counts of spot-mapped territories are given in Appendix 5.1.

Overall abundance of bird species is greatest in DF (383 species-occupancies), intermediate in VE (275 species-occupancies), and lowest in CF (235 species-occupancies, Table 5.9). Relative species diversity of birds (H') is significantly higher in DF than CF or VE (t_H, $P < 0.001$), and no different between CF and VE. Species richness and effective diversity (D) of birds do not differ significantly between any pair of adjacent zones ($X^2_{0.05}$, Table 5.11). CF has more bird species in common with DF than with VE, and the decline in shared species is greater from CF to DF than from DF to VE (Table 5.12).

Abundance of small mammals is greatest in DF (98 species-occupancies), intermediate in CF (65 species-occupancies) and lowest in VE (45 species-occupancies, Table 5.9). No small mammal diversity index differs significantly across zones ($X^2_{0.05}$), although H' and D are slightly higher in DF (Table 5.13). CF has more small mammal species in common with DF than with VE, and the decline in shared species is greater from CF to DF than from DF to VE (Table 5.14).

Among avian dietary guilds, the most species-rich are facultative insectivores (30 sp.), obligate insectivores (28 sp.), facultative frugivores (23 sp.), omnivores (19 sp.), and facultative granivores (17 sp.), and the least species-rich are facultative herbivores and nectarivores (7 sp. ea.). Among small mammals, the most species-rich dietary guilds are facultative insectivores (8/9 sp.) and facultative granivores (5/8 sp.), and the least rich are omnivores (3/8 sp.) and facultative fruigvores (2/9 sp.). Foraging strata of some small mammal species are somewhat unusual, including human dwellings (brown rat *Rattus rattus*, pygmy shrew *Suncus etruscus*, house mouse *Mus musculus*), the shrub canopy (brown rat, chestnut rat *Niviventer fulvescens*), mid-canopy (brown rat) and soil (long-clawed shrew *Soriculus nigrescens*).

Guild abundance (total detections of member species), is more strongly influenced by zonal habitat differences than guild richness (number of member species present in a zone). Guilds that fare worse with increasing disturbance are avian strict frugivores and nectarivores, small mammals that are occasional carnivores, and birds that nest or forage strictly in the mid-canopy, nest strictly in the shrub canopy, or forage occasionally in the high canopy (Tables 5.15 and 5.16). Species that are inflexible with regard to diet or nesting substrate respond especially poorly to disturbance.

Guilds that fare better with increasing disturbance are birds with a mixed diet of insects and leaves or buds, that forage strictly in the high canopy or occasionally on the ground, build open cup nests, nest strictly on the ground or occasionally in ground-level cavities, birds that nest occasionally in the high canopy or occasionally build domed nests, and fossorial small mammals. Species that exploit foraging and nesting niches facultatively fare better with disturbance.

Effects of specific harvest practices

The habitat variables affected most by resource harvest are listed in Table 5.17. All harvest types I investigated appear to contribute to covariance of species abundance, and guild representation, with harvest-affected variables at the macrohabitat scale (Tables 5.18-20), as well as covariance of passerine breeding densities with harvest-affected variables at the microhabitat scale (Table 5.21). Species whose abundances are not correlated with harvest-affected variables tend to be habitat generalists.

The supply (basal area) of high-ranking fuelwood species (Chapter 2, Table 5.3) declines significantly across the three progressively disturbed habitat zones (U, $P < 0.0001$, Fig. 5.3.2). Average-ranked fuelwood species also decline with proximity to the village, whereas poor-quality species peak in DF. VIBERU (*Viburnum erubescens*) is unique among high-ranking fuelwood species in that it is ubiquitous throughout the study area and highly tolerant of anthropogenic disturbance (Schmidt-Vogt 1990).

The harvest of green-felled fuelwood (Chapter 2, Figs. 2.8 and 4.3) primarily affects features of the forest canopy and shrub layer (Table 5.17). It directly diminishes high-value fuelwood species (Table 2.2), and indirectly increases the frequency of low-value pioneer species. In areas where green-felling has only recently begun, felling creates gaps in the forest canopy, to which "gap-phase" plant and animal species respond positively (e.g., HYDHET, *Symplocus* spp., white-browed shortwing). But habitat is simultaneous diminished for species and guilds that are positively associated with canopy volume (T_CV/M) or tree basal area (TBA/H, Tables 5.18-21).

Where fuelwood harvest has progressed at unsustainable levels, the forest canopy becomes increasingly sparse, diminishing habitat for animal species and guilds positively associated with high-value fuelwood species (*Quercus* spp., RHOARB), high tree height-to-DBH ratio (HT:DBH), bamboo cover (BAM_COV), leaf litter (LITTER), and logs (LOG). Conversely, habitats are increased for species positively associated with shrub cover (SRB_COV) and cut stumps (STUMP). LITTER declines because canopy foliage volume declines. BAM_COV declines because malingo bamboo prefers shaded habitat, HT:DBH decreases because competition for sunlight is reduced, and LOG declines because large trees are removed before they topple from natural causes.

Where fuelwood harvest continues at unsustainable levels, the forest canopy is essentially eliminated, and the area becomes dominated by sunlight-tolerant, low-value, shrubs, improving habitat for animal species and guilds positively associated with BERARI, EURACU, or LYOOVA, or negatively associated with T_CV/M and TBA/H, L_DBH, and LOG (Tables 5.18-21). Alternatively, if the cleared area is repeatedly grazed or burned, it is converted to a shrubby pasture.

Harvest of dead-and-down fuelwood (dead trees which have toppled naturally) reduces accumulation of logs and large woody debris on the forest floor, diminishing habitat for species and guilds positively associated with LOG, but there is little or no direct impact to the forest canopy. Over the long term, if dead and down logs are removed faster than they are replenished, habitats for organisms ranging from decomposer bacteria to foraging bears will be diminished.

The supply of high-ranking timber species (Chapter 2, Table 5.3) declines significantly across the three progressively disturbed habitat zones (*U*, $P < 0.0001$; Fig. 5.3.6). Even average quality timber species are proportionately infrequent in VE. The effects of timber harvest are similar to those of green fuelwood felling (Table 5.17), except target species differ somewhat (Table 5.3), and the impact is lower, because demand is lower, and more dispersed, because only tress with optimal conformation are felled for timber. The same animal species and guilds affected by fuelwood felling are affected by timber harvest (Tables 5.18-21).

The supply of high-ranking tree fodder species (Chapter 2, Table 5.3) declines significantly from CF of DF (U, $P < 0.0001$), and even further from DF to VE, though not significantly (Fig. 5.3.5). The distribution of FICNER is uniquely bimodal because it is semi-cultivated or preserved in VE for sustained fodder lopping.

The principal effects of tree fodder harvest are gradual reduction in the abundance and canopy volume of high-value tree fodder species (Table 5.3), and a consequent reduction in leaf fall (Table 5.17). Initially, fodder lopping reduces the height and volume of tree canopies, negatively affecting species and guilds associated with HT:DBH, T_CV/M, or LITTER, and positively affecting those associated with CUT (Tables 5.18-21). Repeatedly-lopped trees ultimately die, due to stress or disease (Metz 1987, Shrestha 1989), reducing habitat for species and guilds positively associated with TBA/H or frequency and basal area of high-value fodder species. Fodder lopping is the primary cause of premature death of trees >61 cm DBH (VL_DBH), because such large trees are seldom harvested for fuelwood or timber.

The supply of leaf litter (~forest canopy volume) decreases across progressively disturbed habitat zones (U, $P \leq 0.001$, Fig. 5.3.4). Litter collection (Fig. 2.16) disrupts seed dispersal and germination, and degrades habitats of animals that forage and nest on the forest floor. However, the method I used to sample leaf litter in the field proved to be inadequate to test animal species' associations with litter. Over time, leaf litter collection negatively affects soil composition, nutrient cycling, rainfall infiltration, soil erosion, and long-term forest health (Oli and Manandher

2002), but these topics are beyond the scope of this study.

Malingo bamboo is absent from VE and DF habitat zones, presumably due to over-harvest and excessive exposure to sunlight due to thinning of the forest canopy. The small amount of BAM_COV detected in DF (Fig. 5.3.7) is of dwarf or *ringal* species. Nine animal species and one animal guild are positively associated with BAM_COV (Tables 5.18-21).

The supply of pasturage increases across progressively disturbed habitat zones (U, $P \leq 0.003$). Pastures in VE are grazed by village-based herds year-round, and by itinerant herds in fall and winter (Chapter 1). Most pastures in DF are used year-round by village-based herds and seasonally by itinerant herds, including goats and sheep belonging to Rai herders from nearby villages. Pastures in CF are forest-interior *khArka*s (N. pasture, Chapter 1), and are used exclusively, and only seasonally, by itinerant herds.

Persistent livestock grazing (including browsing) maintains an open vegetation structure inhospitable to shade-adapted species (Fig. 4.2), including most late-successional and mesic-edge pioneer species. Pasturage reduces frequency and basal area of palatable late-successional species (i.e., tree fodder species, Tables 5.3 and 5.17), negatively affecting animal species and guilds positively associated with those species (Tables 5.18-21). Declines in palatable species are caused primarily by low recruitment, a topic beyond the scope of this study. Pasturage indirectly increases the frequency of grazing-tolerant tree species (Table 5.4) and animal species and guilds positively associated with them (Tables 5.18-21), and decreases cover of most shrub species (SRB_COV) and malingo bamboo (BAM_COV), although some species can regenerate and spread rapidly by root-sprouting (Table 5.4). According to local informants, excessive grazing destroyed colonies of malingo bamboo that formerly grew closer to the village.

Discussion

Effects of disturbance on species diversity

In similar forest in Sikkim, Chettri et al. (2001, 2002) compared woody species diversity at open canopy sites near human settlements to relatively undisturbed and distant closed canopy sites, and also found more disturbed sites to have more species. In contrast to my findings, Chettri et al.'s disturbed sites had the highest species diversity H′, presumably because fewer species were rare. The conflicting results might be the result of different sampling designs (see Chettri et al. 2005). Or, perhaps my closed-canopy sites were less disturbed, or Chettri et al.'s open canopy sites were actually more like DF sites at Chitre than VE sites. Several other studies in the region have documented low frequency and regeneration of late-successional tree species (e.g., *Acer* spp., *Machilus* spp., *Magnolia* spp., *Michelia* spp., *Persea* spp., *Quercus* spp.) and high frequency and regeneration of pioneer species (e.g., *Eurya* spp., *Symplocus* spp., *Lyonia* spp., *Viburnum* spp.) in anthropogenically disturbed forest (Sundriyal and Sharma 1996, Chettri et al. 2002, Metz 1998).

Most Nepalese bird species that Inskipp (1989) classifies as "adapted to man-modified habitats" are widespread ecological generalists. In Sikkim, Chettri et al. (2001) also found proportionately more generalist species in anthropogenically disturbed temperate broadleaved forest than in relatively undisturbed forest. In South India, highly disturbed patches of tropical forest (plantations) are dominated by generalist species that are adapted to xeric habitats (Beehler et al. 1986, Daniels et al. 1992, Daniels et al. 1995), and in Northeast India, disturbed slash-and-burn patches have a greater number of widespread generalists adapted to "open country" (Raman et al. 1998, Raman 2001). I found the number of habitat specialists to be highest in DF and lowest in CF, whereas in Raman's (2001) tropical slash-and-burn seres, the distribution of habitat specialists was bimodal, being high in early (fallow) seres and in mature forest.

Indexes of small bird and mammal diversities are highest in DF because relatively few species in DF are rare, and because habitat diversity is highest in DF (MacArthur and MacArthur 1961, MacArthur et al. 1962, Pielou 1975, Roth 1976). In disturbed or secondary forest, horizontal diversity of vegetation is high because of tree falling and establishment of forest-interior pastures, and vertical diversity is high because of secondary growth and invasion of disturbance-tolerant pioneer species near the edges of canopy openings. Consequently, foraging niches in Chitre's DF zone are most diverse, with some animal species foraging high in canopy remnants, some in the lower canopy, some on the ground, and still others at soft forest edges. Furthermore, among the edge-foraging species at Chitre, some prefer more mesic sites and others prefer relatively xeric edges (Chapter 4). In Sikkim, Chettri et al. (2005) also attributed higher bird species richness and diversity at disturbed sites to greater vegetation heterogeneity.

The relatively high diversity of animal species in DF concurs with the intermediate-disturbance hypothesis, which postulates that intermediate levels of disturbance increase alpha diversity (Fox 1979, Picket and White 1985). VE also offers high horizontal habitat diversity (pasture, cropland, shrubland, human dwellings, ruderal forest remnants), but animal diversity is lower than in DF because disturbances in VE are more extreme (beyond intermediate).

Even though observed animal diversity is highest in DF, the zone could actually be a population sink or ecological trap for many species, reducing their fitness through reduced survival or reproductive success and ultimately causing population declines (Pulliam 1988, Schlaepfer et al. 2002, Battin 2004, Robertson and Hutto 2006). Diverse and apparently high-quality habitats also attract more competitor and predator species, and where sharp ecological edges exist (e.g., perimeters of clear-cuts and pastures) predators can be more diverse and effective, and brood parasites can be more abundant (Gates and Gysel 1978, Brittingham and Temple 1983, Thiollay 1985, Anglestam 1986, Yahner 1988). At Chitre, four species of brood-parasitizing cuckoos could potentially be attracted to the DF zone, but I detected them too infrequently to analyze their habitat distributions.

Survival and reproductive success were beyond the scope of this study. However, given the mounting evidence of ecological traps in anthropogenically-disturbed forests (Yahner 1988), and the ubiquity of disturbed forest across the temperate Himalaya (Chapter 1), fitness in disturbed habitats should be given high research priority in the future. The methods for such research are well-established (Yahner 1988), but the required experimental rigor would be unprecedented for the temperate Himalaya. Until more evidence is available regarding fitness in Himalayan habitats subjected to intermediate levels of disturbance, wildlife studies that attribute habitat quality to observed abundance - including the present study - should be interpreted with the possibility of ecological traps or population sinks in mind (Van Horne 1983).

Effects of disturbance on animal ecological guilds

Renner et al. (2006), in a study of avian dietary guilds in Guatemalan cloud forest, also found little change in guild richness (number of member species represented) with disturbance but considerable change in guild abundance (aggregate abundance of member species). Apparently, the resources available in a given zone exert stronger limits on the number of individual organisms representing a guild than on the number of member species.

Cross-site comparisons of guild diversity are generally unproductive if the studies vary widely with respect to region, geographic scale, data collection methods, type of effect, and faunal assemblages (Hill and Hamer 2004, Barlow et al. 2006). The only study comparable to my work at Chitre is Chettri et al.'s work at Yuksom in western Sikkim (Chettri et al. 2001, 2002, 2005), although that study includes additional data from higher elevations, additional species (e.g., pass-through migrants, raptors), and additional impacts from tourism, and apparently lacks truly undisturbed sites. "Closed canopy" sites at Yuksom were only "relatively undisturbed and distant from the village," and apparently all subjected to tree felling and fodder lopping (>40% canopy cover, therefore intermediate levels of disturbance). Guild habitat associations were also analyzed differently. Whereas Chettri et al. (2005) tested for correlations between guild diversity and principal components axis representing habitat structural diversity and disturbance, I tested for correlations between guild diversity and mean habitat variables across progressively degraded habitat zones.

Reported patterns of guild diversity differ considerably between Chitre and the Yuksom study, but many of the differences can be attributed to different study designs. Insectivores, particularly those that forage on or near the ground, are relatively susceptible to forest disturbance because their foraging niches are relatively specialized, and because thinning of the forest canopy: 1) changes forest microclimates, altering the insect prey base, and 2) attracts additional opportunistic, disturbance-adapted, omnivores, thereby increasing interference competition (Canaday 1997). Maximum avian insectivore diversity in Chitre's DF zone is therefore expected, whereas at Yuksom insectivore diversity was uncorrelated with disturbance and positively correlated with structural features the authors attribute to "closed canopy" forest (Chettri et al. 2005).

At Chitre, facultative frugivores and facultative nectarivores are also most abundant in DF habitats (although richness is equal throughout), but at Yuksom frugivore diversity was uncorrelated with either habitat structural diversity or disturbance, and nectarivore diversity decreased with disturbance. In contrast to the Yuksom study, frugivore and nectarivore diversity has elsewhere been reported to increase with disturbance because fruit- and nectar-bearing plants respond positively to opening of the forest canopy (Levey 1988, Restrepo and Gomez 1998). Perhaps the Yuksom results for nectarivore diversity (Chettri et al. 2001) are highly influenced by sunbirds (*Aethopyga* spp.), which I mostly excluded because most are passage migrants at Chitre (Appendix 1.3).

Granivore richness increases with disturbance at both Chitre and Yoksum, although at Chitre the increase is not significant. Such increases are commonly attributed to increases in seed-producing herbaceous plants in open habitats (Johns 1992, Raman et al. 1998). At Yuksom, Chettri et al. (2005) found omnivore diversity to be negatively correlated with disturbance, whereas at Chitre omnivore diversity increases, although insignificantly, with disturbance. Perhaps the Yuksom omnivore findings were highly influenced by corvids (Corvidae; crows, raven, treepies), which I omitted from habitat analysis because they were uncommon and not observed breeding at Chitre. Canaday (1991) has postulated that detection rates for avian omnivores can be biased upward at disturbed sites because they are relatively wide-ranging, appearing in small disturbed patches that other species with smaller breeding territories avoid (i.e., highly territorial insectivores).

Effects of specific harvest practices

Fuelwood harvest has also been cited as the primary agent creating progressively disturbed zones around Sudanese villages (Whitney 1987). At Yuksom, Sikkim, fuelwood and timber harvest do not exceed primary productivity, yet the frequency and regeneration of high-value species are lower in heavily harvested stands and population age structure is altered by preferential harvest of medium-DBH trees (Chettri et al. 2002).

Lopping of *Quercus* trees for fodder has been cites as the primary cause of receding forest around Munglori Village in northwest India (Moench and Bandyopadhyay 1986). There, heavy fodder lopping near the village results in low canopy cover, low seed production, and poor tree regeneration. At intermediate distances, lopping is less intense and the canopy remains patchy, promoting a dense growth of shrubs in the understory. In the most distant zone, fodder lopping pressure is low and the forest canopy is complete, but undesirable or unpalatable species regenerate in the place of *Quercus* because *Quercus* saplings are relentlessly grazed and lopped. *Quercus* spp. are also the primary tree fodder species at Chimlkhola, west-central Nepal (Metz 1987), although at Chitre they are average ranked (Table 2.5).

Conclusions

The findings of this study indicate Chitre's remnant temperate broadleaved forest is becoming biologically homogenized (McKinney and Lockwood 1999, Tabarelli et al. 2012); disturbance-tolerant plants have become ubiquitous, high-value species and locally endemic habitat-specialists are disappearing, and widespread generalists from open, lower-elevation, habitats are coming to dominate the most disturbed habitats. Viewed more optimistically, my findings indicate disturbed or secondary temperate Himalayan broadleaved forests do support a relatively high diversity of small animal species, including some regional endemics.

After about 100 years of year-round occupancy (Chapter 1), three progressively disturbed habitat zones can be recognized around Chitre Village. Beyond ~600 m, in the CF zone, harvest of high-value woody plants is limited, and the essential habitat features of primary forest are evident, including maximum values (relative to other zones at Chitre) for woody plant diversity (H′), frequency of late-successional and high-value tree species, forest cover and canopy volume, tree basal area, bamboo cover, fern cover, and logs. Most xeric-habitat woody pioneer species are rare or absent in the understory, but mesic-habitat understory pioneer species are relatively abundant. Among small animal species, locally endemic habitat-specialists are occasionally encountered, whereas widespread ecological generalists are rare or absent. The avian frugivore guild is best represented in DF, whereas avian ground foragers, avian ground nesters, avian facultative insectivores, avian high canopy foragers, avian open cup nesters, and fossorial small mammals are least well represented.

At ~300-600 m from the village center, in the DF zone, maximum levels of woody plant harvest take place, and the characteristic habitat features of disturbed secondary forest are evident, including patchy forest canopy, intermediate canopy volume and tree basal area, intermediate height and girth of large trees, high shrub cover and shrub edge, intermediate bamboo and fern cover, and intermediate numbers of small pastures. Whereas woody plant diversity (H′) is at a minimum (relative to other zones), due to relatively low species equitability, diversity of small birds and mammals are at their maximum, due to increased horizontal and vertical heterogeneity, which increase available foraging and nesting niches. Avian guilds best represented in DF include strict insectivores, facultative nectarivores, facultative frugivores, facultative mid-canopy and shrub canopy foragers, strict dome and hanging nest builders, facultative tree cavity nesters, and those that nest facultatively on the ground or in the shrub or mid-canopy. Among small mammal dietary guilds, only facultative carnivores are not best represented in DF.

Within ~300 of the village center, in the VE zone, woody plants have been over-exploited, and most high-value species are either rare or absent. The forest canopy has largely been eliminated, except an occasional ruderal patch, creating xeric habitats that are more like open habitats at lower elevations than temperate broadleaved forest. Canopy cover, canopy volume, tree basal area, density of large trees, height and girth of large trees, bamboo cover, fern cover, logs, and leaf litter are all at their minimum in VE, whereas pasture, hedge, and other human disturbance variables (stumps, lopped branches, footpaths) are at their maximum. Woody plant species diversity (H′) is intermediate relative to CF and DF, but species richness is at its maximum due to the presence of widespread but locally rare, disturbance-tolerant, xeric-habitat species. Bird species diversity is lower than in DF but approximately equal to that in CF. Small animal guilds best represented in VE include avian facultative herbivores, whereas avian strict nectarivores, small mammalian carnivores, birds than forage facultatively in the high canopy or strictly in the mid-canopy, and birds that nest in the mid- or shrub canopies are least well represented.

The methods and results of this study can serve as a catalyst for future conservation related research. My methodological approach should be broadened, to include the resource needs of taxa I omitted (e.g., passage migrants, raptors, larger mammals), as well as refined and simplified. Once refined, the approach should be tested and applied at larger geographic scales, because habitat associations and responses to disturbance sometimes differ at larger scales (Picket and White 1985, Wiens 1989a, 1989b). In Chapter 6, I explore generalized models for the succession of plant and animal communities in anthropogenically-altered temperate broadleaved forest across the TSENH.

In order to detect, assess, and potentially forestall, further homogenization and loss of endemic biodiversity, scientifically-valid environmental monitoring programs need to be developed and implemented in the TSENH. Several viable models now exist for developing an efficient ecological monitoring system based on animal community composition, including Croonquist and Brooks' (1991) "response guild" approach and the "disturbance assemblage" approach of Stotz et al. (1996), Canterbury et al. (2000) and O'Connell et al. (2000). My work at

Chitre can serve as a model for collecting baseline ecological data necessary to begin this important work.

TABLE 5.1. Ecological guild designations for bird species.

Species	Diet[A]	Food stratum[B]	Nest type[C]	Nest placement[D]	Height (m)[E]
Babbler, black-eared shrike	I	MC	OC	MC	5.2
Babbler, black-headed shrike	I	G, MC, HC	OC	HC	7.8
Babbler, green shrike	O (I,F,G)	SH, MC, HC	OC[G]	MC, HC	2.0
Babbler, pygmy wren	I	G	DO[G]	SH, MC	1.5
Babbler, rufous-capped	I, F	SH	DO, OC	G, SH	1.9
Babbler, rufous-throated wren	I	SH	DO	G	2.0
Babbler, streak-breasted scimitar	I	G	DO	G, SH	1.0
Babbler, scaley-breasted wren	I	G	DO	G, SH	1.0
Barbet, great	O (F,I,H)	SH, MC, HC	CA	MC	7.0
Barwing, hoary-throated	O (I,G,F,H)	MC, HC	OC	MC, HC	7.0
Blackbird, grey-winged	I, F	G, SH	OC	G, SH, MC	8.1
Bulbul, striated	F, I	SH, MC, HC	OC	SH	9.5
Bushchat, grey	I, G	G, SH	OC	G[F]	1.4
Cuckoo, Eurasian	I	G, HC	BP	--	4.0
Cuckoo, large hawk	I	HC	BP	--	6.0
Cuckoo, oriental	I	G, MC	BP	--	6.0
Drongo, ashy	O (I,C,N)	SH, MC, HC	OC	HC	4.0
Fantail, yellow-bellied	I	SH, MC, HC	OC	MC	13.8

TABLE 5.1. Continued.

Species	Diet[A]	Food stratum[B]	Nest type[C]	Nest placement[D]	Height (m)[E]
Flowerpecker, fire-breasted	O (I,N,F)	SH, MC	DO[G]	MC, HC	2.5
Flycatcher, grey-headed	I	SH, MC	OC	SH, MC, HC	5.2
Flycatcher, pygmy blue	I	G, SH, MC, HC	OC	SH	11.5
Flycatcher, rufous-gorgetted	I	SH, MC, HC	OC, CA	G,[F] SH, MC	7.3
Flycatcher, slaty-backed	I	MC, HC	OC	G,[F] SH	8.0
Flycatcher, snowy-browed	I	SH	OC	G,[F] SH	1.3
Flycatcher, verditer	I	G, SH, MC	OC	G, SH, MC	3.9
Fulvetta, rufous-winged	O (I,G,N)	SH, MC	CA, DO	G, SH	4.3
Fulvetta, white-browed	I, F	SH, MC	OC	SH, MC	2.0
Laughingthrush, chestnut-crowned	O (I,C,F,H)	G, SH, MC	OC	SH	1.5
Laughingthrush, striated	O (I,F,G)	SH, MC, HC	OC	SH, MC	8.8
Laughingthrush, streaked	O (I,F,G)	G, SH	OC	SH	4.2
Leiothrix, red-billed	O (I,G,F)	G, SH	OC	SH	2.5
Minla, blue-winged	I	SH, MC	OC	SH, MC	7.0
Minla, chestnut-tailed	I, N	SH, MC	OC	SH	5.3
Minla, red-tailed	O (I,F,G)	G, MC, HC	OC	SH, MC	7.0
Niltava, rufous-bellied	I, F	G, SH	OC	G	3.8
Nuthatch, white-tailed	I, G	SH, MC, HC	CA	SH, MC, HC	10.5

TABLE 5.1. Continued.

Species	Diet[A]	Food stratum[B]	Nest type[C]	Nest placement[D]	Height (m)[E]
Partridge, hill	O (G,H,F,I)	G	OC	G	0.0
Pheasant, kalij	O (G,H,I)	G	OC	G	0.0
Pigeon, ashy wood	F, G	G, HC	OC	MC	4.0
Pigeon, wedge-tailed green	F	MC, HC	OC	MC, HC	6.0
Pipit, olive-backed	O (I,G,H)	G	OC	G	1.8
Prinia, striated	I	G, SH	DO	G, SH	1.7
Robin, Indian blue	I	G, SH	OC	G[F]	3.0
Robin, white-tailed	I, F	G, SH	OC, DO	G[F]	2.2
Shortwing, white-browed	I	G, SH	DO	G, SH	1.2
Sibia, rufous	O (I,F,N)	MC, HC,	OC	MC, HC	9.0
Sunbird, green-tailed	N	SH, MC, HC	DO[G]	SH	7.3
Tesia, chestnut-headed	I	G, SH	DO[G]	SH	1.2
Tesia, grey-bellied	I	G, SH	DO	SH	1.0
Tit, black-throated	O (I,G,F)	SH, MC	DO	SH, MC	3.5
Tit, green-backed	O (I,H,F)	G, SH, MC	CA	G, SH, MC	2.3
Wagtail, grey	I, G	G	OC	G	0.0
Warbler, ashy-throated	I	SH, MC, HC	DO[G]	MC	9.2
Warbler, brownish-flanked bush	I	G, SH	OC, DO	SH	1.0

TABLE 5.1. Continued.

Species	Diet[A]	Food stratum[B]	Nest type[C]	Nest placement[D]	Height (m)[E]
Warbler, buff-barred	I	SH, MC, HC	DO[G]	MC	10.0
Warbler, chestnut-crowned	I	MC, HC	DO	MC, HC	8.3
Warbler, golden-spectacled	I	SH, MC	DO	G	4.0
Warbler, grey-hooded	I, F	SH, MC	DO	G	4.5
Woodpecker, Darjeeling pied	I	SH, MC, HC	CA	SH	4.0
Yuhina, stripe-throated	O (I,F,N,G)	SH, MC	OC	G, SH	11.7
Yuhina, whiskered	O (I,N,F,G)	SH, MC	DO, OC	G, SH, MC	9.4

[A] Breeding season diets (based on Ali and Ripley 1987, and del Hoyo et al. 1997): C = carnivorous (small animals), I = insectivorous, F = frugivorous, G = granivorous, N = nectarivorous, H = herbivorous (leaves, buds), O = omnivorous (grains, insects and leaves).

[B] Foraging substrates: G = ground, SH = shrub layer, MC = mid-canopy, HC = high canopy.

[C] Nest types (based on Ali and Ripley 1987, and del Hoyo et al. 1997): OC = open cup, DO = domed, CA = cavity, BP = brood parasite.

[D] Nest placement (based on Ali and Ripley 1987, and del Hoyo et al. 1997): G = ground, SH = shrub layer (<2 m ht), MC = mid-canopy (2-6 m ht), HC = high canopy (>6 m ht).

[E] Mean height of field detections or interpreted from Ali and Ripley (1987).

[F] Usually, or occasionally, built in depression or concavity on sloping ground.

[G] Nest hanging or suspended purse-like from limb or branch.

TABLE 5.2. Ecological guild designations for terrestrial small mammals.

Species	Diet [A]	Foraging stratum [B]
Mouse, house	G, I	G, ST
Rat, brown	O (G,I,F,H)	G, SH, MC, ST
Rat, chestnut	O (I,G,F,H)	G, SH
Rat, smoke-bellied	O (I,G,H)	G
Shrew, brown-toothed	C, I	G
Shrew, Indian long-tailed	I, C	G
Shrew, large-clawed	I, C	G, SU
Shrew, pygmy	I, C	G, ST
Vole, Sikkim	G, H	G

[A] Diets (based on Mitchell 1977): C = carnivorous (excluding insects), I = insectivorous, F = frugivorous, G = granivorous, H = herbivorous (leaves and buds), O = omnivorous (insects, grains & leaves).

[B] Foraging substrate (based on Mitchell 1977 and personal observation): SU = subterranean, G = ground, SH = shrub canopy, ST = man-made structure, MC = mid-canopy.

TABLE 5.3. High-value[A] woody plant species at Chitre Village, as ranked by village informants.

Species	Code	Fuelwood	Timber	Tree fodder
Acer campbelli	ACECAM	average	good	average
Castanopsis hystrix	CASHYS	average	good	poor
Ficus neriifolia	FICNER	average	poor	good
Litsea elongata	LITELO	average	good	good
Michelia kisopa	MICKIS	average	good	good
Myrsine semiserrata	MYRSEM	good	poor	average
Persea clarkeana	PERCLA	average	good	good
Persea duthiei	PERDUT	average	average	good
Quercus lamellosa	QUELAM	good	poor	average
Quercus oxyodon	QUEOXY	good	poor	average
Schefflera impressa	SCHIMP	average	poor	good
Viburnum erubescens	VIBERU	good	poor	poor

[A] Ranked "good" for at least one of the three uses.

TABLE 5.4. Pioneer woody plant species at Chitre Village (values in bold differ significantly across adjacent zones[A]; CF, closed-canopy forest; DF, disturbed forest; VE, village environments).

Species	Pioneer type[B]	Habitat preference	No./100 in CF	No./100 in DF	No./100 in VE
Alnus nepalensis	Habitat[C] pioneer	xeric	0.5	**0.2**	**2.7**
Berberis aristida	Habit[D] pioneer	xeric	0.0	**7.3**	**15.5**
Eurya acuminata	Understory component[F]	xeric	5.9	**7.4**	**12.4**
Hydrangea heteromalla	Habit[D] pioneer	mesic	**0.8**	**3.2**	**0.8**
Lyonia ovalifolia	Canopy component[E]	xeric	4.5	**6.0**	**10.4**
Rhododendron arboreum	Canopy component[E]	xeric	4.5	**1.6**	**0.5**
Rhus chinensis	Understory component[F]	xeric	0.0	**0.2**	**1.3**
Symplocos theifolia	Understory component[F]	mesic	**13.2**	**37.8**	**12.0**
Viburnum erubescens	Understory component[F]	mesic	17.7	19.7	20.5

[A] Mann-Whitney *U* test with continuity correction for small sample size.

[B] Based on ecological criteria of Ohsawa et al. (1986).

[C] Habitat-specific, long-lived trees with erect central stem(s). Shade intolerant, colonizing bare soil. Rapid initial growth, sometimes becoming a canopy component in marginal areas.

[D] Shrubby, short-lived biological nomads with spreading crown. Colonize rapidly regardless of cause of disturbance or soil conditions. Rapid initial growth and rapid shoot replenishment from root suckers.

[E] Very long-lived trees that colonize bare soil. Initial growth rate is moderate. Usually become canopy components of mesic, mixed climax forest.

[F] Long-lived shrubby understory trees. Thrive in a full range of light, from direct sunlight to full shade. Initial growth is slow. Often persist through intense forest deterioration to become the initial successional species. Can replenish shoots from root suckers.

TABLE 5.5. Woody plant taxa that differ in abundance across adjacent habitat zones (species with <10 detections omitted). Underscored species are high-value species.[A] Values in bold differ across adjoining zones.[B]

Taxon	Frequency/100 samples			Highest in CF	Decline with proximity	Lowest in VE	Lowest in DF	Highest in DF	Increase with	Highest in VE
	CF	DF	VE							
Lindera assamica	**1.2**	**0.1**	0.0	✔						
Meliosma pinnata	**3.5**	**0.0**	0.3	✔						
Michelia kisopa	**1.2**	**0.1**	0.1	✔						
Myrsine semiserrata	**2.7**	**0.0**	0.5	✔						
Tetradium fraxinifolium	**3.4**	**1.3**	0.3	✔						
Ficus neriifolia [C]	**5.2**	**0.0**	**3.0**[B]	✔						
Lauraceae	**19.9**	**5.7**	**0.4**		✔					
Fagaceae	**8.3**	**3.3**	**0.8**		✔					
Litsea elongata	**6.0**	**2.1**	**0.3**		✔					
Persea clarkeana	**10.5**	**2.3**	**0.0**		✔					
Quercus oxyodon	**5.0**	**0.5**	**0.0**		✔					
Acer campbellii	2.8	**0.9**	**0.1**			✔				
Lindera pulcherrima	1.7	**0.9**	**0.0**			✔				
Prunus venosa	0.8	**0.6**	**0.0**			✔				
Quercus lamellosa	3.4	**2.9**	**0.1**			✔				
Rhododendron arboreum	4.5	**1.6**	**0.5**			✔				
Theaceae	**20.3**	**45.5**	**25.3**					✔		
Hydrangea heteromalla	**0.8**	**3.2**	**0.8**					✔		
Symplocos theifolia	**13.2**	**37.8**	**12.0**					✔		

TABLE 5.5. Continued.

	Frequency/100 samples									
Taxon	CF	DF	VE	Highest in CF	Decline with proximity	Lowest in VE	Lowest in DF	Highest in DF	Increase with	Highest in VE
Ericaceae	9.2	**7.5**	**10.8**							✔
Alnus nepalensis	0.5	**0.2**	**2.7**							✔
Lyonia ovalifolia	4.5	**6.0**	**10.4**							✔
Rhus chinensis	0.0	**0.2**	**1.3**							✔

[A] Species ranked by local informants as "good" for timber, fuelwood, or fodder (Chapter 2).

[B] Mann-Whitney *U* test with continuity correction for small sample size.

[C] VE value positively influenced by preservation of trees near the village for sustained lopping.

TABLE 5.6. Relative diversity of woody plant species[A] in progressively disturbed habitat zones.

Zone	Species richness [B]	Species diversity (H') [C]	Effective diversity (D) [D]	Species equitability (J') [E]
Closed-canopy Forest	30	2.83[G]	16.9[H]	0.09
Disturbed Forest	31	2.17	8.8	0.07
Village Environment	38	2.31	10.1	0.06

[A] Woody plants >2 cm DAB only; not absolute plant species diversity. Based on 864 sample plants for each zone (from two 9-ha plots). [B] Number of species. [C] Species richness weighted by species evenness (H'(ln); Shannon and Weaver 1949, Barbour et al. 1987). [D] Number of equally-common species (exp(H'), MacArthur 1965). [E] Distribution of individuals among species (H'/sp. in sample, Pielou 1969). [G] $P < 0.001$, $t_{H\ 0.05}$. [H] $P = 0.006$, $X^2_{\ 0.05}$.

TABLE 5.7. Three indexes of woody plant species turnover (similarity) across progressively disturbed habitat zones.

Zone comparison	Proportion of shared species	BC [A]	C_{MH} [B] (P)
CF / DF	0.69	0.59	0.70
DF / VE	0.50	0.61	0.76
VE / CF	0.48	0.52	0.68

[A] Bray-Curtis coefficient of similarity (Bray and Curtis 1957).

[B] Horn-Morisita index of similarity (Horn 1966).

TABLE 5.8. Structural habitat variables that differ across progressively disturbed habitat zones (CF, Closed-canopy Forest; DF, Disturbed Forest; VE, Village Environment; Mann-Whitney $U_{0.05}$). Values in bold differ across adjoining zones.

Variable^A	CF ($\bar{x}$ ± SD)	DF ($\bar{x}$ ± SD)	VE ($\bar{x}$ ± SD)	Decline with proximity	Lowest in VE	Increase with proximity	Highest in VE
CANCOV (%)	**94 ± 16**	**86 ± 18**	**44 ± 36**	✔			
T_CV/H (m^3/ha)	**11486 ± 8641**	**8881 ± 9554**	**2588 ± 3356**	✔			
L_CV/H (m^3/ha)	**8822 ± 8764**	**7018 ± 9329**	**1196 ± 1577**	✔			
M_CV/H (m^3/ha)	**2006 ± 1896**	**1356 ± 1589**	**980 ± 2021**	✔			
S_CV/H (m^3/ha)	**657 ± 668**	**506 ± 1722**	412 ± 634	✔			
TBA/H (m^2/ha)	**247 ± 200**	**206 ± 209**	**131 ± 179**	✔			
BA_high-value species^B (m^2/ha)	**116 ± 98**	**53 ± 75**	**23 ± 84**	✔			
LG_DBH (cm)	**46 ± 23**	**43 ± 9**	**30 ± 16**	✔			
LG_HT (m)	**13.7 ± 4.0**	**10.8 ± 4.2**	**4.5 ± 2.6**	✔			
MD_HT (m)	**8.2 ± 1.9**	**6.9 ± 2.2**	**4.0 ± 1.7**	✔			
SM_HT (m)	**3.6 ± 0.8**	**2.8 ± 0.8**	**2.4 ± 0.6**	✔			
L_LCAN (m)	**6.4 ± 2.4**	**4.0 ± 2.2**	**1.3 ± 0.9**	✔			

TABLE 5.8. Continued.

Variable^{A}	CF ($\bar{x}$ ± SD)	DF ($\bar{x}$ ± SD)	VE ($\bar{x}$ ± SD)	Decline with proximity	Lowest in VE	Increase with proximity	Highest in VE
M_LCAN (m)	**4.0 ± 1.4**	**3.1 ± 1.6**	**1.7 ± 0.7**	✔			
BAM_COV (cm/20m)	**1070 ± 806**	**74 ± 169**	**3.2 ± 23.8**	✔			
FRN_COV (cm/20m)	**1008 ± 814**	**707 ± 577**	**379 ± 385**	✔			
BLDR (presence in 4 quadrants)	**2.9 + 1.2**	**2.2 ± 1.3**	**1.2 ± 1.2**	✔			
LOG (count)	**3.1 ± 2.2**	**2.7 ± 2.3**	**0.2 ± 0.4**	✔			
MOSS (mode, 0-4)	**2**	**3**	**2**	✔			
LITTER (mode, 0-4)	**3^{C}**	**3**	**1**	✔			
VL_DENS	30.4 ± 46	**26.6 ± 50**	**0.4 ± 3.8**		✔		
L_DENS + M_DENS (trees/ha)	139 ± 40	**147 ± 38**	**105 ± 65**		✔		
SD_CC	**6.6**	**13.4**	**21.7**			✔	
SRB_EDG (count)	**1.8 ± 2.5**	**5.7 ± 3.1**	6.3 ± 5.0			✔	
SRB_COV (cm/20m)	**72 ± 81**	**220 ± 142**	242 ± 233			✔	
CUT (trees/100)	**10.2 ± 12.5**	**20.0 ± 16.0**	**48.1 + 21.3**			✔	

TABLE 5.8. Continued.

Variable[A]	CF ($\bar{x}$ ± SD)	DF ($\bar{x}$ ± SD)	VE ($\bar{x}$ ± SD)	Decline with proximity	Lowest in VE	Increase with proximity	Highest in VE
STUMP (count)	**5.3 ± 5.8**	**16 ± 9**	17 ± 15			✔	
PATH (m)	**14 ± 23**	**38 ± 40**	**53 ± 36**			✔	
PAST (count of quadrants)	**0.5 ± 1.1**	**1.1 ± 1.4**	**1.9 ± 1.7**			✔	
HEDGE (m)	0.0	**1.9 ± 8.5**	**29 ± 44**				✔

[A] Measured at 72 sampling points (two 9-ha plots) in each zone, see Appendix 4.1 for explanations of codes.

[B] Species ranked by local informants as good for timber, fuelwood, or fodder. [C] Modal values in CF and DF zones are both 3, but a non-parametric Mann-Whitney *U* test indicates sample values in CF are significantly higher.

TABLE 5.9. Relative abundance[A] of animal species in progressively disturbed habitat zones (CF, Closed-canopy Forest; DF, Disturbed Forest; VE, Village Environment). Values in bold differ across adjoining zones ($X^2_{0.05}$, adjusted values). Values in brackets are adjusted for habitat outliers.

	Abundance index[B]										
Species	CF	DF	VE	Highest in CF	Decline with proximity	Lowest in VE	Highest in DF	Lowest in CF	Increase with proximity	Highest in VE	Equal throughout
Partridge, common hill	**18**	**3**	**1**	✔							
Pigeon, ashy wood	1	0	0	✔							
Tesia, grey-bellied	**14**	**1**	2[0][C]	✔							
Vole, Sikkim	2	0	0	✔							
Warbler, ashy-throated	**15**	**6**	4	✔							
Barbet, great	1	0[D]	0	✔							
Barwing, hoary-throated	2	0[D]	0	✔							
Pigeon, wedge-tailed green	1	0[D]	0	✔							
Flycatcher, snowy-browed	**5**	**1**	0	✔							
Babbler, streak-breasted scimitar	**4**	**1**	5[0][C]	✔							
Shrew, brown-toothed	**27**	**13**	**2**		✔						

TABLE 5.9. Continued.

Species	Abundance index[B] CF	DF	VE	Highest in CF	Decline with proximity	Lowest in VE	Highest in DF	Lowest in CF	Increase with proximity	Highest in VE	Equal throughout
Babbler, rufous-throated wren	**3**	**1**	1[0][C]		✔						
Robin, white-tailed	5	4	8[0][C]			✔					
Laughingthrush, striated	8	3	0			✔					
Minla, blue-winged	3	3	0			✔					
Babbler, black-headed shrike	3	2	0			✔					
Niltava, rufous-bellied	17	**26**	**3**			✔					
Shrew, Indian long-tailed	1	3	0			✔					
Sunbird, green-tailed	24	**23**	**9**			✔					
Babbler, black-eared shrike	1	**4**	**0**			✔					
Flycatcher, pygmy blue [D]	3[E]	2	0[D]			✔					
Flycatcher, slaty-backed	2	3	0			✔					

TABLE 5.9. Continued.

	Abundance index[B]										
Species	CF	DF	VE	Highest in CF	Decline with proximity	Lowest in VE	Highest in DF	Lowest in CF	Increase with proximity	Highest in VE	Equal throughout
Bulbul, striated	**1**	**5**	**0**				✔				
Rat, chestnut	**12**	**22**	**10**				✔				
Warbler, golden-spectacled	**13**	**24**	**9**				✔				
Fantail, yellow-bellied	0	3	0				✔				
Warbler, buff-barred	**3**	**13**	**5**				✔				
Nuthatch, white-tailed	0	3	0				✔				
Rat, smoke-bellied	**7**	**20**	**2**				✔				
Woodpecker, Darjeeling pied	0[D]	1	0				✔				
Babbler, scaley-breasted wren	**4**	**17**	**1**				✔				
Shortwing, white-browed	**16**	**31**	**4**				✔				
Flycatcher, rufous-gorgetted	**0**[D]	**6**	**0**				✔				
Minla, red-tailed	0	1	0				✔				

TABLE 5.9. Continued.

	Abundance index[B]										
Species	CF	DF	VE	Highest in CF	Decline with proximity	Lowest in VE	Highest in DF	Lowest in CF	Increase with proximity	Highest in VE	Equal throughout
Minla, chestnut-tailed	**1**	**8**	**1**				✓				
Babbler, pygmy wren	**4**	**14**	**9**				✓				
Tesia, chestnut-headed	**11**	**35**	**6**				✓				
Yuhina, stripe-throated	0	3	0				✓				
Yuhina, whiskered	**10**	**24**	**8**				✓				
Sibia, rufous	**4**	**14**	**6**				✓				
Shrew, large-clawed	**7**	**22**	**11**				✓				
Tit, green-backed	0	2	5					✓			
Fulvetta, rufous-winged	**7**	**21**	14					✓			
Blackbird, grey-winged	0	6	3					✓			
Tit, black-throated	0	2	4					✓			
Babbler, rufous-capped	0	2	6					✓			

TABLE 5.9. Continued.

	Abundance index[B]										
Species	CF	DF	VE	Highest in CF	Decline with proximity	Lowest in VE	Highest in DF	Lowest in CF	Increase with proximity	Highest in VE	Equal throughout
Fulvetta, white-browed	0	4	2					✓			
Cuckoo, large hawk	0	3	3					✓			
Rat, lesser Nepalese brown	**3**	**10**	4					✓			
Robin, Indian blue	**1**	**23**	**43**						✓		
Shrew, Himalayan pygmy	4	7	13						✓		
Warbler, grey-hooded	2	5	7						✓		
Flycatcher, verditer	1[0][F]	**2**	**9**							✓	
Pheasant, Nepal kalij	0	0[D]	2							✓	
Bushchat, grey	0	**2**	**22**							✓	
Drongo, ashy	0	**0**	**4**							✓	
Flowerpecker, fire-breasted	0	0	2							✓	
Laughingthrush, streaked	0	**0**	**5**							✓	
Leiothrix, red-billed	0	0	2							✓	

TABLE 5.9. Continued.

	Abundance index[B]										
Species	CF	DF	VE	Highest in CF	Decline with proximity	Lowest in VE	Highest in DF	Lowest in CF	Increase with proximity	Highest in VE	Equal throughout
Pipit, olive-backed	1	**2**	**14**							✔	
Prinia, striated	0	0	3							✔	
Wagtail, grey	0	0	1							✔	
Warbler, brownish-flanked bush	0	**0**	**7**							✔	
Babbler, green shrike	0	0[D]	3							✔	
Mouse, Himalayan house	2	1	3								✔
Cuckoo, Eurasian	2	1	3								✔
Flycatcher, grey-headed	1	1	1								✔
Laughingthrush, chestnut-crowned	21	21	26								✔
Cuckoo, oriental	1	0[D]	0								✔
Warbler, chestnut-crowned	1	1	2								✔

TABLE 5.9. Continued.

[A] Birds: five census repetitions per 9-ha plot, 21 April - 18 June, 1993. Presumed or confirmed breeding species only. Nocturnal species, swallows, swifts, birds of prey, unidentified *Phylloscopus* warblers, unidentified *Carpodacus* rosefinches, and birds flying high overhead are excluded. Terrestrial small mammals: first six trap nights, 10 May - 11 July, 1993.

[B] Number of sampling points where a species was detected on one or more occasions during the survey period (Max. 72/ zone).

[C] Individuals that occupied lush riparian strips near the perimeter of VE plots were omitted from diversity analyses.

[D] Additional territorial individuals were detected in this zone subsequent to 5th census repetition.

[E] Pygmy blue flycatchers were probably underestimated in CF because of their small size and use of the high canopy.

[F] A territorial individual was detected in atypical CF habitat subsequent to the 5th census run (in a small forest-interior pasture).

TABLE 5.10. Estimated breeding densities of selected understory passerines in progressively disturbed habitat zones (territorial males/100ha). Values in bold differ significantly across zones (X^2, P <0.05).

Species	Closed-canopy Forest	Disturbed Forest	Village Environments
Babbler, p w	37.8	**33.3**	**8.3**
Babbler, sc-b w	**5.6**	**25.6**	**5.6**
Bushchat, g	0.0	**0.0**	**38.9**
Robin, I b	**8.9**	**86.7**	72.2
Shortwing, w-b	**8.9**	**55.6**	**0.0**
Tesia, c-h	**10.0**	**66.7**	**11.1**
Tesia, g-b	**22.2**	**2.2**	0.0

TABLE 5.11. Relative bird species diversity[A] in progressively disturbed habitat zones.

Zone	Species richness [B]	Species diversity (H') [C]	Effective diversity (D) [D]	Species equitability (J') [E]
Closed-canopy Forest	38	3.04	20.8	0.08
Disturbed Forest	47	3.19 [F]	24.2	0.07
Village Environment	38	2.99	20.0	0.08

[A] Species detected by daytime auditory/visual census only; not absolute species diversity.
[B] Number of species. [C] Species richness weighted by species evenness (H'_{ln}; Shannon and Weaver 1949, Barbour et al. 1987). [D] Number of equally-common species (exp(H'), MacArthur 1965).
[E] Distribution of detections among species (H'/sp. in sample, Pielou 1969). [F] $\underline{P} < 0.001$, $t_{H\ 0.005}$.

TABLE 5.12. Indexes of bird species turnover (similarity) across progressively disturbed habitat zones.

Zone comparison	Ratio of shared species [A]	BC [B]	C_{MH} [C] (*P*)
CF / DF	0.62	0.56	0.76
DF / VE	0.52	0.47	0.61
VE / CF	0.39	0.38	0.41

[A] Ratio of shared species to all species in either zone.

[B] Bray-Curtis coefficient of similarity (Bray and Curtis 1957).

[C] Horn-Morisita index of similarity (Horn 1966).

TABLE 5.13. Relative diversity of terrestrial small mammal species[A] in progressively disturbed habitat zones.

Zone	Total species	Species diversity (H') [B]	Effective diversity (D) [C]	Species equitability (J') [D]
Closed-canopy Forest	9	1.71	5.5	0.2
Disturbed Forest	8	1.84	6.3	0.2
Village Environment	7	1.75	5.7	0.2

[A] First-time captures, six trap nights/9-ha plot, two 9-ha plots/zone, 208 total detections.
[B] Species richness weighted by species evenness (H'_{ln}; Shannon and Weaver 1949, Barbour et al. 1987). [C] Number of equally-common species (exp(H'), MacArthur 1965). [D] Distribution of individuals among species (H'/sp. in sample, Pielou 1969).

TABLE 5.14. Indexes of species turnover (similarity) of terrestrial small mammals across progressively disturbed habitat zones.

Zone comparison	Ratio of shared species [A]	BC [B]	C_{MH} [C] (P)
CF / DF	0.89	0.59	0.85
DF / VE	0.88	0.52	0.56
VE / CF	0.78	0.55	0.45

[A] Ratio of shared species to all species in either zone.

[B] Bray-Curtis coefficient of similarity (Bray and Curtis 1957).

[C] Horn-Morisita index of similarity (Horn 1966).

TABLE 5.15.1. Richness and abundance of avian dietary guilds in progressively disturbed habitat zones (CF, Closed-canopy Forest; DF, Disturbed Forest; VE, Village Environment). Based on census results for 61 species.^{A} Values in bold differ across zones ($X^2_{0.05}$).

Dietary guild ^{B}	Richness (abundance)^{C}				Highest in CF	Lowest in VE	Highest in DF	Lowest in CF	Increase with proximity	Highest in VE	Equal throughout
	Entire study area	CF	DF	VE							
Frugivores,^{D} strict	1 (1)	1 (1)	0 (0)	0 (0)	✔						
Nectarivores, strict	1 (56)	1 (24)	1 (**23**)	1 (**9**)		✔					
Nectarivores, facultative	7 (127)	4 (**22**)	5 (**70**)	6 (**35**)			✔				
Insectivores, strict	28 (419)	21 (**111**)	**25** (**199**)	**15** (**109**)			✔				
Frugivores,^{D} facultative	23 (299)	12 (**90**)	16 (**126**)	15 (**83**)			✔				
Insectivores, facultative	30 (401)	14 (**98**)	21 (**162**)	22 (141)				✔			
Herbivores,^{E} facultative	7 (119)	5 (43)	4 (**28**)	5 (**48**)						✔	
Carnivores,^{F} facultative	2 (72)	1 (21)	1 (21)	2 (30)							✔
Granivores, facultative	17 (187)	7 (47)	10 (64)	11(76)							✔
Omnivores ^{G}	19 (264)	9 (72)	11 (96)	14 (96)							✔

TABLE 5.15.1. Continued.

[A] Five census repetitions in each 9-ha plot, 21 April - 18 June, 1993, two 9-ha plots per zone. Presumed or confirmed breeding species only. Nocturnal species, swallows, swifts, birds of prey, unidentified *Phylloscopus* warblers, unidentified *Carpodacus* rosefinches, and birds flying high overhead are excluded. Species occupying lush riparian strips near the perimeter of VE plots are considered habitat outliers and omitted from analysis.

[B] See Table 5.1 for designation of species to ecological guilds.

[C] Guild richness, number of member species; guild abundance, number of sampling points where member species were detected during the census period, summed for all member species.

[D] Diet consists of fruits and/or berries.

[E] Diet consists of leaves and/or buds.

[F] Diet includes animals other than insects.

[G] Diet consists of >2 categories of food.

TABLE 5.15.2. Richness and abundance of avian foraging stratum guilds in progressively disturbed habitat zones (CF, Closed-canopy Forest; DF, Disturbed Forest; VE, Village Environment). Based on censuses of 61 species.[A] Values in bold differ across zones ($X^2_{0.05}$).

Foraging stratum guild[B]	Richness (abundance)[C] Entire study area	CF	DF	VE	Highest in CF	Lowest in VE	Highest in DF	Lowest in CF	Increase with proximity	Highest in VE	Equal throughout
High canopy foragers, facultative	22 (193)	15 (70)	**16** (**87**)	**8** (**36**)		✔					
Mid-canopy foragers, strict	1 (5)	1 (1)	1 (**4**)	0 (**0**)		✔					
Mid-canopy foragers, facultative	35 (453)	22 (**126**)	28 (**206**)	19 (**121**)			✔				
Mean observed height >6 m	19 (216)	13 (**76**)	**17** (**108**)	**6** (**32**)			✔				
Shrub canopy foragers, facultative	39 (702)	21 (**177**)	31 (**314**)	27 (**211**)			✔				
Mean observed height <2 m	16 (332)	10 (**100**)	12 (**130**)	13 (102)				✔			
Ground foragers, facultative	21 (396)	12 (**95**)	15 (**160**)	13 (141)				✔			
Mean observed height 2-6 m	26 (330)	15 (**59**)	18 (**146**)	19 (125)				✔			
High canopy foragers, strict	1 (6)	0 (0)	1 (3)	1 (3)				✔			
Ground foragers, strict	7 (160)	5 (43)	5 (63)	6 (54)							✔
Shrub canopy foragers, strict	4 (26)	2 (10)	4 (10)	1 (6)							✔

TABLE 5.15.2. Continued.

[A] Five census repetitions in each 9-ha plot, 21 April - 18 June, 1993, two 9-ha plots per zone. Presumed or confirmed breeding species only. Nocturnal species, swallows, swifts, birds of prey, unidentified *Phylloscopus* warblers, unidentified *Carpodacus* rosefinches, and birds flying high overhead are excluded. Species occupying lush riparian strips near the perimeter of VE plots are considered habitat outliers and omitted from analysis.

[B] See Table 5.1 for designation of species to ecological guilds.

[C] Guild richness, number of member species; guild abundance, number of sampling points where member species were detected during the census period, summed for all member species.

TABLE 5.15.3. Richness and abundance of avian nest type guilds in progressively disturbed habitat zones (CF, Closed-canopy Forest; DF, Disturbed Forest; VE, Village Environment). Based on censuses of 61 species.[A] Values in bold differ across zones ($X^2_{0.05}$).

Nest type guild[B]	Richness (abundance)[C]				Highest in CF	Lowest in VE	Highest in DF	Lowest in CF	Increase with proximity	Highest in VE	Equal throughout
	Entire study area	CF	DF	VE							
Domed nest, strict	17 (395)	14 (**124**)	15 (**198**)	14 (**73**)			✔				
Tree cavity nest,[D] facultative	2 (48)	1 (**7**)	2 (**27**)	1 (**14**)			✔				
Domed nest, facultative	4 (67)	2 (**12**)	3 (**28**)	3 (27)				✔			
Open cup nest, strict	34 (433)	20 (**105**)	25 (**172**)	19 (156)				✔			
Ground cavity nesters,[E] facultative	5 (109)	3 (**9**)	5 (**35**)	2 (**65**)				✔			
Hanging nest (open or domed)	7 (186)	5 (**57**)	5 (**91**)	7 (**38**)							✔
Open cup nest, facultative	3 (25)	1 (5)	2 (7)	2 (13)							✔
Tree cavity nest,[D] strict	4 (12)	1 (1)	3 (6)	1 (5)							✔
Brood parasites	3 (13)	2 (3)	2 (4)	2 (6)							✔

TABLE 5.15.3. Continued.

[A] Five census repetitions in each 9-ha plot, 21 April - 18 June, 1993, two 9-ha plots per zone. Presumed or confirmed breeding species only. Nocturnal species, swallows, swifts, birds of prey, unidentified *Phylloscopus* warblers, unidentified *Carpodacus* rosefinches, and birds flying high overhead are excluded. Species occupying lush riparian strips near the perimeter of VE plots are considered habitat outliers and omitted from analysis.

[B] See Table 5.1 for designation of species to ecological guilds.

[C] Guild richness, number of member species; guild abundance, number of sampling points where member species were detected during the census period, summed for all member species.

[D] Includes secondary cavities.

[E] Nest built in depression or concavity on sloping ground.

TABLE 5.15.4. Richness and abundance of avian nest placement guilds in progressively disturbed habitat zones (CF, Closed-canopy Forest; DF, Disturbed Forest; VE, Village Environment). Based on 61 species.[A] Values in bold differ across zones ($X^2_{0.05}$).

	Richness (abundance)[C]										
Nest placement guild[B]	Entire study area	CF	DF	VE	Highest in CF	Lowest in VE	Highest in DF	Lowest in CF	Increase with proximity	Highest in VE	Equal throughout
Mid-canopy nesters, strict	7 (66)	6 (22)	5 (**34**)	3 (**10**)		✔					
Shrub canopy nesters,[D] strict	35 (227)	7 (75)	8 (**96**)	7 (**56**)		✔					
Ground nesters, facultative	14 (221)	7 (**49**)	13 (**119**)	9 (**53**)			✔				
Shrub canopy nesters,[D] facultative	22 (284)	**11** (**65**)	**21** (**150**)	13 (**69**)			✔				
Mid-canopy nesters, facultative	19 (176)	9 (**34**)	15 (**88**)	12 (**54**)			✔				
Ground nesters, strict	11 (253)	8 (**60**)	9 (**91**)	9 (102)				✔			
High canopy nesters, facultative	8 (42)	5 (9)	4 (19)	5 (14)							✔
High canopy nesters, strict	2 (9)	1 (3)	1 (2)	1 (4)							✔

[A] Five census repetitions in each 9-ha plot, 21 April - 18 June, 1993, two 9-ha plots per zone. Presumed or confirmed breeding species only. Nocturnal species, swallows, swifts, birds of prey, unidentified *Phylloscopus* warblers, unidentified *Carpodacus* rosefinches, and birds flying high overhead excluded. Species occupying lush riparian strips near the perimeter of VE plots are habitat outliers and omitted from analysis.

[B] See Table 5.1 for designation of species to ecological guilds.

[C] Guild richness, number of member species; guild abundance, number of sampling points where member species were detected during the census period, summed for all member species.

[D] Typically builds nest within 2 m of the ground.

TABLE 5.16. Richness and abundance of small terrestrial mammal dietary guilds in progressively degraded habitat zones (CF, Closed-canopy Forest; DF, Disturbed Forest; VE, Village Environment). Based on trapping results for 9 species.[A] Values in bold differ across zones ($X^2{}_{0.05}$).

	Richness (abundance)[C]							
Guild [B]	Entire study area	CF	DF	VE	Lowest in VE	Highest in DF	Lowest in CF	Equal throughout
Carnivores,[G] facultative	4 (110)	4 (39)	4 (**45**)	3 (**26**)	✔			
Omnivores [D]	3 (90)	3 (**22**)	3 (**52**)	3 (**16**)		✔		
Frugivores,[E] facultative	2 (61)	2 (**15**)	2 (**32**)	2 (**14**)		✔		
Granivores, facultative	5 (98)	5 (**26**)	4 (**53**)	4 (**19**)		✔		
Insectivores, facultative	8 (206)	8 (**63**)	8 (**98**)	7 (**45**)		✔		
Herbivores,[F] facultative	4 (92)	4 (**24**)	3 (**52**)	3 (**16**)		✔		
Shrub foragers, facultative	2 (61)	2 (**15**)	2 (**32**)	2 (**14**)		✔		
Fossorial foragers, strict	1 (40)	1 (**7**)	1 (**22**)	1 (11)			✔	
Mid-canopy foragers, facultative	1 (17)	1 (3)	1 (10)	1 (4)				✔
Structure[H] foragers, facultative	3 (47)	3 (9)	3 (18)	3 (20)				✔

TABLE 5.16. Continued.

[A] First-time captures, first 6 trap nights/9-ha plot, 2 plots/ zone, 10 May - 11 July, 1993.

[B] See Table 5.2 for species membership in guilds.

[C] Guild richness, number of member species detected; guild abundance, number of sampling points where member species were trapped during the trapping period, summed for all member species.

[D] Diet consists of >2 categories of food.

[E] Diet consists of fruits and/or berries.

[F] Diet consists of leaves and/or buds.

[G] Diet includes animals other than insects.

[H] Forages within man-made structures and dwellings.

TABLE 5.17. Habitat variables most affected by specific resource harvests. Values in bold differ significantly across adjoining habitat zones (CF, Closed-canopy Forest; DF, Disturbed Forest; VE, Village Environment; *U*, *P* $\leq$0.05).

	Zonal means			Presumed contributory effects^{B}						
Variable^{A}	CF	DF	VE	Pasturage	Timber^{D}	Fuelwood^{E}	Tree fodder^{F}	Forest litter	Bamboo	Pollarded stems
T_CV/M	**9.2**	**7.1**	**2.0**		−D‡	−D	−D			
VL_DENS	30.4	**26.6**	**0.4**				−I			
L_DENS + M_DENS	139	**147**	**105**		−D‡	−D	−I			
BA_LG + MD	235	**241**	**118**		−D‡	−D				
L_DBH	46.2	**42.5**	**37.9**		−D‡	−D				
T_HT:DBH	0.5	0.4	0.3		−I‡*	−I	−D			−I
ACECAM	**2.2**	**0.9**	**0.1**	−D†	−D†	−D				
BA_ACECAM, LG + MD	**5.8**	**0.9**	0.0	−I†	−D†	−D				
ALNNEP	0.5	**0.2**	**2.7**^{G}		+I*	+I				
BA_ALNNEP, LG + MD	0.7	**0.0**	**0.4**^{G}		+I*	$\pm$I				
BERARI	**0.0**	**7.3**	**15.4**	+I*	+I*	+I				
BA_EURACU, LG + MD	5.9	**8.2**	**11.4**	+I*	+I*	+I				
FICNER	**5.2**	**0.0**	**2.9**^{G}	−D†			−I			
BA_FICNER, LG + MD	**2.1**	**0.0**	**0.5**^{G}	−I†			−I			

TABLE 5.17. Continued.

	Zonal means			Presumed contributory effects						
Variable[A]	CF	DF	VE	Pasturage	Timber	Fuelwood	Tree fodder	Forest litter	Bamboo	Pollarded stems
HYDHET	**0.8**	**3.2**	**0.8**		±I*	±I				
LITELO	**6.0**	**2.1**	**0.2**	−D†	−D†		−I			
BA_LITELO, LG + MD	**6.1**	**3.9**	**0.1**	−I†	−D†		−I			
LYOOVA	4.5	**6.0**	**10.4**	+I*	+I*	−D/±I				
MICKIS	**1.16**	**0.12**	0.12	−D†	−D†		−I			
BA_MICKIS, LG + MD	**6.00**	**0.02**	0.14[H]	−I†	−D†		−I			
MYRSEM	**2.7**	**0.0**	0.5			−D				
BA_MYRSEM, LG + MD	**0.4**	**0.0**	0.1			−D				
PERCLA + PERDUT (*Persea* spp.)	**11.0**	**2.5**	**0.1**	−D†	−D†		−I			
BA_PERCLA + PERDUT, LG + MD (BA_*Persea* spp.)	**22.0**	**6.4**	**4.4**	−I†	−D†		−I			
QUELAM+QUEOXY+QUESEM (*Quercus* spp.)	**8.3**	**3.4**	**0.1**	−D†		−D				
BA_QUELAM+QUEOXY+QUESEM, LG + MD (BA_*Quercus* spp.)	13.5	**11.3**	**0.1**	−I†		−D				
QUELAM	3.2	**2.9**	**0.1**	−D†		−D				
BA_QUELAM, LG + MD	4.4	**10.7**	**0.1**	−I†		−D				

TABLE 5.17. Continued.

	Zonal means			Presumed contributory effects						
Variable^A	CF	DF	VE	Pasturage	Timber	Fuelwood	Tree fodder	Forest litter	Bamboo	Pollarded stems
RHOARB	4.5	**1.6**	**0.5**			−D				
BA_RHOARB, LG + MD	**5.1**	**1.8**	0.2			−D				
SYMTHE + SYMRAM (*Symplocus* spp.)	**14.4**	**38.0**	**12.8**	+I*	+I*	+I				
BA_SYMTHE + SYMRAM, LG + MD (BA_ *Symplocus* spp.)	**5.5**	**34.6**	**12.6**	+I*	+I*	+I				
CUT	**10.2**	**20.0**	**48.1**				+D			+D
SRB_COV	**7.2**	**22.1**	24.3	−D‡	+I ‡	+I				
BAM_COV	**107**	**7.4**	**0.3**	−D	−I	−I			−D	
LITTER	3	**3**	**1**		−I	−I	−D	−D		
LOG	2	**1**	**0**		−D	−D				
STUMP	**21.3**	**64.6**	68.5		+D	+D				

TABLE 5.17. Continued.

[A] See Appendix 4.1 for definitions of variable codes.

[B] D, direct/immediate effect; I, incidental or gradual effect; +/-, positive or negative effect.

[C] Browsing and grazing by village-based livestock.

[D] Tree species rated “good” for building stone and timber structures by a local informant group. Poles of *Symplocos* and *Eurea* are also frequently used to build semi-permanent dwellings and livestock shelters.

[E] Species rated “good” for fuelwood by local informants.

[F] Species rated “good” for livestock fodder by a local informant group. Effects include lopping of upper branches as well as browsing near the ground.

[G] Many FICNER and ALNNEP in VE are protected or semi-cultivated for livestock fodder or fuelwood, respectively.

[H] A single large MICKIS in VE was omitted from statistical test.

* Presumption of effect is justified by published research.

† Presumption of effect is justified by designation as a high-value resource by local informants.

‡ Presumption of effect is justified by widely-recognized ecological principles.

TABLE 5.18. Harvest-affected variables^{A} that correlate significantly with animal species abundances^{B} across progressively disturbed habitat zones. The first + or - indicates whether a species' zonal abundance is positively or negatively correlated with a habitat variable (Pearson *r* correlation, ∝ = 0.05), and the second + or - indicates whether harvest of the resource has a positive or negative effect on that habitat variable. Where signs match, harvest can benefit the species, whereas mis-matched signs indicate harvest can decrease abundance. Species uncorrelated with harvest-affected variables are not listed.

Species	Pasturage^{C}	Timber^{D}	Fuelwood^{E}	Tree fodder^{F}	Other
Babbler, black-headed shrike	BA_LITELO +-	T_CV/M +- BA_LITELO +-	T_CV/M +-	T_CV/M +- BA LITELO +-	
Babbler, green shrike		TBA/H --	TBA/H --		
Babbler, pygmy wren	FICNER --			FICNER --	
Babbler, rufous-capped		T_CV/M -- BA LITELO --	T_CV/M --	T_CV/M -- BA LITELO --	
Babbler, rufous-throated wren	BA_ACECAM +- LITELO +-	BA_ACECAM +- LITELO +-	BA_ACECAM +- RHOARB +- BA_RHOARB +-	LITELO +-	
Babbler, scaley-breasted wren					
Babbler, streak-breasted scimitar	*Persea* spp. +-	PERCLA +-	RHOARB +-	*Persea* spp. +-	
Barbet, great	MICKIS +- BA_MICKIS +- BAM_COV +-	MICKIS +- BA_MICKIS +- BAM_COV +- STUMP -+	BAM_COV +- STUMP -+	MICKIS +- BA_MICKIS +-	Bamboo harvest: BAM_COV +-
Barwing, hoary-throated	MICKIS +- BA_MICKIS +- BAM_COV +-	MICKIS +- BA_MICKIS +- BAM_COV +- STUMP -+	BAM_COV +- STUMP -+	MICKIS +- BA_MICKIS +-	Bamboo harvest: BAM_COV +-
Blackbird, grey-winged	FICNER --			FICNER --	

TABLE 5.18. Continued.

Species	Pasturage[C]	Timber[D]	Fuelwood[E]	Tree fodder[F]	Other
Bushchat, grey	*Quercus* spp. -- BA_*Quercus* spp. --		*Quercus* spp. -- BA_*Quercus* spp. --	VL_DENS --	
Cuckoo, large hawk	MICKIS -- BA_MICKIS -- BAM_COV --	MICKIS -- BA_MICKIS -- BAM_COV -- STUMP ++	RHOARB -- STUMP ++	MICKIS -- BA_MICKIS --	Bamboo harvest: BAM_COV --
Cuckoo, oriental	MICKIS +- BA_MICKIS +- BAM_COV +-	MICKIS +- BA_MICKIS +- BAM_COV +- STUMP -+	BAM_COV +- STUMP -+	MICKIS +- BA_MICKIS +-	Bamboo harvest: BAM_COV +-
Drongo, ashy		TBA/H --	TBA/H --		
Fantail, yellow-bellied		HYDHET +±[G] *Symplocus* spp. ++	HYDHET +±[G] *Symplocus* spp. ++		
Flowerpecker, fire-breasted		TBA/H --	T BA/H --		
Flycatcher, pygmy blue	BA_LITELO +-	T_CV/M +- BA_LITELO +-	T_CV/M +-	T_CV/M +- BA_LITELO +-	
Flycatcher, rufous-gorgeted		HYDHET +±[G] *Symplocus* spp. ++	HYDHET +±[G] *Symplocus* spp. ++		
Flycatcher, snowy-browed	BA_ACECAM +- BA_*Persea* spp. +- SRB_COV -- BAM_COV +-	BA_ACECAM +- BA_PERCLA +- SRB_COV -+ BAM_COV +- STUMP -+	BA_ACECAM +- SRB_COV -+ BAM_COV +- STUMP -+	BA_*Persea* spp. +-	Bamboo harvest: BAM_COV +-
Flycatcher, verditer	BA_*Quercus* spp. --	T_CV/M -- LYOOVA ++	T_CV/M -- LYOOVA +± BA_*Quercus* spp. --	T_CV/M -- CUT ++	Stem pollarding: CUT ++

TABLE 5.18. Continued.

Species	Pasturage[C]	Timber[D]	Fuelwood[E]	Tree fodder[F]	Other
Fulveta, rufous-winged	FICNER --			FICNER --	
Fulveta, white-browed	FICNER --			FICNER --	
Laughingthrush, chestnut-cr.		TBA/H --	TBA/H --		
Laughingthrush, streaked		TBA/H --	TBA/H --		
Laughingthrush, striated	BA_ACECAM +- LITELO +-	BA_ACECAM +- LITELO +-	BA_ACECAM +- RHOARB +-	LITELO +-	
Leiothrix, red-billed		TBA/H --	TBA/H --		
Minla, blue-winged		TBA/H +-	TBA/H +-		
Minla, chestnut-tailed		HYDHET +±[G] *Symplocus* spp. ++	HYDHET +±[G] *Symplocus* spp. ++		
Minla, red-tailed		HYDHET +±[G] *Symplocus* spp. ++	HYDHET +±[G] *Symplocus* spp. ++		
Nuthatch, white-tailed		HYDHET +±[G] *Symplocus* spp. ++	HYDHET +±[G] *Symplocus* spp. ++		
Partridge, common hill	BA_ACECAM +- BA_*Persea* spp. +- SRB_COV -- BAM_COV +-	BA_ACECAM +- BA_PERCLA +- SRB_COV -+ BAM_COV +- STUMP -+	BA_ACECAM +- SRB_COV -+ BAM_COV +- STUMP -+	BA_*Persea* spp.+-	Bamboo harvest: BAM_COV +-
Pheasant, Nepal kalij		TBA/H --	TBA/H --		
Pigeon, ashy wood	MICKIS +- BA_MICKIS +- BAM_COV +-	MICKIS +- BA_MICKIS +- BAM_COV +- STUMP -+	BAM_COV +- STUMP -+	MICKIS +- BA_MICKIS+-	Bamboo harvest: BAM_COV +-

TABLE 5.18. Continued.

Species	Pasturage^{C}	Timber^{D}	Fuelwood^{E}	Tree fodder^{F}	Other
Pigeon, wedge-tailed green	MICKIS +- BA_MICKIS+- BAM_COV +-	MICKIS +- BA_MICKIS +- BAM_COV +- STUMP -+	BAM_COV +- STUMP -+	MICKIS +- BA_MICKIS+-	Bamboo harvest: BAM_COV +-
Pipit, olive-backed	*Quercus* spp. --		*Quercus* spp. --	VL_DENS --	
Prinia, striated		TBA/H --	TBA/H --		
Robin, Indian blue	BERARI ++	L_DBH -- HT:DBH +- LOG --	L_DBH -- HT:DBH +- LOG --	HT:DBH +-	Stem pollarding: HT:DBH +-
Shortwing, white-browed	BA_QUELAM +-		BA_QUELAM +-		
Shrew, brown-toothed	ACECAM +-	HT:DBH +- ACECAM +- LOG +-	HT:DBH +- ACECAM +- LOG +-	HT:DBH +-	Stem pollarding: HT:DBH +-
Shrew, Himalayan pygmy	BA_LITELO --	T_CV/M -- BA_LITELO --	T_CV/M --	T_CV/M -- BA_LITELO --	
Shrew, long-clawed		BA_*Symplocus* spp. ++	BA_*Symplocus* spp.++		
Sibia, rufous		BA_*Symplocus* spp. ++	BA_*Symplocus* spp. ++		
Sunbird, green-tailed	*Quercus* spp. +-		*Quercus* spp. +-	VL_DENS +-	
Tesia, grey-bellied	MICKIS +- BA_*Persea* spp. +- SRB_COV -- BAM_COV +-	MICKIS +- BA_PERCLA +- SRB_COV -+ BAM_COV +- STUMP -+	SRB_COV -+ BAM_COV +- STUMP -+	BA_*Persea* spp. +-	Bamboo harvest: BAM_COV +-
Tit, black-throated	BERARI ++	L_DBH-- HT:DBH --	L_DBH-- HT:DBH --	HT:DBH --	Stem pollarding: HT:DBH --

TABLE 5.18. Continued.

Species	Pasturage[C]	Timber[D]	Fuelwood[E]	Tree fodder[F]	Other
Tit, green-backed	BA_EURACU ++ BA_LITELO --	BA_EURACU ++ BA_LITELO --	BA_EURACU ++	BA_LITELO --	
Vole, Sikkim	MICKIS +- BA_MICKIS +- BAM_COV +-	MICKIS +- BA_MICKIS +- BAM_COV +- STUMP -+	BAM_COV +- STUMP -+		Bamboo harvest: BAM_COV +-
Wagtail, grey		TBA/H --	TBA/H --		
Warbler, ashy-throated	BA_ACECAM +- *Persea* spp. +- BA_*Persea* spp. +- SRB_COV --	BA_ACECAM +- PERCLA +- BA_PERCLA +- SRB_COV -+	BA_ACECAM +- SRB_COV -+	*Persea* spp. +- BA_*Persea* spp. +-	
Warbler buff-barred		BA_*Symplocus* spp. ++	BA_*Symplocus* spp. ++		
Warbler, br.-flanked bush		TBA/H --	TBA/H --		
Warbler, chestnut-crowned		TBA/H --	TBA/H --		
Warbler, grey-hooded	BA_ACECAM --	BA_ACECAM --	BA_ACECAM --		
Woodpecker, Darjeeling pied		HYDHET +±[G] *Symplocus* spp. ++	HYDHET +±[G] *Symplocus* spp. ++		
Yuhina, stripe-throated		HYDHET +±[G] *Symplocus* spp. ++	HYDHET +±[G] *Symplocus* spp. ++		
Yuhina, whiskered		*Symplocus* spp. ++	*Symplocus* spp. ++		

TABLE 5.18. Continued.

[A] See Table 5.17 for a full list of harvest-affected habitat variables.

[B] Number of sampling points where a species was detected at least once. Individuals of certain mesic-habitat species detected in lush riparian strips near the perimeter of VE plots were omitted from zonal comparisons (see Table 5.9).

[C] Browsing and grazing by village-based livestock.

[D] Harvest of tree species rated “good” for building of stone and timber structures by a local informant group. Poles of *Symplocos* and *Eurea* are also frequently used to build semi-permanent dwellings and livestock shelters.

[E] Harvest of woody species rated “good” for fuelwood by local informants.

[F] Harvest of woody species rated “good” for livestock fodder by a local informant group. Effects include lopping of upper branches as well as browsing near the ground.

[G] The initial effect of timber and fuelwood harvest is to increase HYDHET, which responds positively to small canopy openings, but as timber harvest increases and the forest canopy continues to thin, HYDHET decreases and eventually disappears.

TABLE 5.19. Harvest-affected habitat variables[A] that correlate significantly with abundances[B] of bird ecological guilds across progressively disturbed habitat zones. The first + or - indicates whether guild abundance is positively or negatively correlated with a habitat variable (Pearson *r* correlation, ∝ = 0.05), and the second + or - indicates whether harvest of the resource has a positive or negative effect on that habitat variable. Where signs match, harvest can increase the number of individuals in a guild, whereas mis-matched signs indicate harvest can decrease guild abundance. Guilds uncorrelated with harvest-affected variables are not listed.

Guild	Pasturage[C]	Timber[D]	Fuelwood[E]	Tree fodder[F]	Other
Frugivores, strict	BA_MICKIS +- BAM_COV +-	BA_MICKIS +- BAM_COV +- STUMP -+	STUMP -+	MICKIS +- BA_MICKIS +-	Bamboo harvest: BAM_COV +-
Granivores, facultative	ACECAM -- *Quercus* spp. --	ACECAM --	ACECAM -- *Quercus* spp. --		
Omnivores	BA_MICKIS -- BAM_COV --	BA_MICKIS -- BAM_COV -- STUMP ++	STUMP ++	MICKIS -- BA_MICKIS --	Bamboo harvest: BAM_COV --
Nectarivores, strict	QUELAM +-		QUELAM +-		
Nectarivores, facultative	BA_*Symplocus* spp. ++	BA_*Symplocus* spp. ++	BA_*Symplocus* spp. ++		
Carnivores, facultative		TBA/H --	TBA/H --		
Ground foragers, facultative	BA_FICNER --		BA_MYRSEM --	BA_FICNER --	
Shrub canopy foragers, strict		TBA/H +-	TBA/H +-		
Shrub canopy foragers, fac.	BA_*Symplocus* spp. ++	BA_*Symplocus* spp. ++	BA_*Symplocus* spp. ++		
Mid-canopy foragers, facultative	*Symplocus* spp. ++	HYDHET +±[G] *Symplocus* spp. ++	HYDHET +±[G] *Symplocus* spp. ++		

TABLE 5.19. Continued.

Guild	Pasturage[C]	Timber[D]	Fuelwood[E]	Tree fodder[F]	Other
High canopy foragers, strict	MICKIS -- BA_MICKIS -- BAM_COV --	MICKIS -- BA_MICKIS -- BAM_COV -- STUMP ++	STUMP ++	MICKIS -- BA_MICKIS --	Bamboo harvest: BAM_COV --
Open cup nest, strict	BA_FICNER--		BA_MYRSEM -- MYRSEM --	BA_FICNER--	
Open cup nest, facultative		T_CV/M -- LYOOVA ++	T_CV/M -- LYOOVA ++	T_CV/M -- CUT ++	Stem pollarding: CUT ++
Domed nest, strict	BA_QUELAM +-		BA_QUELAM +-		
Domed nest, facultative	MICKIS -- BA_MICKIS --	MICKIS -- BA_MICKIS --		MICKIS -- BA_MICKIS --	
Hanging nest	BA_QUELAM +-		BA_QUELAM +-		
Tree cavity nest, strict	BA_FICNER --		BA_MYRSEM -- MYRSEM --	BA_FICNER –	
Depression nest, facultative	BERARI ++ BA_EURACU ++	HT:DBH -- BERARI ++ BA_EURACU ++ LOG --	HT:DBH -- BERARI ++ BA_EURACU ++ LOG --	HT:DBH --	Stem pollarding: HT:DBH --
Brood parasites	BA_LITELO --	T_CV/M. -- BA_LITELO --	T_CV/M --	T_CV/M -- BA_LITELO --	
Ground nesters, strict	LITELO -- *Persea* spp. --	LITELO -- *Persea* spp. --	RHOARB -- BA_RHOARB --	LITELO -- *Persea* spp.--	
Ground nesters, facultative		HYDHET +±[G]	HYDHET +±[G]		
Shrub canopy nesters, facultative		HYDHET +±[G]	HYDHET +±[G]		

TABLE 5.19. Continued.

Guild	Pasturage[C]	Timber[D]	Fuelwood[E]	Tree fodder[F]	Other
Mid-canopy nesters, facultative		BA_ALNNEP -+	BA_ALNNEP -±[H]		
High canopy nesters, facultative	FICNER --			FICNER --	

[A] See Table 5.17 for a full list of harvest-affected habitat variables.

[B] Guild abundance is the number of sampling points where member species were detected during the general faunal surveys, summed for all member species. Individuals of certain mesic-habitat species detected in lush riparian strips near the perimeter of VE plots were omitted from zonal comparisons. See Table 5.1 for species membership and definitions of ecological guilds.

[C] Browsing and grazing by village-based livestock.

[D] Harvest of tree species rated “good” for building of stone and timber structures by a local informant group. Poles of *Symplocos* and *Eurea* are also frequently used to build semi-permanent dwellings and livestock shelters.

[E] Harvest of woody species rated “good” for fuelwood by local informants.

[F] Harvest of woody species rated “good” for livestock fodder by a local informant group. Effects include lopping of upper branches as well as browsing near the ground.

[G] The initial effect of timber and fuelwood harvest is to increase HYDHET, which responds positively to small canopy openings, but as timber harvest increases and the forest canopy continues to thin, HYDHET decreases and eventually becomes absent.

[H] The initial effect of fuelwood harvest is to decrease ALNNEP as natural supplies are unsustainably harvested. Over time, village inhabitants plant and semi-cultivate ALNNEP near the village for fuelwood.

TABLE 5.20. Harvest-affected habitat variables[A] that correlate significantly with abundances[B] of small mammal dietary guilds across progressively disturbed habitat zones. The first + or - indicates whether guild abundance is positively or negatively correlated with a habitat variable (Pearson *r* correlation, ∝ = 0.05), and the second + or - indicates whether a forest use has a positive or negative effect on that habitat variable. Where signs match, harvest can increase guild abundance, whereas mis-matched signs indicate harvest can decrease guild abundance. Guilds uncorrelated with harvest-affected variables are not listed.

Guild	Pasturage[C]	Timber[D]	Fuelwood[E]	Tree fodder[F]
Insectivores, facultative	BA_QUELAM +-		BA_QUELAM +-	
Frugivores, facultative	*Symplocus* spp. ++	HYDHET +±[G] *Symplocus* spp. ++	HYDHET +±[G] *Symplocus* spp. ++	
Shrub canopy foragers, facultative	*Symplocus* spp. ++	HYDHET +±[G] *Symplocus* spp. ++	HYDHET +±[G] % *Symplocus* spp. ++	
Structure foragers, facultative	BA_ACECAM -- *Persea* spp. -- BA_*Persea* spp. -- SRB_COV +-	BA_ACECAM -- *Persea* spp. -- BA_*Persea* spp. -- SRB_COV ++	BA_ACECAM -- SRB_COV ++	*Persea* spp. -- BA_*Persea* spp. --
Fossorial foragers, strict	BA_*Symplocus* spp. ++	BA_*Symplocus* spp. ++	BA_*Symplocus* spp. ++	

[A] See Table 5.17 for a full list of harvest-affected habitat variables.

[B] Guild abundance is the number of sampling points where member species were detected during the general faunal surveys, summed for all member species. See Table 5.2 for species membership and definitions of ecological guilds.

[C] Browsing and grazing by village-based livestock.

[D] Harvest of tree species rated “good” for building of stone and timber structures by a local informant group. Poles of *Symplocos* and *Eurea* are also frequently used to build semi-permanent dwellings and livestock shelters.

[E] Harvest of woody species rated “good” for fuelwood by local informants.

[F] Harvest of woody species rated “good” for livestock fodder by a local informant group. Effects include lopping of upper branches as well as browsing near the ground.

[G] The initial effect of timber and fuelwood harvest is to increase HYDHET, which responds positively to small canopy openings, but as timber harvest increases and the forest canopy continues to thin, HYDHET decreases and eventually becomes absent.

TABLE 5.21. Harvest-affected variables[A] that differ between sites occupied versus unoccupied by seven understroy bird species at the microhabitat scale (Mann-Whitney *U*, ∝ = 0.05, with continuity correction for small sample size). The first + or - indicates whether occupancy is positively or negatively associated with a habitat variable, and the second + or - indicates whether harvest of the resource has a positive or negative effect on the habitat variable. Where signs match, harvest can increase occupancy, whereas mis-matched signs indicate harvest can decrease occupancy.

Species	Pasturage[B]	Timber[C]	Fuelwood[D]	Tree fodder[E]	Other
Babbler, pygmy wren	BA_EURACU -+ BA_*Persea* spp. +- BAM_COV --	BA_EURACU -+ HYDHET +±[X] LYOOVA -+ BA_PERCLA +- *Symplocus* spp. ++ BAM_COV -- LOG +-	BA_EURACU -+ HYDHET +±[X] LYOOVA -± *Symplocus* spp. ++ LOG +-	BA_*Persea* spp. +-	Bamboo harvest: BAM_COV --
Bushchat, grey	BERARI ++ FICNER -- BA_FICNER -- LITELO -- *Persea* spp. -- BA_*Persea* spp. -- *Quercus* spp. -- BA_*Quercus* spp. -- BAM_COV --	T_CV/M -- L_DENS + M_DENS -- TBA/H -- L_HT:DBH -- ALNNEP +- BA_ALNNEP +- LITELO -- PERCLA -- BA_PERCLA -- *Symplocus* spp. -+ BA_*Symplocus* spp. -+ BAM_COV -- LOG -- STUMP -+	T_CV/M -- L_DENS + M_DENS -- TBA/H -- L_HT:DBH -- ALNNEP +± BA_ALNNEP +± *Quercus* spp. -- BA_*Quercus* spp. -- *Symplocus* spp. -+ BA_*Symplocus* spp. -+ LOG -- STUMP -+	L_HT:DBH -- FICNER -- BA_FICNER -- LITELO -- *Persea* spp. -- BA_*Persea* spp. --	Stem pollarding: L_HT:DBH -- CUT ++ Bamboo harvest: BAM_COV --
Babbler, sc.-breasted wren	FICNER -- QUELAM +-	HYDHET +±	HYDHET +± QUELAM +-	FICNER --	

TABLE 5.21. Continued.

Species	Pasturage[A]	Timber[B]	Fuelwood[C]	Tree fodder[D]	Other
Robin, Indian blue	BERARI ++ BA_FICNER -- BA_LITELO -- LITELO -- BA_*Persea* spp. -- *Quercus* spp. -- SRB_COV +- BAM_COV --	T_CV/M -- L_HT:DBH -- BA_LITELO -- LITELO -- LYOOVA ++ BA_PERCLA -- SRB_COV ++ BAM_COV -- LOG -- STUMP ++	T_CV/M -- L_HT:DBH -- LYOOVA ++ *Quercus* spp. -- SRB_COV ++ LOG -- STUMP ++	T_CV/M -- L_HT:DBH -- BA_FICNER -- BA_LITELO -- LITELO -- BA_*Persea* spp. -- CUT ++	Stem pollarding: L_HT:DBH -- CUT ++ Bamboo harvest: BAM_COV --
Shortwing, white-browed	BERARI -+ FICNER -- BA_FICNER -- BA_LITELO +- LITELO +-	HYDHET +± BA_LITELO +- LITELO +- *Symplocus* spp. ++	HYDHET +± *Symplocus* spp. ++	FICNER -- BA_FICNER -- BA_LITELO +- LITELO +-	
Tesia, chestnut-headed	FICNER -- BA_FICNER -- BA_LITELO +- LITELO +- BA_*Quercus* spp. +-	ALNNEP -- HYDHET +± BA_LITELO +- LITELO +- LYOOVA -+ *Symplocus* spp. ++ LOG +-	FICNER -- ALNNEP -± HYDHET +± LYOOVA -+ BA_*Quercus* spp. +- *Symplocus* spp. ++ LOG +-	BA_LITELO +- LITELO +-	
Tesia, grey-bellied	BERARI -+ BA_LITELO -- LITELO -- *Quercus* spp. +- BA_*Quercus* spp. +- BAM_COV --	T_CV/M +- L_HT:DBH -- LITELO BA -- LITELO -- LYOOVA -+ *Symplocus* spp. ++ BAM_COV -- LOG +-	T_CV/M +- L_HT:DBH -- LYOOVA -+ *Quercus* spp. +- BA_*Quercus* spp. +- *Symplocus* spp. ++ LOG +-	T_CV/M +- L_HT:DBH -- BA_LITELO -- LITELO --	Stem pollarding: L_HT:DBH -- Bamboo harvest: BAM_COV --

TABLE 5.21. Continued.

[A] See Table 5.17 for a full list of harvest-affected habitat variables

[B] Browsing and grazing by village-based livestock.

[C] Harvest of tree species rated “good” for building of stone and timber structures by a local informant group. Poles of *Symplocos* and *Eurea* are also frequently used to build semi-permanent dwellings and livestock shelters.

[D] Harvest of woody species rated “good” for fuelwood by local informants.

[E] Harvest of woody species rated “good” for livestock fodder by a local informant group. Effects include lopping of upper branches as well as browsing near the ground.

[F] The initial effect of timber harvest is to increase HYDHET, which responds positively to small canopy openings, but as timber harvest increases and the forest canopy continues to thin, HYDHET decreases and eventually becomes absent.

[G] The initial effect of fuelwood harvest is to decrease ALNNEP as natural supplies are unsustainably harvested. Over time, village inhabitants plant and semi-cultivate ALNNEP near the village for fuelwood.

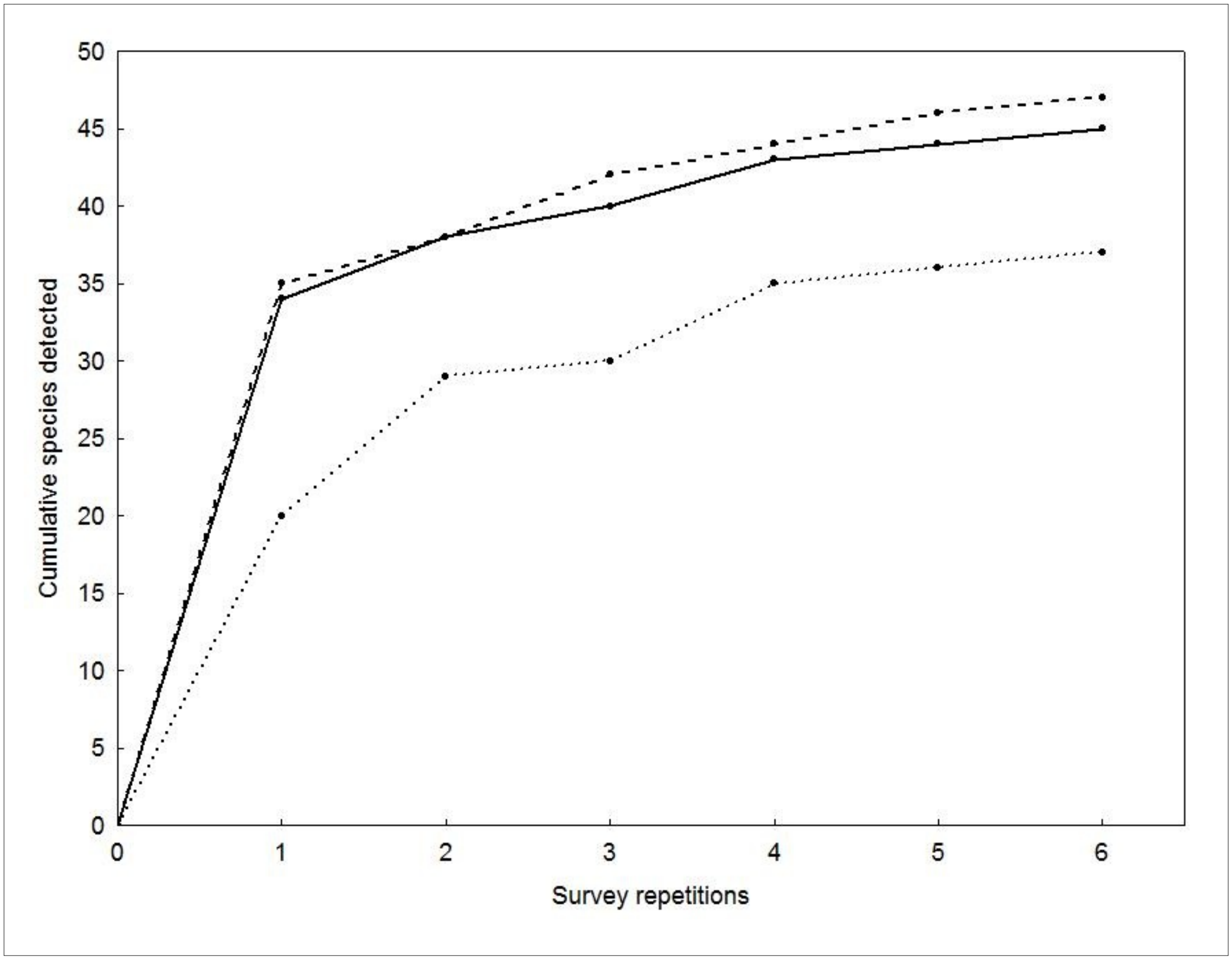

FIGURE 5.1. Species accumulation curves for bird surveys in three habitat zones: Closed-canopy Forest, dotted line; Disturbed Forest, dashed line; Village Environments, solid line.

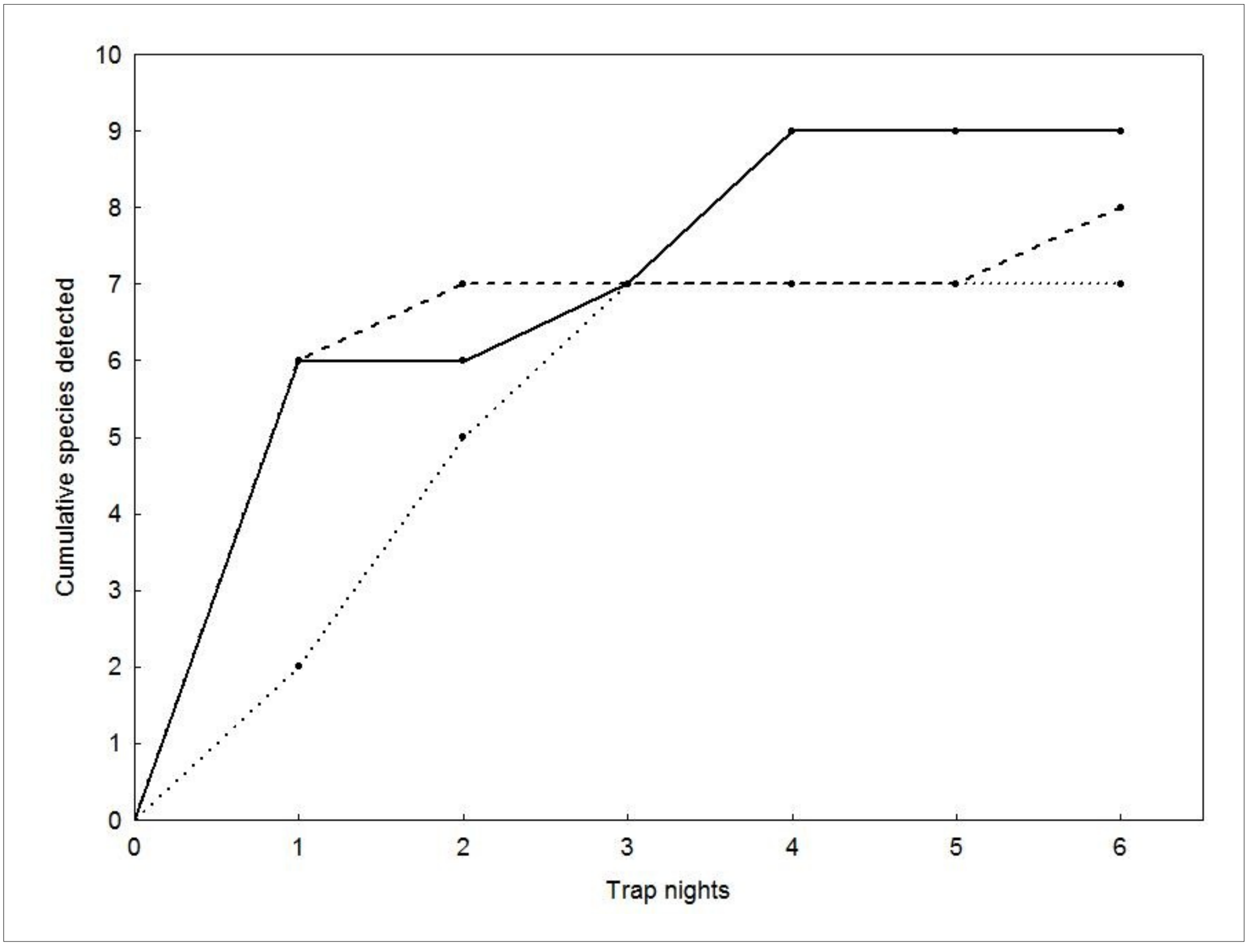

FIGURE 5.2. Species accumulation curves for small mammal trapping in three habitat zones: Closed-canopy Forest, dotted line; Disturbed Forest, dashed line; Village Environments, solid line.

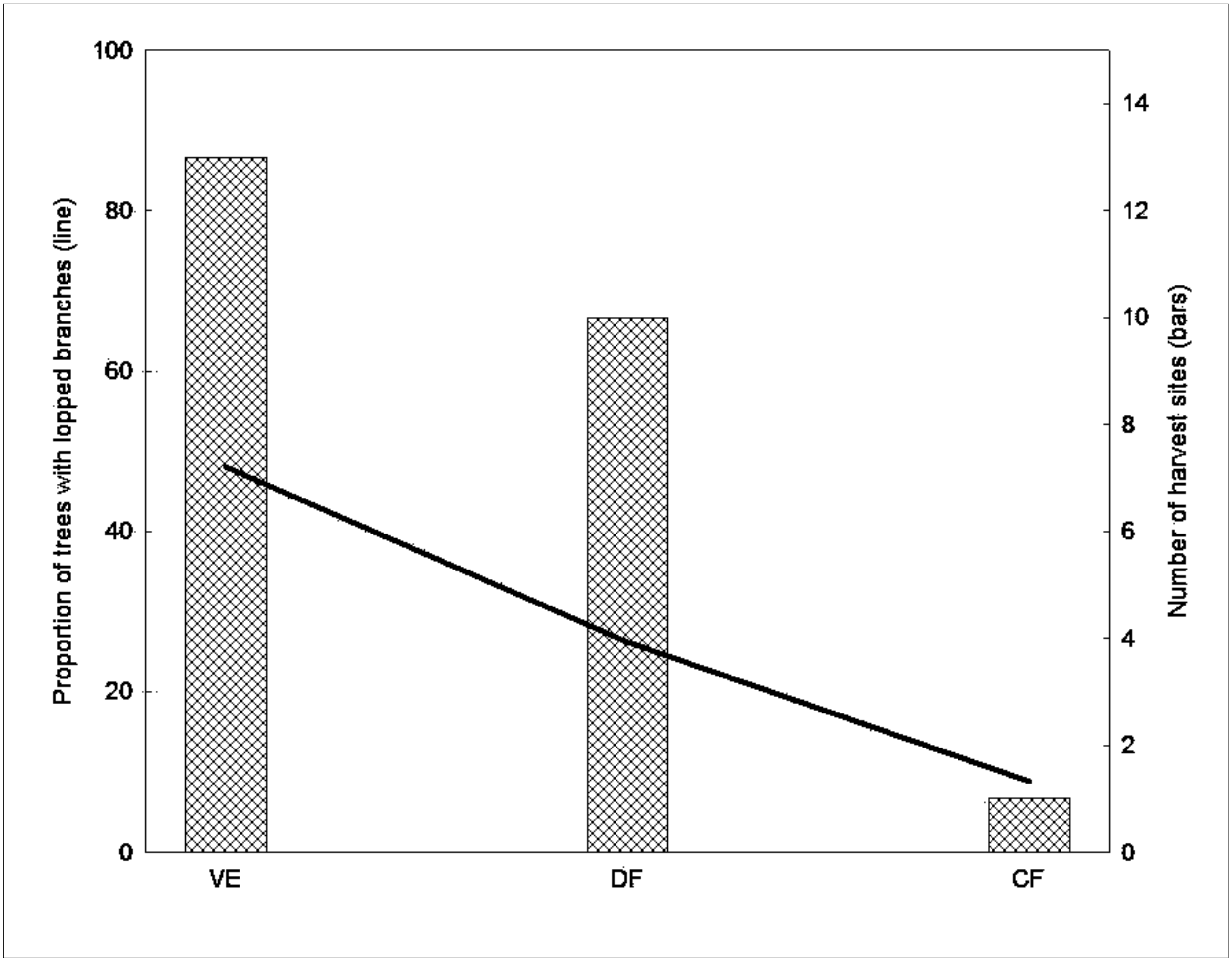

FIGURE 5.3.1. Relative intensity of pollarded stem harvest across progressively disturbed habitat zones (VE, Village Environments; DF, Disturbed Forest; CF, Closed-canopy Forest).

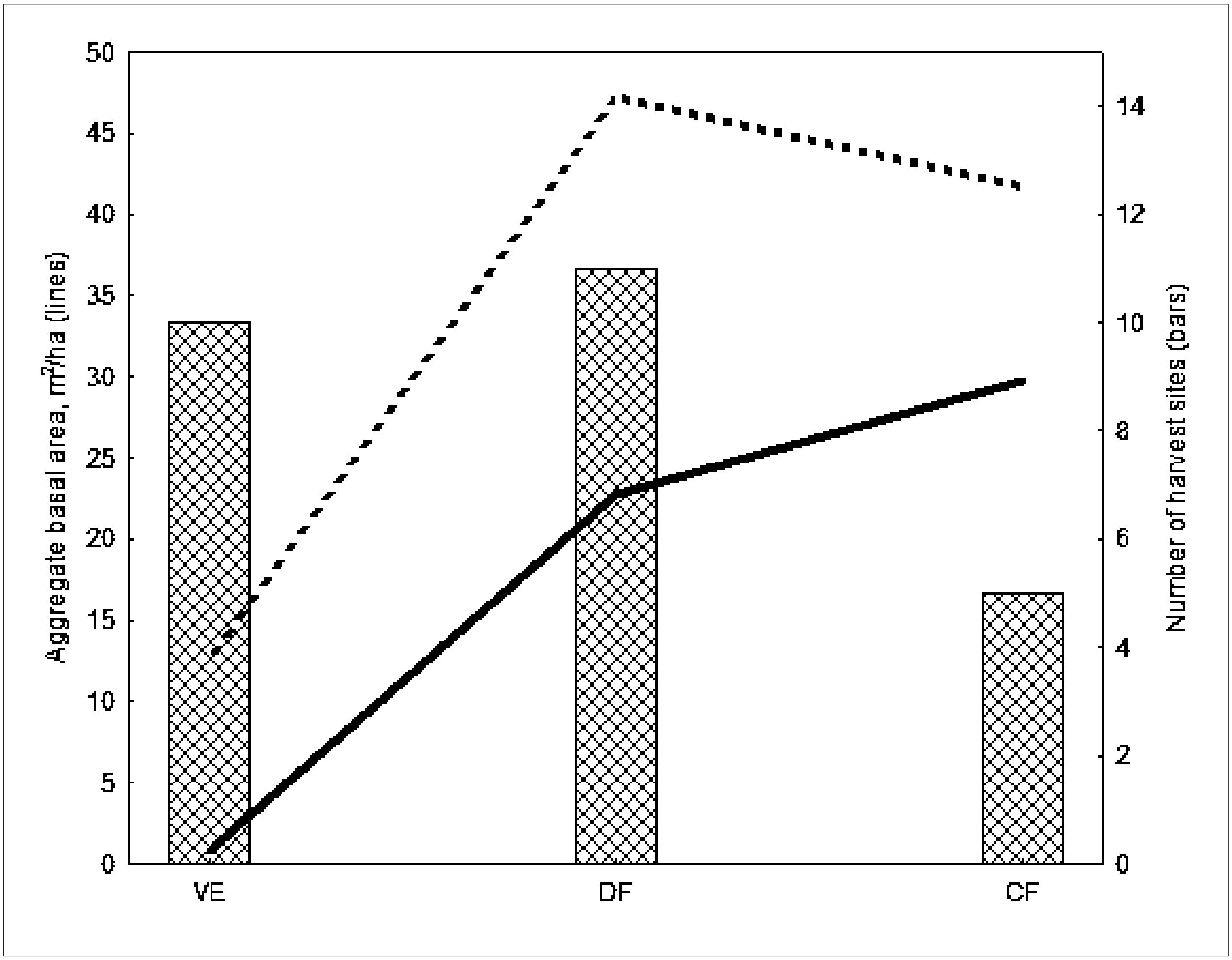

FIGURE 5.3.2. Relative harvest intensity and supply of fuelwood across progressively disturbed habitat zones (VE, Village Environments; DF, Disturbed Forest; CF, Closed-canopy Forest). Dotted line indicates aggregate basal area (m^2/ha) of the four highest-ranked fuelwood species; solid line, aggregate basal area of all high-ranked fuelwood species excluding *Viburnum erubescens*, a disturbance-tolerant, early-successional species.

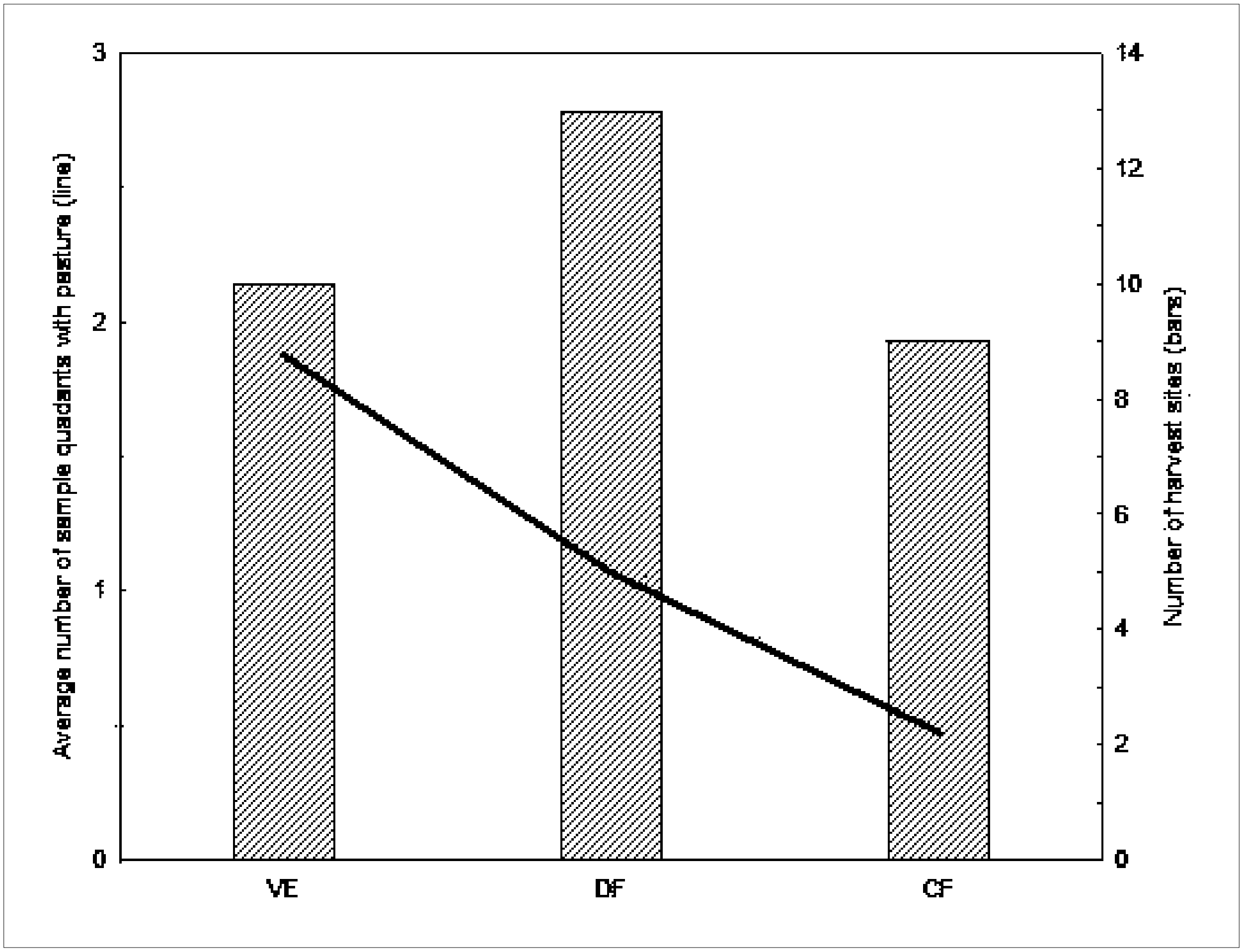

FIGURE 5.3.3. Relative supply and intensity of use of pasture across progressively disturbed habitat zones (VE, Village Environments; DF, Disturbed Forest; CF, Closed-canopy Forest). Line indicates a count of quadrants in a 1-ha plot around each sampling point (≤4) where pasture was present.

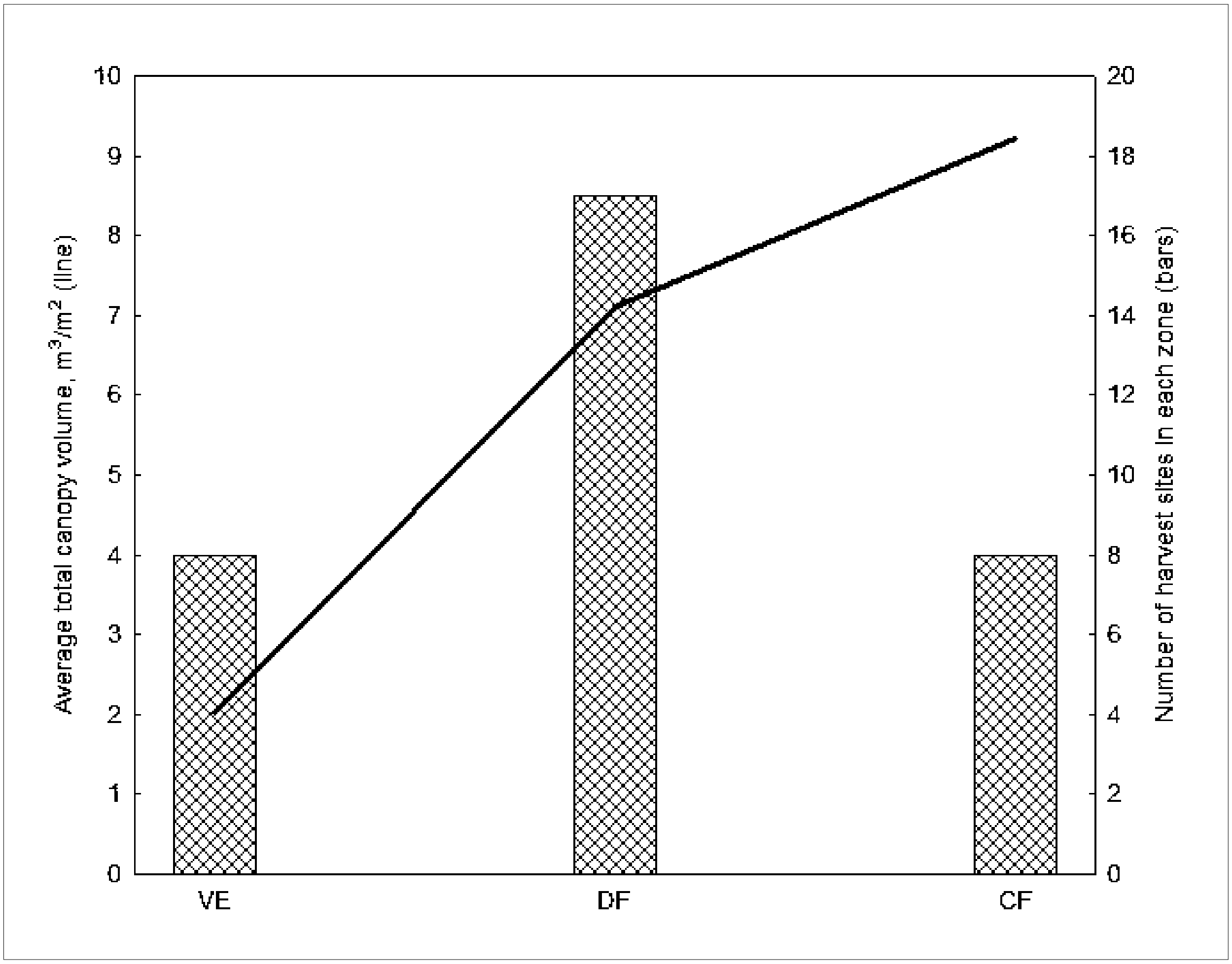

FIGURE 5.3.4. Relative supply and harvest intensity of leaf litter across progressively disturbed habitat zones (VE, Village Environments; DF, Disturbed Forest; CF, Closed-canopy Forest).

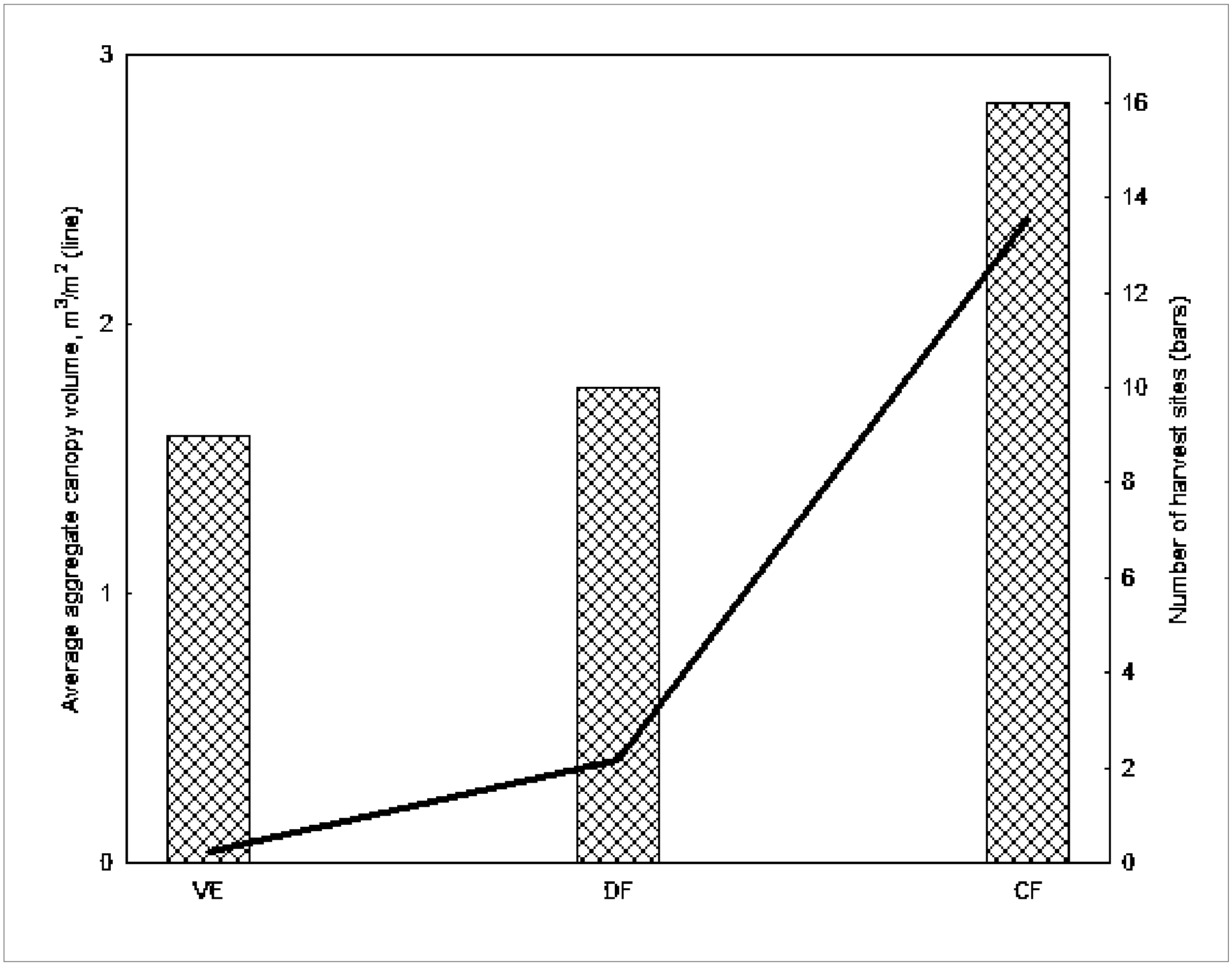

FIGURE 5.3.5. Relative harvest intensity and supply of tree fodder across progressively disturbed habitat zones (VE, Village Environments; DF, Disturbed Forest; CF, Closed-canopy Forest). Line indicates average aggregate canopy volume of the six highest-ranked tree fodder species (m^3/m^2).

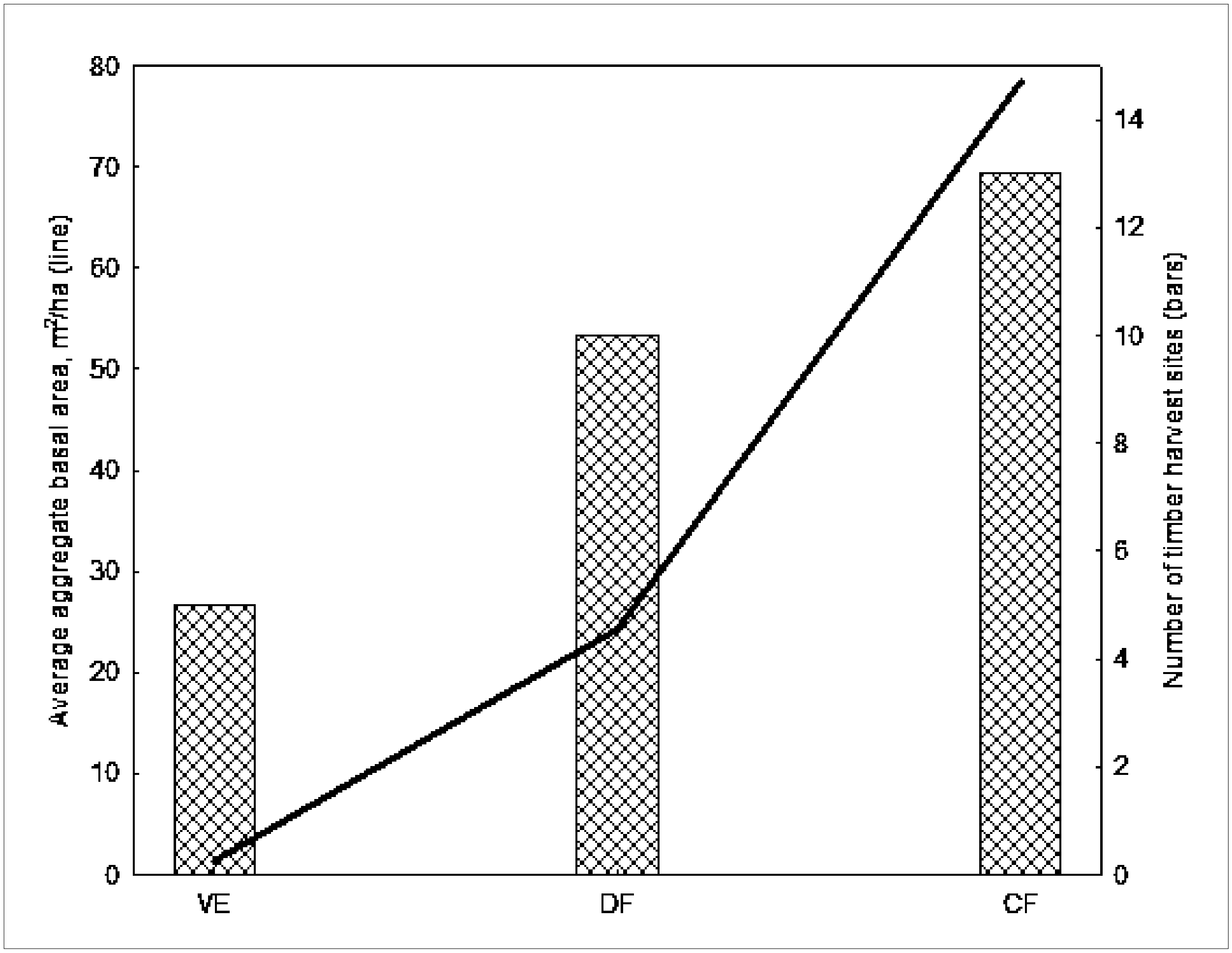

FIGURE 5.3.6. Relative harvest intensity and supply of timber species across progressively disturbed habitat zones (VE, Village Environments; DF, Disturbed Forest; CF, Closed-canopy Forest). Line indicates average aggregate basal area (m^2/ha) of the five highest-ranked timber species.

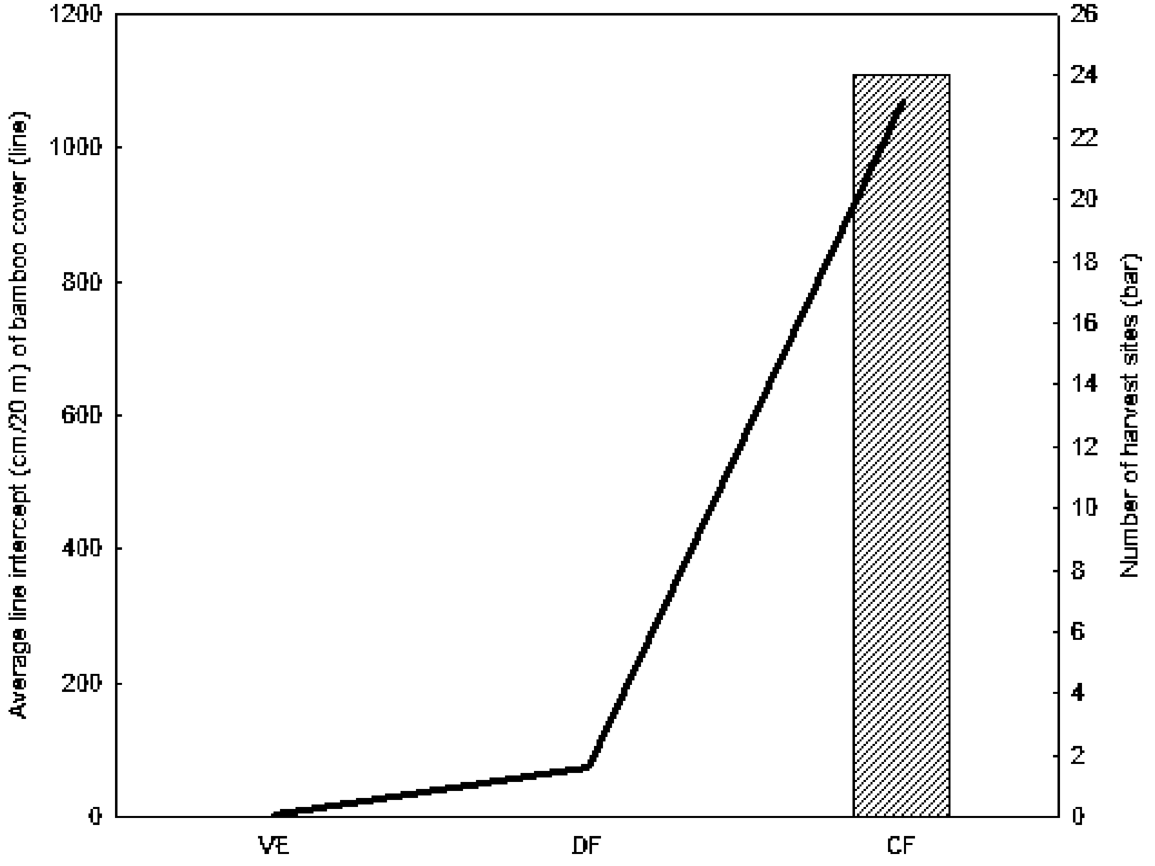

FIGURE 5.3.7. Relative supply and intensity of bamboo harvest across progressively disturbed habitat zones (VE, Village Environments; DF, Disturbed Forest; CF, Closed-canopy Forest).

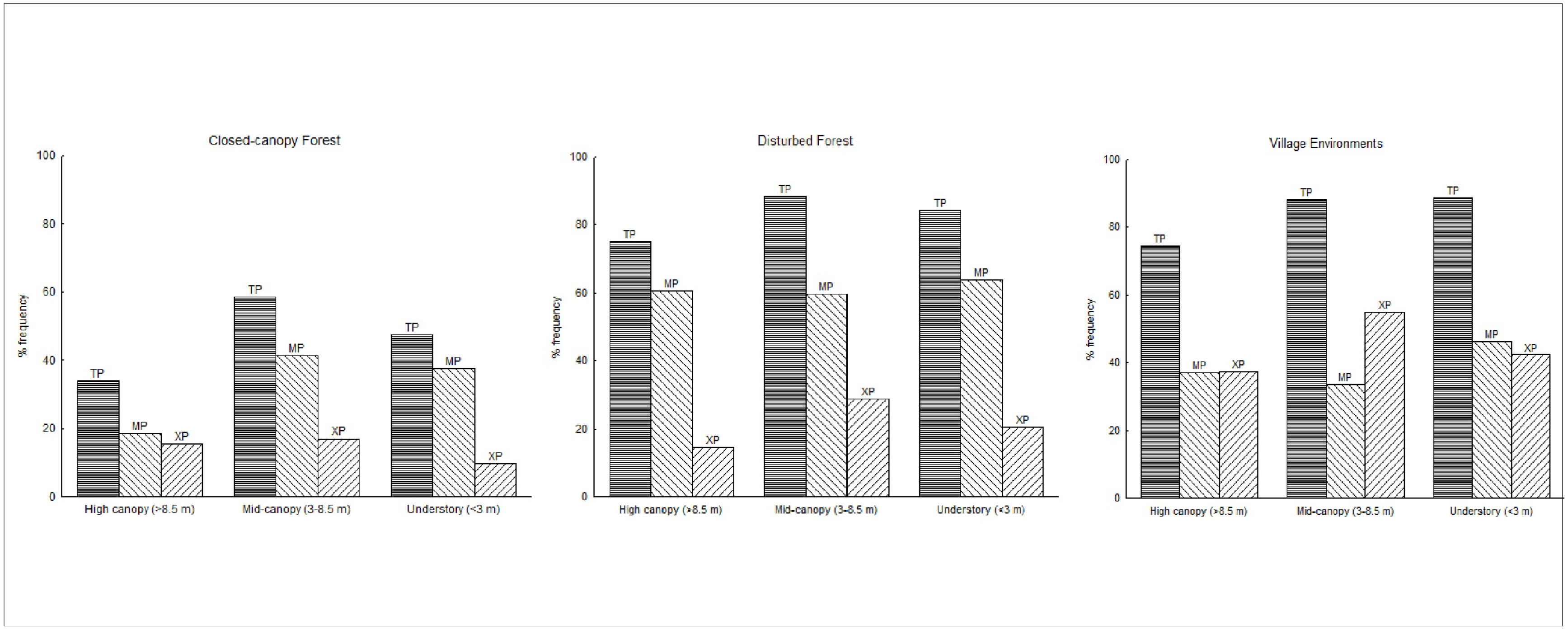

Figure 5.4. Proportion of woody pioneer species in different canopy layers across progressively disturbed habitat zones. TP is all pioneer species combined (9 species, Table 5.4); MP, mesic-habitat pioneers; XP, xeric-habitat pioneers.

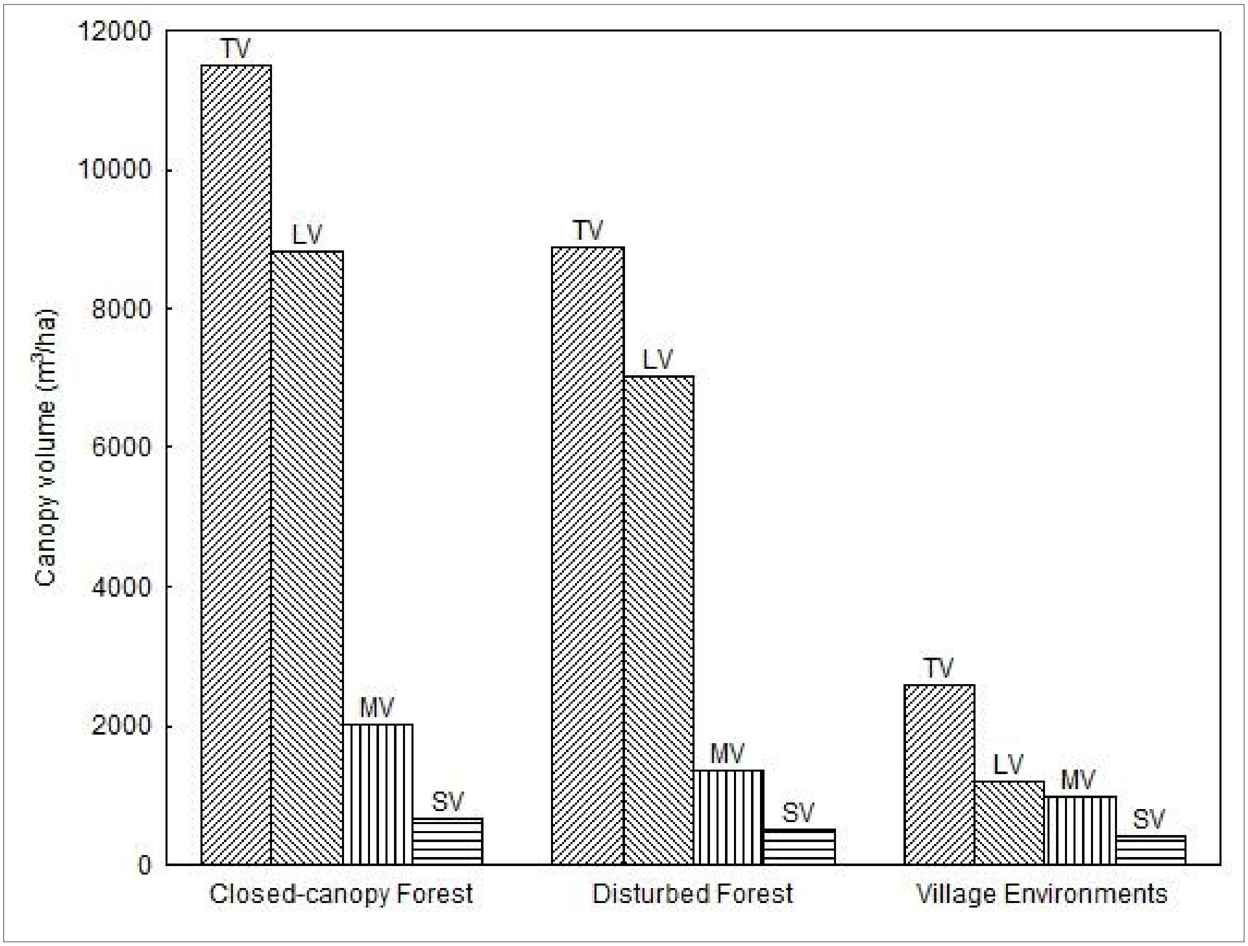

FIGURE 5.5. Changes in forest canopy volume across progressively disturbed habitat zones. TV indicates total canopy volume of all tree sizes; LV, canopy volume of trees >25 cm DBH; MV, canopy volume of trees 10-25 cm DBH; SV, canopy volume of trees 2-10 cm DBH.

APPENDIX 5.1. Number of breeding territories in study plots (territorial males/9 ha, selected understory passerine species, numbers in parentheses are whole numbers used for habitat analysis[A]).

Location	Babbler p w	Babbler sc-b w	Bushchat g	Robin I b	Shortwing w-b	Tesia c-h	Tesia g-b	Totals
Village Environments								
Chitre Bari	0	0	5	3	0	0	0	8
Chitre Kharka	1.5 (1)	1	2	10	0	2	0	16.5
Zone mean	0.75	0.5	3.5	6.5	0	1.0	0	12.25
Disturbed Forest								
Upper Chaite	5	4	0	5.5 (5)	6	5	0	25.5
Lower Chaite	2	0	0	11	4	3.5	0.5 (1)	21
Hile	2	3	0	7	5	9.5	0	26.5
Zone mean	3.0	2.3	0	7.8	5.0	6.0	0.2	24.3
Closed-canopy Forest								
Alu Bari	3	0	0	3	4	5.5	4 (5)	19.5
Bagalekhop	0.5 (1)	1.5 (2)	0	1	6 (7)	8.5	3	20.5
Tauke	0	1	0	0	3.5 (4)	3	0	7.5
Chakedho	1	0	0	0	0	0	1	2
Bhelli	0	0	0	0	0		2	2
Zone mean	3.4	0.5	0	0.8	0.8	0.9	2.0	10.3
Totals	37	10.5 (11)	7	10.5 (12)	40.5 (40)	15	10.5 (12)	149

[A] For density estimation, territories extending well outside 9-ha plots were computed as half-territories. For habitat analysis, such territories were computed as full territories if isolated from other territories, or excluded if immediately adjoining other territories of the same species.