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S39-1 The impact of forest management on bird communities in Taiwan

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Abstract Many forest-management practices have negative impacts on forest birds. Here we compare the bird communities between, first, an old-growth forest and a 30-year-old monoculture conifer plantation, and secondly, an old-growth forest and an old-growth forest that was "improved" silviculturally 9 years earlier. We collected data on tree species composition and variables important for analysis of forest structure. We sampled breeding birds using variable-distance transect and variable circular-plot methods, and recorded the microhabitat and food habits of each species. Results showed that the monoculture plantation held only 51.5% of the species found in old-growth forest. Bird species richness and density in the silviculturally improved forest were also lower than that in old-growth forest. Examining the avian guilds of these forest communities, we found that upperstory flycatching insectivores, upperstory gleaning insectivores, and ground-feeding omnivores all suffered severely in the managed forests, whereas upperstory trunk-probing insectivores and understory gleaning insectivores increased in numbers. Although the effects of forest improvement are less drastic for forest birds than conversion to monoculture, the alteration of forest structure still changed microhabitat and available resources. The implications of these findings for birds in southeast Asia and forestry practices elsewhere are discussed.

Key words Forest bird communities, Monoculture plantation, Natural forest, Forest improvement

1 Introduction

Many studies have documented serious impacts on bird communities from forest clear-cutting and conversion to monocultural plantations. Although alternative techniques have been developed commercially to reduce the impacts, such methods can still result in significant disruption and decline (Johns, 1988; Thiollay, 1992; 1997; Mason, 1996; Marsden, 1998). Forests cover 59% of Taiwan Island, but only 72% of these are natural (Taiwan Forestry Bureau, 1995). From 1965 to 1971, under the support of FAO, many stands of natural broadleaf forest were clear-cut and replaced with monoculture softwoods, mostly Japanese cedar, (*Cryptomeria japonica*), a fast-growing exotic.

From 1983 to 1989, in step with international forestry practices, a Timber Stand Improvement (TSI) program was implemented to increase the volume of commercial timber in natural broadleaf forests in Taiwan. This program involved the removal of subcanopy and understory vegetation, including saplings, vines, shrubs, and snags, and planting of seedlings of native commercial tree species (Taiwan Forestry Bureau, 1995). The effects of such forestry practices on bird communities in Taiwan have not been examined before. Accordingly, our studies compare the bird communities of, first, a Japanese cedar plantation and an old-growth broadleaf forest, and secondly, a TSI stand and an old-growth broadleaf forest. Our aims were to quantify the change in vegetation structure in conifer plantation and TSI stand, to analyze the effects of forestry practices on breeding bird communities, and to determine the responses of individual bird species and guilds.

2 Materials and methods

2.1 Study sites

Our study area was located at Lalashan in northern Taiwan (24°49'00"N, 121°25'00"E, elevation 800–1 300 m). Average annual temperature is 16°C, and average annual precipitation over 3 000 mm (Wang, 1987). The monocultural Japanese cedar plantation was about 30 years old; and the control broadleaf forest was 2 km from that plantation. The TSI stand had been treated 9 years before; its understory had been cleared and saplings of *Chamaecyparis formosensis* and *Calocedrus formosana* planted. Subsequently, the understory was cleared another 11 times, at a little more than once a year, and the canopy thinned once. In 1994, sapling densities in TSI stands were 320–470 per hectare. A natural forest 5 km away was used as the control site for this study. Neither natural broadleaf forest sites had ever been harvested; their dominant trees included *Persea thunbergii* and *Litsea acutivena hayata* (Lauraceae) and *Castanosis borneensis* and *Cyclobalanopsis acuta* (Fagaceae).

2.2 Methods

The variable line transect method was used to survey bird communities in the plantation study, whereas, because of steep slope and rugged topography, the variable circular-plot method was used in the TSI study. We identified

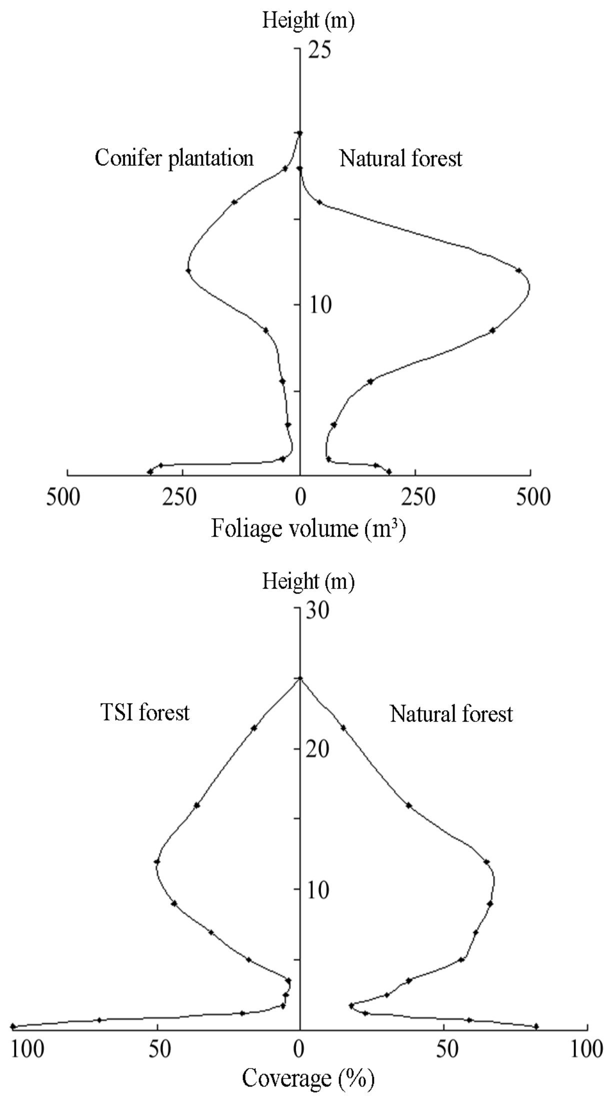

Fig. 1 Foliage coverage and volume for the four forest stands sampled

each bird species and recorded the number of individuals seen, their distances to the transect line or to observer, and their foraging behaviors. Foraging behavior included food type, foraging stratum, foraging substrate, and foraging method.

We sampled 30 habitat variables in twelve 20 × 20 m quadrats in both plantation and control forests to quantify vegetation structure and to determine foliage volume of different layers (Lee, 1995). In the TSI study, we sampled 45 habitat variables in five 10 × 10 m quadrats around each bird sampling point in both TSI and control forests, and measured vertical foliage distribution at 20 point locations in each quadrat (Fang, 1996).

3 Results

The Japanese cedar plantation had a sparser canopy, subcanopy, and shrub layer but a denser grass layer than the control natural forest (Fig. 1). Tree species richness, sapling and pole-timber densities, and the coverage of the subcanopy were all significantly lower in the plantation. For subsequent analysis, upperstory refers to the canopy and subcanopy, and understory to shrub and grass strata (Lee, 1995). The TSI stand also had a sparser subcanopy and a denser grass layer than its control natural forest (Fig. 1). Tree species richness, sapling and pole-timber densities, and the coverage of the subcanopy were significantly lower in the TSI stand. Density of trees with larger trunk diameter at breast height (DBH), and the coverage of the grass layer, were significantly higher in the TSI stand than in the control (Fang, 1996).

We recorded 33 species of breeding birds in the plantation study and 30 species in the TSI study. Bird species richness, density, and total biomass were all lower in the plantation than in the control forest (Table 1). In the TSI study, bird species richness and density were again lower in the TSI stand, but total biomass was higher (Table 1). Bird biomasses in the canopy and ground layer were significantly lower in the plantation than in the control forest,

Table 1 Comparison of species richness, density, and biomass of bird communities in treatment forests and controls

Study index	Plantation		*P*	TSI		*P*
	Plantation	Control		TSI forest	Control	
Species Richness	17	33		25	29	
Density (birds/100 ha)	586	673	ns	267	325	ns
Total biomass (kg/100 ha)	18.4	27.1	*	99.9	89.8	*
Canopy	8.8	13.4	**	55.0	31.1	***
Subcanopy	4.9	4.8	ns	16.1	24.2	***
Shrub	0.9	1.3	ns	4.4	11.6	***
Grass	3.4	2.7	ns	20.1	11.1	**
Ground	0.4	4.9	***	4.1	11.9	ns

Mann-Whitney U test: * = $P < 0.05$; ** = $P < 0.01$; *** = $P < 0.001$. Large differences in bird density and biomass between the two studies resulted from different survey methods.

but were similar in subcanopy, shrub, and grass layers. Biomasses in the canopy and the grass layer in the TSI stand were significantly higher, but those in the subcanopy and shrub layer (10–0.6 m) much lower (Table 1).

We assigned bird species to different guilds according to their foraging strata, foraging methods, and food type. As a group, upperstory flycatching insectivores, upperstory gleaning insectivores, upperstory trunk-probing insectivores, and ground-feeding omnivores were all markedly sparser in the plantation, from which most guild members were absent (Table 2). In the TSI stand, the same guilds were also depauperate (Table 2), although some of their species favored the TSI stand. Upperstory trunk-probing insectivores and understory gleaning insectivores were also more frequent in the TSI stand.

Overall, bird densities in the plantation were 19%–100% lower across the guilds except for understory gleaning insectivores and upperstory gleaning omnivores. The densities in ground-feeding omnivores and upperstory flycatching insectivores in the plantation were significantly lower. Upperstory trunk-probing insectivores were absent from the plantation, but this difference was not statistically significant because of the low density of trunk probers in the control forest. The differences in relative abundance of different guilds demonstrated both quantitative and qualitative differences between the avian communities in the conifer plantation and control forest (Fig. 2). In the TSI stand, the numbers of upperstory trunk-probing insectivores were significantly higher and of upperstory gleaning insectivores significantly lower. Ground-feeding omnivore density in the TSI stand was also lower, almost significantly so. The species that were absent, or less frequent, in managed stands tended to be endemic or forest-interior species, whereas those species more frequent were all edge species that are common in most wooded and disturbed areas.

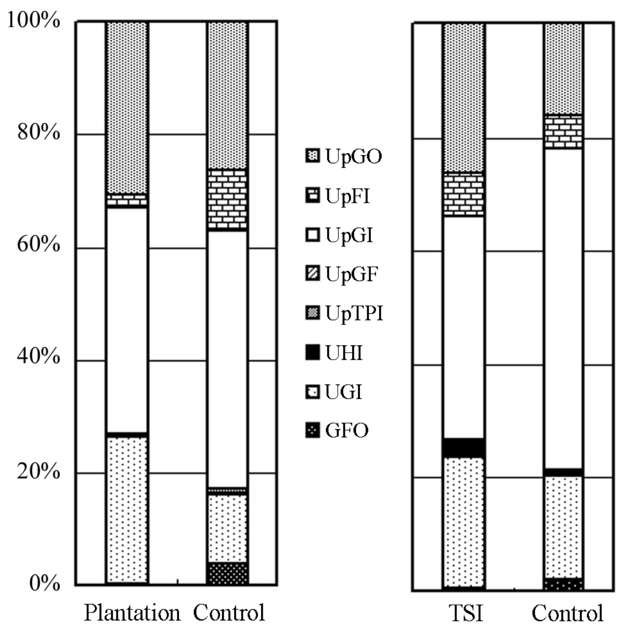

Fig. 2 Comparison of relative abundances of birds in different guilds between treatment forests and controls
UpGO = upperstory gleaning omnivores, UpFI = upperstory flycatching insectivores, UpGI = upperstory gleaning insectivores, UpGF = upperstory gleaning frugivores, UpTPI = upperstory trunk-probing insectivores, UHI = understory hovering insectivores, UGI = understory gleaning insectivores, GFO = ground-feeding omnivores.

4 Discussion

The two forestry practices studied involved structural fragmentation of forest habitat. In the TSI forest, gaps were opened in foliage structure, and the habitat shifted toward "edge" conditions, even though the dominant tree species were substantially unchanged. In the plantation, sparse canopy foliage permitted more light penetration, resulting in habitat similar to "edge" conditions. In both cases, an increase in "edge" bird species occurred concomitantly with a fall in forest-interior species; but the extent of the changes differed with species and guild. Basic species richness was lower generally; ground-feeding omnivores, upperstory gleaning insectivores, and upperstory flycatching insectivores were fewer; and upperstory gleaning omnivores and understory gleaning insectivores were more frequent in the managed stands. These results are consistent with those of other such studies conducted in tropical rain forests (Johns, 1988; Mason, 1996; Thiollay, 1997).

Reduction in diversity of plant species and vegetation structure in the upperstory reduced the nest sites for some upperstory bird species (cf. Powell and Steidl, 2000), and reduced the foraging habitat for arthropods (cf. Recher et al., 1996; Schowalter and Ganio, 1998), especially herbivorous insects that rely on the tender shoots and leaves of shade-tolerant tree species. Reduction of canopy foliage changed the microclimate within the entire canopy layer (Mason, 1996), which modified arthropod diversity and, in turn, affected upperstory gleaning and flycatching insectivores (cf. Karr and Freemark, 1983; Recher et al., 1996).

Reduced canopy foliage also changed microclimate in the understory, thus influencing composition and abundance in ground arthropods (Levings and Windsor, 1984; Karr et al., 1990). Sparse canopy and subcanopy allowed more sunlight to penetrate to the understory, resulting in denser growth of the grass layer. Such growth made foraging more difficult for some ground feeders (Severinghaus and Severinghaus, 1987). Moreover, managed forests accumulated less litter, so supporting fewer ground-dwelling arthropods (Liu and Kao, 1994). Increase in foraging difficulty and drops in prey density combined in a negative impact on ground-feeding omnivores. For understory gleaning insectivores, however, increased vegetation in the grass layer created more feeding habitat (Turchi et al., 1995), resulting in a rise in density.

During the past decade, forest coverage in southeast Asia has been reduced by around 10% (FAO, 2000), and forest coverage in most countries has declined significantly.

Furthermore, an average of 9.5% of the forest has been converted to plantation in this region (FAO, 2000); the percentage is especially high for Thailand, Taiwan, and Vietnam. Logging of old-growth forest in Taiwan has been stopped by conservation efforts, but the TSI program continues. In southeast Asia, at least 59 endemic forest bird species are endangered, and 72 forest bird species are vulnerable (FAO, 2000). The survival of these species can be seriously affected by forest management practices. Even if the original cause of decline was not forest loss or degradation, further loss of habitat can only exacerbate the trend.

The results of our two studies should alert researchers in southeast Asian countries to monitor forest management practices closely. The impacts of various techniques need to be assessed carefully by research before they can be accepted as ecologically responsible.

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Table 2 Comparison of densities of guilds and birds in treatment and control forests (per 100 hectares)

Guild and Species	Plantation		*P*	TSI		*P*
	Plantation	Control		TSI forest	Control	
Ground-feeding omnivores (4 species)	1	26	**	18	63	
Lophura swinhoii	0	4	**	0	12	
Cinclidium leucurum	0	17	***	2	42	**
Understory gleaning insectivores (5 species)	154	82		608	588	
Pomatorhinus erythrogenys	7	7		69	20	**
Pomatorhinus ruficollis	2	2		73	25	***
Stachyris ruficeps	11	5	*	86	81	
Garrulax poecilorhynchus	0	5	*	87	71	
Alcippe brunnea	134	63	*	293	392	
Understory hovering insectivores (1 species)	2	3		0	0	
Upperstory trunk-probing insectivores (3 species)	0	4		83	15	**
Dendrocopos canicapillus	0	2		51	11	**
Dendrocopos leucotos	0	1		17	0	**
Picus canus	0	1		15	4	*
Upperstory gleaning frugivores (2 species)	1	1		3	15	
Upperstory gleaning insectivores (10 species)	237	307		1 044	1 824	**
Cuculus sparverioides	0	7	***	7	10	
Alcippe morrisonia	194	160		562	1 249	***
Parus monticolus	0	27	***	0	24	*
Parus varius	14	39	**	225	161	
Parus holsti	0	2		0	5	
Upperstory flycatching insectivores (4 species)	13	73	**	200	180	
Pericrocotus solaris	13	17		152	58	*
Abroscopus albogularis	0	49	***	49	83	
Niltava vivida	0	5		0	38	**
Upperstory gleaning omnivores (6 species)	179	176		692	516	
Megalaima oorti	25	58	*	168	127	**
Hypsipetes leucocephalus	122	77	*	231	195	
Garrulus glandarius	17	14		179	23	***
Dendrocitta formosae	10	12		25	11	**

Only species showing significant differences are tabulated. Mann-Whitney U test: * = $P < 0.05$; ** = $P < 0.01$; *** = $P < 0.001$.

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