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Short-term Responses of Animal Communities to Thinning in a *Cryptomeria japonica* (Taxodiaceae) Plantation in Taiwan

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Hsiao-Wei Yuan, Tzung-Su Ding, and Hsin-I Hsieh (2005) Short-term responses of animal communities to thinning in a *Cryptomeria japonica* (Taxodiaceae) plantation in Taiwan. *Zoological Studies* **44**(3): 393-402. We determined whether the community composition of birds, small mammals and ground invertebrates differed among 3 levels of thinning (40%, 53%, and 67%) and 1 unthinned treatment in a *Cryptomeria japonica* plantation up to 1 y after thinning. The understory cover in the moderately thinned treatment (MT, 53% thinned) was significantly higher than those of the other 3 treatments. Different levels of thinning had no significant effect on the species richness and abundance of small mammals and non-breeding birds. Breeding bird species richness and total density and ground invertebrate biomass were greatest with the MT. Most of the avian guilds showed no significant difference among treatments except the densities of tree-omnivores and shrub-insectivores, both guilds of which were more abundant with the MT and less abundant with the light thinning treatment. Results suggested that although abruptly altering the forest structure, thinning in a *C. japonica* plantation had a neutral, if not a positive, short-term impact on various animal communities. By opening up the forest canopy opening and allowing more plant species to colonize the plantation, we anticipate that more-diverse animal communities will gradually appear within thinned *C. japonica* plantations.
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Key words: Bird community, Ground invertebrates, Habitat selection, Small mammals, Thinning.

As interest in ecosystem management and concern for maintaining biodiversity have increased, forest managers have been urged to make decisions based on both economics and environmental values (Reid and Miller 1989, Hunter 1990, Plochman 1992, Goodland 1995, Perry 1998). Recently, the public has become more concerned about the effects of human disturbances, particularly on the composition and diversity of wildlife and its ability to survive in fragmented and degraded habitats (Raman et al. 1998, Wendy and Martin 1998). Over the past 15 yrs, forest management has become more complex as it has had to take into consideration a number of new concepts, including biodiversity preservation (Ehrlich and Wilson 1991, Hunter 1996), landscape-level management (Oliver 1992), and global forest ecosystem management (Potvin et al. 1999).

Thinning is one of the most important silvicultural practices in forest management. Some studies have shown that thinning abruptly alters the forest structure and causes a variety of impacts to wildlife communities, including decreased species diversity, increased abundance of dominant species, and higher turnover rates (Niemela 1997, Wendy and Martin 1998, Basset et al. 2001). However, other studies have also shown that the long-term (> 5 yr) effects of thinning might even be positive to certain species because thinning

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increases luminosity and the amount of coarse woody debris on the ground, providing good cover and more-abundant food (herbaceous plants and invertebrates) for wildlife (Fredericksen et al. 1999). Thus, species diversity may steadily increase with time after thinning (Johnson and Leopold 1998).

The effects of thinning on different animal species may depend, in part, on the home range size and specific habitat needs of each species. Thus, red squirrels (*Tamiasciurus hudsonicus*) and northern flying squirrels (*Glaucomys sabrinus*), which require uncut forest habitats, can subsist in buffer strips large enough to accommodate their home ranges (Potvin et al. 1999). Moreover, animals of different ecological guilds or trophic levels may have different responses to thinning. For example, the abundance of birds that lived in shrubby areas or along forest edges increased after thinning, but this lasted for only 1~2 yr (Baker and Lacki 1997), and some of the forest-interior bird species may disappear (Dellasala et al. 1996). Harpole and Hass (1999) also found that some amphibians decrease in abundance due to a loss of foraging opportunities after thinning.

The island of Taiwan straddles the Tropic of Cancer and, thus, lies in both the tropics and subtropics. Nearly 60% of the area of Taiwan is forested and most of the forests grow on hills and mountains. During the 1960s and 1970s, large monocultural plantations of *Cryptomeria japonica* were planted for commercial purposes (Kao et al. 1991). Thinning has been used as a common practice to improve the productivity of the plantations. However, little research has been conducted on the effects of different levels of thinning to wildlife, especially in subtropical montane forests in general. In this study, we determined the short-term effects (within 1 y) of different levels of thinning in *C. japonica* plantations on the species richness, abundance, and composition of bird, small mammal and ground invertebrate communities. Results of this study provide assessments of the impacts of thinning practice on wildlife communities and can benefit future silviculture practice that has increasingly adopted wildlife conservation as one of its major goals.

MATERIALS AND METHODS

This study was conducted in a subtropical montane forest at Guanwu in north-central Taiwan (121°07'E, 24°31'N). Most of the forest was planted in 1974. It was dominated by *C. japonica* with a few Taiwania (*Taiwania cryptomerioides*), Taiwan red false-cypress (*Chamaecyparis formosensis*) and Lunta fir (*Cunninghamia konishii*). The study area encompasses about 30 ha and extends from 2000 to 2250 m in elevation. The air temperature averaged 13°C and annual precipitation was 3330 mm from 1993 to 2002. The initial tree density averaged 1500 trees/ha. Four treatments of 6~8 ha each were randomly assigned and in Dec. 2001, three treatments were thinned (Fig. 1). For the lightly thinned treatment (LT), 40% of the trees were removed, leaving 900 trees/ha. The other 2 treatments were moderately thinned (MT, 53% removal, with a final density of 700 trees/ha) and heavily thinned (HT, 67% removal, with a final density of 500 trees/ha). The unthinned treatment (UN) was assigned as a control and was located within the same stand as the other 3 treatments. There was no significant difference in mean tree density, mean diameter at breast height (DBH), and standard deviation (SD) of the DBH among the 4 treatments before thin-

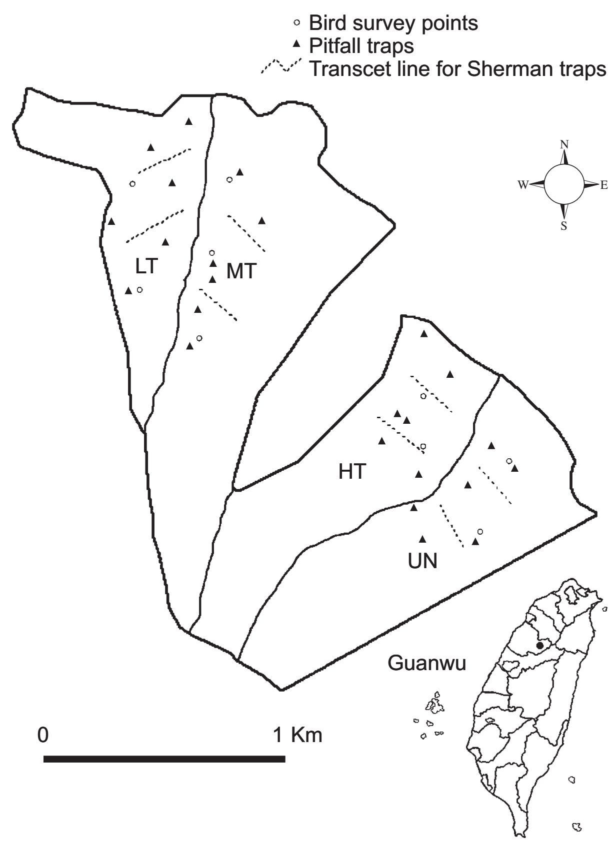

Fig. 1. Location of Guanwu and different thinning treatments. (UN, unthinned; LT, lightly thinned; MT, moderately thinned; HT, heavily thinned).

ning (Weng 2004). The slope, aspect, and soil texture of the 4 treatments were all very similar and the 4 plots had received the same silvicultural practices before thinning. Due to the diverse silvicultural practices for *C. japonica* and the steep terrain in Taiwan's mountainous areas, it was difficult to find other nearby *C. japonica* stands similar to our study site in terms of stand structure and physical environment. Therefore, we were unable to replicate each treatment because different silvicultural practices and physical environmental conditions may have confounded the thinning effects on wildlife (Moore and Allen 1999).

Bird surveys

Bird surveys were conducted for 4 consecutive days (2 d for LT and HT, and 2 d for MT and UN) on clear and calm days and began within 0.5 h after local sunrise time in Feb., Apr., June, Aug., Oct. and Dec. 2002. The fixed-distance circular-plot method (Reynolds et al. 1980) was used to estimate bird density. Two to 3 survey points, at least 100 m apart, were established within each treatment. We counted all birds seen or heard within 50 m of each survey point during a 10 min period. We recorded bird species and numbers of individuals at each point twice on 2 consecutive mornings. The order of points surveyed was reversed for the 1st and 2nd morning to avoid time effects. The same observer conducted the entire data collection to eliminate possible observer bias. When we heard, but were unable to see, more than 1 bird of a flocking species, we assumed it to be a single group of that species. In this case, we used the average group size for that species during the season in question (breeding or non-breeding) to estimate the number of individuals. We calculated the average density per point per month in different treatment for every bird species and guild group. Breeding season (Mar. to Aug.) and non-breeding season (Sept. to Feb.) data were analyzed separately. Each bird species was placed in one of 5 ecological guilds based on foraging site, feeding behavior, and diet. The avian guilds were: (1) ground-insectivores, (2) air-insectivores, (3) tree-insectivores, (4) tree-omnivores, and (5) shrub-insectivores (Shiu 1995).

Ground-dwelling animal surveys

Ground-dwelling animals (small mammals and invertebrates) were sampled with drift fence-pitfall traps and Sherman live traps. Each pitfall trap was comprised of 2 buckets (respectively 22 and 12 cm in diameter, and 26 cm in depth) sunk into the ground at each end of a 1.8 m long, 50 cm high drift fence, which was modified from Chou et al. (2002). The fence was made of corrugated plastic board, and the lower edge was buried 5 cm in the ground.

In each treatment, 6 pitfall traps, set at least 70 m apart, were opened for 9 consecutive days in Feb. (winter), May (spring), Aug. (summer), and Nov. (autumn) 2002. Invertebrates were dried and weighed to determine their biomass. Because there are few studies on the taxonomy of insects except for spider and beetle groups in Taiwan, only spiders and beetles could be easily identified to species level for most of the specimens collected and were able to be placed in different ecological guilds. The spider guilds, which were classified by foraging behavior, were: (1) sit-and-wait ambushers, (2) active hunters, (3) ground-level web builders, and (4) ant eaters (Hsieh 2001). The beetle guilds, which were diet-based, were (1) vegetarians, (2) carnivores, and (3) carrion eaters (Chang 1998).

To survey small mammals that were unlikely to enter the pitfall traps, 20 Sherman live-traps (8 x 9 x 23 cm), 7 m apart in two 70 m transect lines, were set in each treatment. Live-trapping was conducted for 5 consecutive days (4 trap-nights) when the pitfall traps were open.

Habitat sampling

To avoid affecting pitfall and live-trap captures, habitat surveys were conducted in Apr., July, and Oct. 2002. Habitat variables were sampled in sixteen 10 x 10 m grids for each treatment, subdivided into one hundred 1 x 1 m plots, which centered on each pitfall trap and every other live-trap. We measured the following horizontal habitat variables (percent of 100 plots covered, n = 16): stone cover (S), log cover (CL), and naturally fallen wood cover (CW). Within each 10 x 10 m grid, we randomly selected five 1 x 1 m plots and measured the vertical habitat variables for each plot: 3 vertical levels of ground vegetation cover (GC1, 0~30 cm; GC2, 30~60 cm; and GC3, 60~110 cm) and litter depth (L).

Data analysis

The bird and ground invertebrate communities in different thinning treatments were compared with the ANOSIM test in PRIMER 5.0 (Clarke and

Warwick 1994). The ANOSIM test was developed to compare the composition similarity (combining both species richness and abundance) among animal communities. In each treatment, species observed only once were excluded from the analysis. Data were square root-transformed before calculating R, an index to indicate the degree of difference between sites (with a higher R value indicating a greater difference):

$$R = (r_{Between} - r_{Within})/(M/2);$$

where $r_{Between}$ and r_{Within} are the respective differences in average rank dissimilarities between and within sites, and M is $n(n - 1)/2$, where n is the sample size.

The Kruskal-Wallis test and Mann-Whitney *U* test (Steel et al. 1997) were used to examine whether the habitat variables and abundance of a single species or an ecological guild differed among treatments. X^2 test was used for comparison of the small-mammal community.

RESULTS

Habitat structure

Because there was no typhoon, earthquake, fire, or other event to change the land cover of our

Table 1. Habitat variable values (mean ± SE) in each treatment in Apr. (a), July (b), and Oct. (c), (UN, unthinned; LT, lightly thinned; MT, moderately thinned; HT, heavily thinned)

(a) Apr.					
Variable[a]	UN	LT	MT	HT	*P* value[b]
S (%)	0.8 ± 1.5	0.6 ± 1.8	5.4 ± 4.3	-	**
CL (%)	-	6.7 ± 3.7	9.2 ± 5.2	18.6 ± 18.2	***
CW (%)	5.6 ± 2.9	2.8 ± 2.4	2.4 ± 3.8	3.3 ± 7.3	NS
GC3 (%)	3.3 ± 3.5	3.0 ± 0.0	2.0 ± 0.0	3.0 ± 0.0	NS
GC2 (%)	5.3 ± 7.3	1.5 ± 0.9	2.3 ± 2.0	1.5 ± 0.6	NS
GC1 (%)	1.8 ± 1.0	2.1 ± 2.0	9.3 ± 11.8	1.6 ± 2.4	**
L (cm)	2.5 ± 1.2	11.0 ± 4.3	9.2 ± 6.0	23.0 ± 20.5	**
(b) July					
Variable[a]	UN	LT	MT	HT	*P* value[b]
S (%)	0.8 ± 1.5	0.6 ± 1.8	5.4 ± 4.3	-	**
CL (%)	-	6.7 ± 3.7	9.2 ± 5.2	18.6 ± 18.2	***
CW (%)	5.6 ± 2.9	2.8 ± 2.4	2.4 ± 3.8	3.3 ± 7.3	NS
GC3 (%)	15.2 ± 13.2	-	35.7 ± 29.1	7.6 ± 4.8	*
GC2 (%)	5.2 ± 5.9	4.2 ± 3.5	22.4 ± 17.2	5.0 ± 6.4	*
GC1 (%)	3.9 ± 2.4	2.3 ± 1.8	17.6 ± 18.0	2.9 ± 2.7	*
L (cm)	4.2 ± 1.5	6.9 ± 3.3	7.7 ± 3.7	11.1 ± 7.4	*
(c) Oct.					
Variable[a]	UN	LT	MT	HT	*P* value[b]
S (%)	0.8 ± 1.5	0.6 ± 1.8	5.4 ± 4.3	-	**
CL (%)	-	6.7 ± 3.7	9.2 ± 5.2	18.6 ± 18.2	***
CW (%)	5.6 ± 2.9	2.8 ± 2.4	2.4 ± 3.8	3.3 ± 7.3	NS
GC3 (%)	7.7 ± 8.2	-	13.3 ± 7.4	1.33 ± 0.6	**
GC2 (%)	3.0 ± 3.0	2.2 ± 1.8	13.0 ± 11.8	4.1 ± 3.6	**
GC1 (%)	1.9 ± 1.0	3.6 ± 4.5	24.1 ± 17.3	4.6 ± 8.1	**
L (cm)	5.0 ± 1.3	7.4 ± 3.5	6.5 ± 2.9	12.4 ± 7.6	NS

[a]S, cover of stone; CL, cover of log; CW, cover of naturally fallen wood; GC1~GC3, ground layer cover (0~30, 30~60 and 60~110 cm, respectively); L, litter depth.
[b]Kruskal-Wallis test, * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; NS: non significant.

study site during the study period, the horizontal habitat variables of S, CL, and CW were the same in each treatment in the 3 seasons. In each season, S (H = 14.45, p < 0.01) and CL (H = 16.86, p < 0.001) differed significantly among treatments with the highest values in the MT and HT, respectively (Table 1). There were significant differences among treatments in the vertical habitat variables GC1 (H = 10.47, p < 0.01) and L (H = 14.45, p < 0.01) in Apr., GC1~GC3 (Kruskal-Wallis test, p < 0.05) and L (H = 10.88, p < 0.05) in July, and GC1~GC3 (Kruskal-Wallis test, p < 0.01) in Oct. (Table 1). The MT had the highest values of GC1~GC3 in July and Oct. and the highest value of GC1 in Apr.; while the HT had the highest value of L of all.

Bird community

We registered 32 bird species during the surveys; 18 species were recorded in the UN, 17 in the LT, 27 in the MT, and 24 in the HT treatments (Fig. 2a). During the non-breeding season, no significant difference was found in community composition among treatments (ANOSIM test, R = 0.39, p > 0.05). Therefore, only breeding season data were included in the subsequent analyses. Total species richness in the breeding season was the highest in the MT (24) and lowest in the LT (14). Bird total density (no./ha) was highest in the MT (50.7 ± 6.6) and lowest in the LT (22.0 ± 6.1, Fig. 2). Bird community composition, in general, significantly differed among treatments (ANOSIM test, R = 0.54, p < 0.001), but only bird communities in the MT and HT did not significantly differ (R = 0.51, p > 0.05), while all the other pair-comparisons showed significant differences (ANOSIM test, p < 0.05).

Among the 5 avian guilds, only the density of tree-omnivores (H = 15.58, p < 0.001) and shrub-insectivores (H = 9.8, p < 0.05) differed significantly among treatments (Table 2). Both guilds were more abundant in the MT and less abundant in the LT treatment (U test, p < 0.05, Table 2). The vertical habitat variable, GC1, was significantly correlated with the abundance of shrub-insectivores and explained 23.6% of the variation in the following linear regression model: $Y = 4.3 + 9.7\ X_{GC1}$, (p_{GC1} < 0.05).

The Pygmy Wren Babbler (*Pnoepyga pusilla*), Taiwan Yuhina (*Yuhina brunneiceps*), Green-backed Tit (*Parus monticolus*), and Steere's

Table 2. Densities (mean ± SE) (no./ha) of 5 avian guilds and major species in each treatment. [a](UN, unthinned; LT, lightly thinned; MT, moderately thinned; HT, heavily thinned)

Guild and species[b]	UN[c]	LT[c]	MT[c]	HT[c]	p^{d}
Air-insectivores	4.1 ± 2.3	4.4 ± 3.2	7.3 ± 5.8	3.0 ± 1.3	NS
Muscicapa ferruginea	-^{B}	1.4 ± 1.2^{A}	0.2 ± 0.6^{A}	2.1 ± 1.4^{A}	**
Tree-insectivores	12.9 ± 5.3	13.7 ± 3.0	22.8 ± 3.4	16.1 ± 1.7	NS
Yuhina brunneiceps※	6.9 ± 5.5^{A}	6.4 ± 4.0^{A}	13.9 ± 2.6^{B}	8.6 ± 2.7^{A}	**
Parus monticolus	0.3 ± 0.7^{B}	3.1 ± 1.3^{A}	2.8 ± 1.8^{A}	2.2 ± 1.7^{A}	**
Alcippe morrisonia	3.2 ± 2.0^{B}	-^{A}	1.1 ± 2.6^{A}	-^{A}	**
Parus ater	-^{A}	0.3 ± 0.5^{A}	0.4 ± 0.5^{A}	1.1 ± 0.8^{B}	*
Tree-omnivores	3.0 ± 3.8^{A}	-^{B}	12.1 ± 2.2^{C}	7.3 ± 5.9^{A}	***
Pyrrhula nipalensis	2.0 ± 5.0^{A}	-^{A}	11.3 ± 4.8^{B}	5.1 ± 4.0^{A}	***
Shrub-insectivores	4.9 ± 1.4^{A}	2.5 ± 2.2^{A,B}	7.4 ± 2.3^{A,C}	5.4 ± 1.1^{A,D}	*
Liocichla steerii※	3.0 ± 0.9	1.2 ± 1.5	3.5 ± 2.0	3.4 ± 2.3	NS
Bradypterus alishanensis	-^{A}	-^{A}	0.1 ± 0.3^{A}	0.7 ± 0.4^{B}	**
Ground-insectivores	2.0 ± 0.8	1.4 ± 0.5	2.7 ± 0.6	2.4 ± 0.8	NS
Pnoepyga pusilla※	0.9 ± 0.9	1.3 ± 0.6	2.1 ± 0.9	1.9 ± 0.8	NS
Brachypteryx montana	-^{A}	-^{A}	0.7 ± 0.5^{B}	0.1 ± 0.2^{A}	**
Cinclidium leucurum	0.7 ± 1.0^{B}	-^{A}	-^{A}	-^{A}	*

[a]Only breeding season densities were used in this analysis.

[b]※Denotes species that were dominant in all treatments.

[c]Mann-Whitney U test, different letters (A, B, C, D) indicate significant difference at p < 0.05.

[d]Kruskal-Wallis test, * p < 0.05; ** p < 0.01; *** p < 0.001; NS: non significant.

Liocichla (*Liocichla steerii*) were found in all treatments (Table 2). In thinned treatments, the Ferruginous Flycatcher (*Muscicapa ferruginea*) and Green-backed Tit were more abundant (*U* test, $p < 0.01$), while the White-tailed Robin (*Cinclidium leucurum*) and Gray-cheeked Fulvetta (*Alcippe morrisonia*) were less abundant (*U* test, $p < 0.05$). The Coal Tit (*Parus ater*) and Taiwan Bush-Warbler (*Bradypterus alishanensis*) were significantly more abundant in the HT than in the other treatments (*U* test, $p < 0.05$). However, the Blue Shortwing (*Brachypteryx montana*) and Brown Bullfinch (*Pyrrhula nipalensis*) were significantly more abundant in the MT than in the other treatments (*U* test, $p < 0.001$, Table 2).

Ground-dwelling animals

Altogether, 160 small mammals belonging to 5 species were collected during this study. The Formosan shrew (*Soriculus fumidus*) and Formosan field mouse (*Apodemus semotus*) were captured in all treatments. The Koshun shrew (*Soriculus sodalis*) and Formosan white-bellied rat (*Niviventer culturatus*) were captured in the UN, MT, and HT treatments, while Kikuchi's field vole (*Microtus kikuchii*) was captured only in the MT. Species richness and total abundance of small

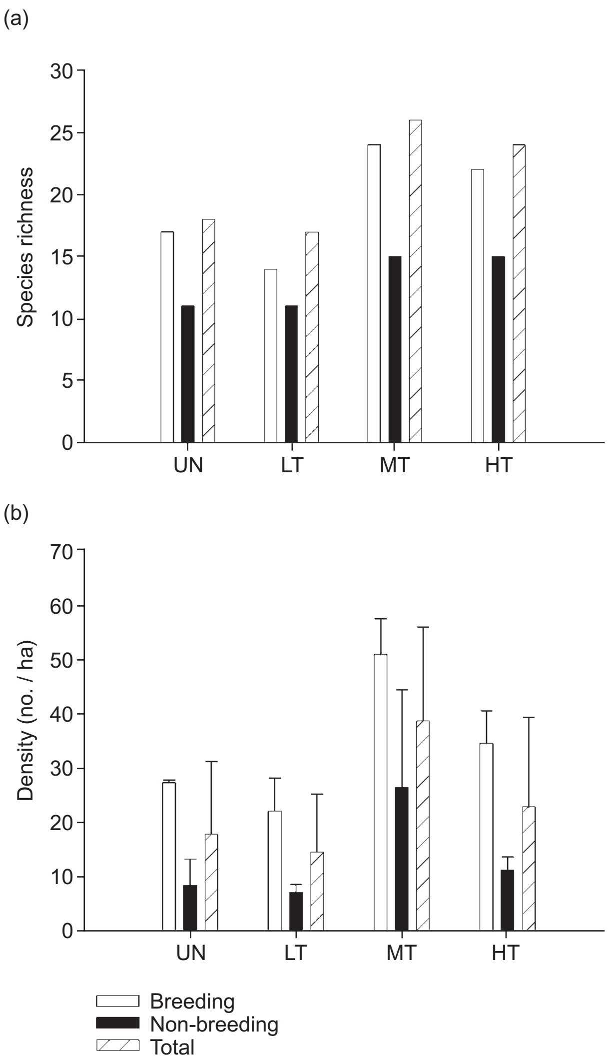

Fig. 2. Bird species richness (a) and density (no./ha) (b) in each treatment during the breeding and non-breeding seasons. (UN, unthinned; LT, lightly thinned; MT, moderately thinned; HT, heavily thinned).

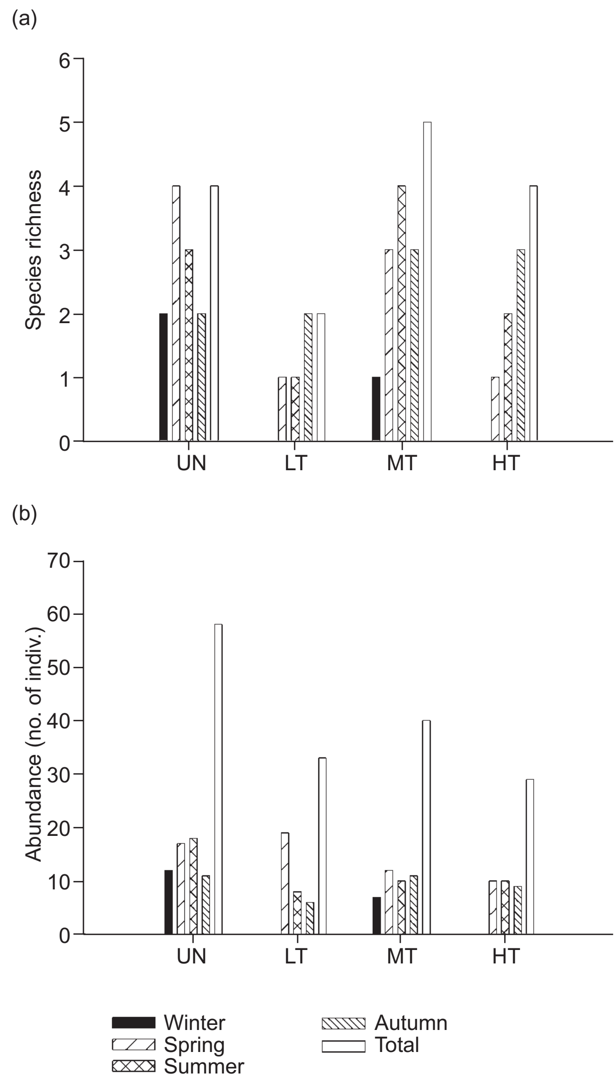

Fig. 3. Small mammal species richness (a) and abundance (b) in each treatment by season. (UN, unthinned; LT, lightly thinned; MT, moderately thinned; HT, heavily thinned).

mammals did not significantly different among treatments regardless of whether one considered the total or different seasons (X^2 test, $p > 0.05$, Fig. 3).

Taxa included in the analyses of ground invertebrates were Arthropoda, Annelida, and Mollusca. We captured 688 individuals in 19 orders in the UN, 595 individuals in 18 orders in the LT, 586 individuals in 17 orders in the MT, and 758 individuals in 17 orders in the HT treatment. We were unable to identify 1.2% of the trapped individuals. Ground invertebrate community composition was most similar in the LT and UN (ANOSIM test, R = 0.06, $p > 0.05$). The communities in the MT and HT significantly differed in composition from that in the UN (R = 0.32 and 0.40, respectively, $p < 0.05$). The Collembola was more abundant in thinned treatments than in the unthinned treatment (U test, $p < 0.05$),while the other taxa showed no significant differences in abundance among treatments (Kruskal-Wallis test, $p > 0.05$, Fig. 4). Orthoptera (30%), Araneae (19%) and Coleoptera (12%) were the dominant orders in all treatments (Fig. 4). The dominant families were the Tettigoniidae (98% of Orthoptera), Agelenidae (54% of Araneae), and Carabidae (49% of Coleoptera). In all treatments, the dominant guilds were ground-level web builders (79% of Araneae) and carnivores (55% of Coleoptera) (Table 3) and there was no significant difference in guild composition among treatments (Kruskal-Wallis test, $p > 0.05$).

The biomass was greatest in the MT (18.1 g) and lowest in the LT (13.1 g) treatment. In spring ($H = 10.66$, $p < 0.05$) and summer ($H = 9.9$, $p < 0.05$) ground invertebrate biomass differed significantly among treatments being greatest in the MT (7.2 g) in spring, and in the UN (10.8 g) during the summer (Fig. 5).

DISCUSSION

Thinning removes a large percentage of trees from stands (40%~67% in this study) and is often considered to create a strong disturbance to former forest ecosystems (McLeod 1980, Hansen et al. 1991). Studies (Niemela 1997, Wendy and Martin 1998, Basset et al. 2001) have reported that within a few months to years, thinning usually decreasing wildlife species diversity through reducing species richness and evenness. In this study, in contrast, we found that thinning had neutral or positive impacts on wildlife species diversity within 1 y after thinning. Although trees were largely thinned, no significant change was found in species richness and abundance of small mammals and ground invertebrates, and bird species richness and total density increased in moderately and heavily thinned sites. The results are consistent with a study by Hayes et al. (2003) who found

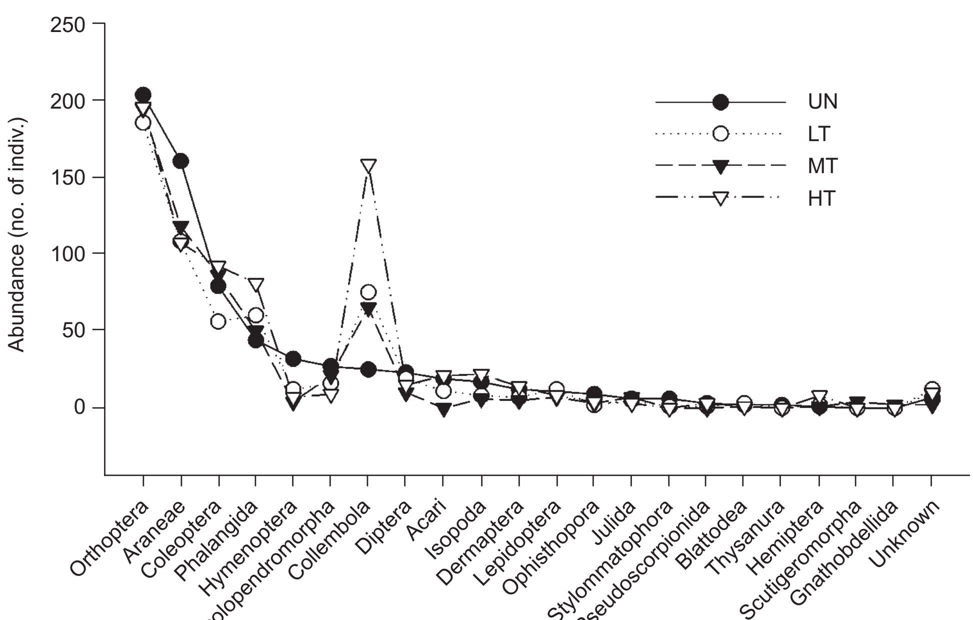

Fig. 4. Abundance of ground invertebrates. The order of abundance rank followed the rank in the unthinned treatment. (UN, unthinned; LT, lightly thinned; MT, moderately thinned; HT, heavily thinned).

the short-term consequences of thinning for most bird species to have positive, neutral, or minor negative effects.

Regarding the composition of animal communities, we found that thinning had minor short-term impacts. No significant difference was found in small mammals. Although the composition of ground invertebrates significantly differed among treatments, it was mainly due to abundance increases in Collembola, the underlying process of which needs further study, while the other taxa and ecological guilds did not significantly differ among treatments. Although the composition of the bird communities in the MT and HT treatments were found to significantly different from that of the UN, the differences were mainly due to additions of species and increases in density in the MT and HT. Only 1 bird species, the White-tailed Robin, disappeared from thinned treatments. The robin usually prefers luxuriant forests with dark thickets (MacKinnon and Phillipps 2000), and thinning might have changed the habitat structure and subsequently caused it to disappear. However, with the high precipitation and fast recovery of the understory in Taiwan, we suggest that the White-tailed Robin, widely distributed in disturbed habitats in Taiwan and abundant in natural and secondary forests located 5~10 km from our study site (Ko 2004), will reappear in thinned *C. japonica* plantations in the long run.

Several avian guilds and species were more abundant in thinned treatments, including tree-omnivores and shrub-insectivores, as well as the Ferruginous Flycatcher, Green-backed Tit, and Taiwan Bush-Warbler. The density of tree-omnivores and bush-insectivores might increase with more brushes, vines, and saplings of diverse broadleaf species in thinned treatments. The increased densities of the Ferruginous Flycatcher and Green-backed Tit, which forage insects mainly using flycatching and hovering tactics respectively (Ding 1993), might be consequences of increased foraging opportunities in more-open structures of thinned treatments. The Taiwan Bush-Warbler, a

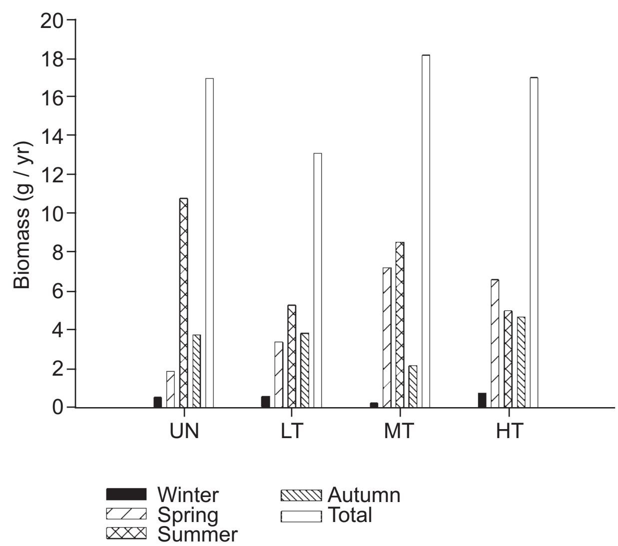

Fig. 5. Ground invertebrate biomass added up from 6 pitfall traps in each treatment by season. (UN, unthinned; LT, lightly thinned; MT, moderately thinned; HT, heavily thinned).

Table 3. Abundance (100 individuals per pitfall-day) of Araneae and Coleoptera functional guilds in each treatment (UN, unthinned; LT, lightly thinned; MT, moderately thinned; HT, heavily thinned)

Functional guild	UN	LT	MT	HT	Total (%)
Araneae[a]					
Sit-and-wait ambushers	20.4	14.8	13.0	22.2	8
Active hunters	24.1	18.5	31.5	16.7	11
Ground-level web builders	213.0	144.4	159.3	150.0	79
Ant eaters	3.7	3.7	3.7	3.7	2
Total	261.1	181.5	207.4	192.6	100
Coleoptera[b]					
Vegetarians	37.0	25.9	20.4	48.1	23
Carnivores	92.6	64.8	88.9	70.4	55
Carrion eaters	16.7	13.0	50.0	51.9	22
Total	146.3	103.7	159.3	170.4	100

[a]Araneae guilds are based on foraging behavior.
[b]Coleoptera guilds are based on diet.

species of dense brush which usually inhabits forest edges (Ding et al. 1997) might colonize thinned plantations, taking advantage of the opening up of the canopy and increased density of shrubs caused by thinning. However, in a similar case reported by Baker and Lacki (1997) and the finding that the Taiwan Bush-Warbler was not present in natural forests near our study site (Ko 2004), we predict that the abundance of this warbler will eventually decrease after secondary trees gradually grow up and the understory is reduced.

We suggest that competitive release from overcrowded plantations and fast growth rates of plants in tropical regions are reasonable explanations for differences in our results from studies in temperate regions. Due to the low market value and public opinion unfavorable to logging, *C. japonica* plantations in the study site (also in Taiwan in general) had not received thinning treatments for many years. Many stands of *C. japonica* plantations are overcrowded in terms of normal silvicultural practicess (Hopwood 1991). A high density of *C. japonica* greatly reduces light penetration, and subsequently other tree species and ground vegetation are greatly suppressed (Ogawa and Hagihara 2003). Thinning opens gaps in previously overcrowded plantations and increases solar radiation and growth site for other plant species (Lindenmayer and Franklin 2002). The high precipitation and mild temperatures in Taiwan together enable plants to grow faster than in temperate regions. Although trees need years to colonize thinned stands, several studies conducted in Taiwan (Kao et al. 1991, Tsai 2000, Weng 2004) have shown a rather-fast recovery of the understory after thinning in conifer plantations. The understory of 20% thinned *C. japonica* plantations was found to recover 55% in 23 mo (Kao et al. 1991), and the understory in a 27% thinned China-fir (*Cunninghamia lanceolata*) plantation reached 84% recovery in only 4 mo (Tsai 2000). In this study, the ground vegetation cover in the moderately thinned treatment was even higher than that in the unthinned treatment after 7 mo after thinning. Together with the fast growth rates of plants and competitive release from previously overcrowded plantations, thinning of *C. japonica* (an introduced species) plantations is not likely to cause severely negative impacts to local animal communities over short-term time scales. In contrast, thinning of monocultural, overcrowded plantations should increase plant species diversity and structural heterogeneity of the habitat (both vertically and horizontally) (Carey and Johnson 1995) , and with more native tree species colonizing, more-diverse animal communities will gradually appear. Ko (2004) compared avian communities in various forest landscapes 5~10 km from our study site and found that natural forests had the highest bird species richness and total density, and *C. japonica* plantations mixed with native broadleaf trees had higher bird species richness and total density than monocultue *C. japonica* plantations. Therefore, we suggest that in the long run, thinning of *C. japonica* plantations on local wildlife should have overall positive effects.

In Taiwan, logging of old-growth forests has been banned for more than 12 y in responses to cries for protecting forests, wildlife, and water resources, and minimizing landslides and erosion. Strong public concern about cutting trees has made it difficult for forest managers to implement thinning in overcrowded plantations or even to restore monocultural forests back to forests nearer to natural conditions. This study is to the best of our knowledge, the first in Taiwan to document the effects of thinning on wildlife (both vertebrates and invertebrates). We have shown that thinning might not necessarily lead to negative short-term effects on animal communities in *C. japonica* plantations and suggest that thinning can benefit wildlife in the long run. In considering restoration of native vegetation and conservation of wildlife biodiversity, we conclude that thinning of monocultural plantations can be a mild, positive, and effective practice.

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