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# Effects of Reforestation Practices on Staphylinid Beetles (Coleoptera: Staphylinidae) in Southwestern China Forests

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**ABSTRACT** In 2004, Staphylinid beetle (Coleoptera) assemblages were studied via pitfall trapping to examine the effects of reforestation in southwestern China forests. Sites included two 100-yr-old mature forest types (hemlock–spruce forest and birch forest), and three 40-yr-old forest types established after harvesting (spruce plantation, larch plantation, and natural broad-leaved forest). Staphylinid species richness was greater in natural broad-leaved forests than those in hemlock–spruce forests and spruce plantations, but no significant difference was found in abundance among the five forest types. Beetle assemblages from young forest stands were significantly different from those in older forest stands, and some environmental characteristics, i.e., elevation, proportion of broad-leaved trees, and coarse woody debris, significantly affected species abundances. Moreover, some staphylinid species predominantly found only in older forest stands indicate that mature forest specialists might be threatened by loss of habitat. So it is necessary to retain adequate patches of older successional stages for conserving these beetle assemblages.

**KEY WORDS** Staphylinidae, biodiversity, natural regeneration, artificial regeneration

Logging and reforestation are two important forest management practices driving fragmentation and changes in forest structure in China (MacKinnon and Xie 2001). Large-scale deforestation has occurred many times over the past thousand years in China, and rapid industrialization continued to accelerate deforestation in the last century (Liu and Diamond 2005). Extensive conifer plantations were established after harvesting to recover the forest ecosystems (MacKinnon and Xie 2001). In some cases, dominant native tree species from the undisturbed forest were introduced for plantation to mimic natural disturbances (Yu et al. 2008). However, compared with studies of boreal forests focusing on formulating management strategies that conserves biodiversity by mimicking natural disturbances in Europe and North America (Niemelä 1997, Spence 2001, Franklin et al. 2002, Work et al. 2004), relatively few studies have been conducted on the general response of forest communities to logging and reforestation by mimicking natural disturbances in China.

Monitoring the changes in the local fauna between unmanaged and disturbed communities is important for assessing human impacts on biological diversity (Didham et al. 1996, Davies and Margules 1998, Stevens and Husband 1998, Toral et al. 2002, Phillips et al. 2006). As the dominant taxa in forest ecosystems, ar-

thropods including insects have great potential as indicators of habitat change and recovery, and are increasingly used in conservation studies (McGeoch 1998). The direct effects of forest practices on epigeic arthropods in China forests have been documented (Yang et al. 2001, Yu et al. 2003, Luo et al. 2006, He et al. 2009). In China, a few studies specifically have examined species-level responses of arthropods to forest harvesting practices and reforestation efforts (Yu et al. 2006, 2007, 2008, 2009, 2010), and almost all published studies have focused on carabid beetles. Staphylinids are also excellent candidates for such studies because they are abundant and diverse, easily sampled, occupy a variety of functional niches, the taxonomy of most subfamilies is well-known in worldwide (Herman 2001, Löbl and Smetana 2004), and they are sensitive to habitat change (Spence et al. 1997, Bohac 1999, Pohl et al. 2007).

We compared the composition and distribution of staphylinid beetle assemblages in 40-yr-old conifer plantations and natural broad-leaved forests established after harvesting to 100-yr-old mature forests. According to the terms of common forest stand dynamic stages by Oliver and Larson (1996), the three 40-yr-old forests are approaching the stem exclusion stage, closing the canopy with minimal die-off of neighboring trees, and the two 100-yr-old forests are at old-growth stage. Specifically, the research objectives of this study were to determine the following: 1) Are staphylinid beetle diversity and abundance re-

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lated to age stand of the forest types? 2) Does natural regeneration result in a beetle assemblage more similar to old-growth forests than plantations does? and 3) Which environmental variables are important in determining the composition and distribution of staphylinids among all forest types?

### Materials and Methods

**Study Site and Sampling.** The study site was located in Wolong Natural Reserve (30° 45'–31° 25' N and 102° 52'–103° 24' E), in the Sichuan Province of southwestern China, a transitional zone between the Sichuan Basin and the Qinhai-Tibet Plateau. The study site, which ranged from 2,370 to 2,600 m, is covered mainly by ≈100-yr-old coniferous trees of hemlock [*Tsuga chinensis* (Franch.)], spruce [*Picea brachytyla* (Franch.)], larch [*Larix mastersian* Rehd. et Wils.] and fir (*Abies faxoniana* Rehd. et Wils.), and broad-leaved trees of birch (*Betula albo-sinensis* Burkill) (Anonymous 1987). Hemlock-spruce forests and birch forests are two dominant and climax forest types in the study site (Anonymous 1987). After the logging of these climax forests in 1960s, many spruce plantations (*P. brachytyla*) or larch plantations dominated by native tree species (*L. mastersian*) and nonnative tree species [*L. kaempferi* (Lamb.)] were established in many places (Anonymous 1987). In addition, natural broad-leaved forests have been well developed in some places, where the climax forests were logged and but not planted with conifer plantations in 1960s.

Five forest types were selected in this study, including two 100-yr-old climax (old-growth) forests (hemlock-spruce forest and birch forest), and three 40-yr-old (young-growth) forests established after harvesting (natural broad-leaved forest, spruce plantation, and larch plantation). Two old-growth forests had relatively high proportion of broad-leaved trees, and had dense shrubs, grasses, and deadwoods. The young-growth natural broad-leaved forest was composed nearly all of broad-leaved trees same as the old-growth forests, but had sparse shrubs and grasses. Two young-growth conifer plantations were nearly dominated by conifer trees, and had sparse shrubs and grasses. The detail characteristics of these forests were described in Table 1, summarized from Yu et al. (2008).

Three replicate forest stands (plots) of >4 ha were established within each forest type, and the distance between the plots was at least 500 m. Pitfall traps were used to capture staphylinid beetles in all plots. The trapping regime used in this study has been described in Yu et al. (2008). Traps were constructed from 400-ml plastic beverage cups (9 cm high by 7.5 cm diameter). A small hole with a diameter of <0.2 cm was drilled on each trap ≈2.5 cm below the upper brim, so that excess rainwater could flow out. Each trap was filled with ≈100 ml (≈2.5 cm high) of a mixed trapping fluid (vinegar:sugar:alcohol:water, 10 ml:5 g:5 ml:20 ml) to collect beetles. All arthropods were collected and staphylinid beetles were sorted from these samples for this study and preserved in 70% alcohol.

Staphylinid beetles were trapped from May to October in 2004, and all traps were emptied and serviced twice a month. Four trapping locations were set at the corners of a 25 by 25 m<sup>2</sup> in each plot. And each trapping location was composed of five traps that were placed into a cross at a distance of ≈1 m between traps. Thus, a total of 300 traps were operated during this study i.e., five forest types, three plots (forest stands) per forest type, four trapping locations per plot, five traps per trapping location. Staphylinid beetle samples were pooled within each plot (forest stand) for the analysis.

All specimens were deposited in Insect Museum, Institute of Zoology, Chinese Academy of Sciences (CAS). Staphylinids were identified by the members of our group through the comparison with type specimens or other reliably identified material in several museums (see Acknowledgments). The nomenclature follows Herman (2001) for Staphylinidae. Staphylinids of the subfamily Aleocharinae were excluded from analyses because reliable taxonomic keys or catalog are unavailable. Of these staphylinids, only 12 species (17%) were identified to named species, and most of the remaining taxa are likely to be new to science and need to be described taxonomically in the future.

Six environmental variables were selected to evaluate the relationships of staphylinid beetle occurrence and selected variables including percentage cover of the (overstorey) canopy layer, of the shrubs, of the herbaceous understorey, of leaf litter, and coarse woody debris, referring to the fallen dead trees and the remains of large branches on the ground in forests, and the depth of leaf litter within a radius of 2 m around the center of each trap location (Table 1). The coverage of each layer was evaluated by visible estimation and the depth by a ruler. These trap location data were averaged to be forest stand for the further analysis.

**Data Analysis.** Species diversity was calculated with Shannon-Wiener information index ( $H'$ ) (Pielou 1975):

$$H' = - \sum_{i=1}^s P_i \ln P_i$$

where  $P_i$  is the proportion of the sample represented by  $i$ th species ( $i = 1-S$ ).

After log transforms for species richness, abundance, and Shannon diversity, the effects of forest type on species richness, abundance (catches for total individuals and abundant species with >50 individuals), and Shannon diversity were tested using analysis of variance (ANOVA) with least significant difference (LSD) for post hoc pairwise comparisons. ANOVA and post hoc comparisons were done with SPSS 7.5 (SPSS 1997).

Staphylinid beetle assemblages among different forest types were compared using nonmetric multidimensional scaling (NMDS) with Bray-Curtis dissimilarity measures (Clarke 1993). NMDS were

Table 1. Characteristics of the five studied forests, summarized from the reference by Yu et al. (2008)

	Hemlock–spruce forests	Birch forests	Natural broad-leaved forests	Spruce plantations	Larch plantations
Elevation (m)	2,495–2,520	2,450–2,500	2,370–2,505	2,380–2,525	2,455–2,570
Forest age (yr)	≈100	≈100	≈40	≈40	≈40
Area (ha)	>200	>100	≈40	≈20	≈30
Canopy layer					
Dominant trees	<i>Tsuga chinensis</i> , <i>Picea brachytyla</i>	<i>Betula albo-sinensis</i>	<i>Acer</i> spp., <i>Betula</i> spp., <i>Prunus</i> spp., <i>Salix</i> spp., <i>Viburnum</i> spp.	<i>P. brachytyla</i>	<i>Larix masterian</i> , <i>L. kaempferi</i>
Subdominant trees	<i>Abies faxoniana</i> , <i>L. masterian</i> , <i>B. albo-sinensis</i> , <i>B. utilis</i> , <i>Acer</i> spp., <i>Corylus</i> spp., <i>Tilia</i> sp.	<i>T. chinensis</i> , <i>P. brachytyla</i> , <i>A. faxoniana</i> , <i>L. masterian</i> , <i>B. utilis</i> , <i>Acer</i> spp., <i>Corylus</i> spp., <i>Tilia</i> sp.	–	<i>Betula</i> spp., <i>Viburnum</i> spp.	<i>Betula</i> spp., <i>Viburnum</i> spp.
Proportion of broad-leaved trees	0.35–0.40	0.85	0.90–0.95	0.15	0.10–0.15
Coverage	0.54–0.75	0.55–0.86	0.74–0.83	0.75–0.83	0.43–0.54
Shrub layer					
Dominant species	<i>Fargesia rebusta</i> , <i>Rhododendron</i> spp., <i>Rosa</i> spp., <i>Sorbus</i> spp., <i>Acanthopanax</i> spp., <i>Lonicera</i> spp., <i>Viburnum</i> spp.	<i>E. rebusta</i> , <i>Rhododendron</i> spp., <i>Rosa</i> spp., <i>Sorbus</i> spp., <i>Acanthopanax</i> spp., <i>Lonicera</i> spp., <i>Viburnum</i> spp.	–	–	<i>Rosa</i> spp.
Coverage	0.03–0.19	0.15–0.29	<0.05	<0.05	<0.05
Herbaceous layer					
Dominant species	<i>Carex</i> spp.	<i>Carex</i> spp.	<i>Carex</i> spp., <i>O. griffithii</i>	<i>Carex</i> spp., <i>O. griffithii</i>	<i>Carex</i> spp., <i>O. griffithii</i>
Coverage	0.05–0.06	0.01–0.10	0.13–0.24	0.06–0.10	0.35–0.93
Litter layer					
Depth (cm)	10.50–11.75	5.50–10.00	5.50–10.00	6.50–7.50	7.25–8.25
Coverage	0.71–0.88	0.85–0.94	0.59–0.75	0.66–0.89	0.10–0.63
Coarse woody debris					
Dominant species	<i>Tsuga chinensis</i> , <i>Picea brachytyla</i> , <i>Betula</i> spp., <i>Acer</i> spp.	<i>Betula albo-sinensis</i> , <i>Acer</i> spp.	<i>Acer</i> spp., <i>Betula</i> spp., <i>Prunus</i> spp., <i>Salix</i> spp., <i>Viburnum</i> spp.	<i>P. brachytyla</i>	<i>Larix masterian</i> , <i>L. kaempferi</i>
Coverage	0.15–0.16	0.16–0.20	0.03–0.05	0.03–0.05	0.10–0.12

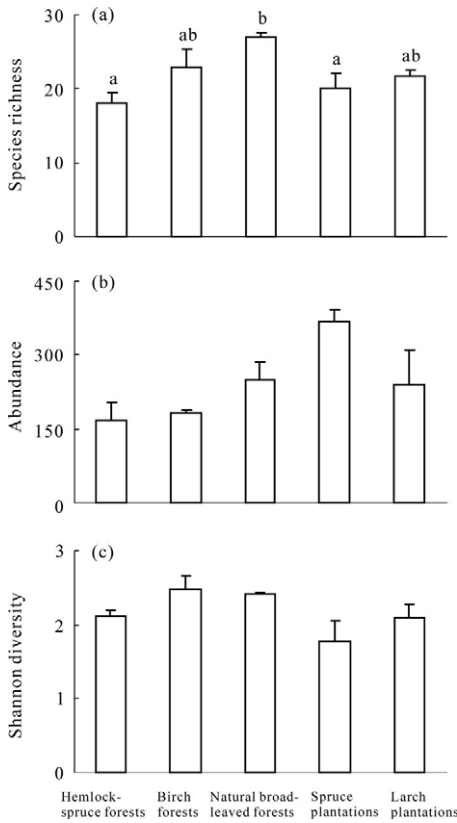


Fig. 1. Mean species richness and, abundance and Shannon diversity per plot of staphylinid beetles within the five forest types.

performed using the "PAST" software package (Hammer et al. 2001). A redundancy analysis (RDA) with Monte Carlo permutation tests of statistical significance was used to compare the relationship between beetle assemblage structure and the selected environmental variables of the forest types (Jongman et al. 1995). Eight environmental variables including elevation, the proportion of broad-leaved tree species, the coverage of canopy cover, shrub cover, herb cover, litter cover and coarse woody debris, and litter depth were included in the analysis. When running the analysis, we transformed data by  $\log(x + 1)$  to down-weight the rare species, centered by species, and added variables with the method of one by one into the model, starting from the most important one until the subsequent variable was statistically nonsignificant. RDA was analyzed by using CANOCO 4.0 software (ter Braak and Šmilauer 1998).

## Results

**Species Composition and Occurrence.** In total, 3,681 specimens of staphylinids were captured corresponding to at least 71 taxa in 9 subfamilies (Appendix 1). The most-rich subfamilies were Tachyporinae (27 spp.), Staphylininae (22 spp.), and Oxytelinae (11 spp.).

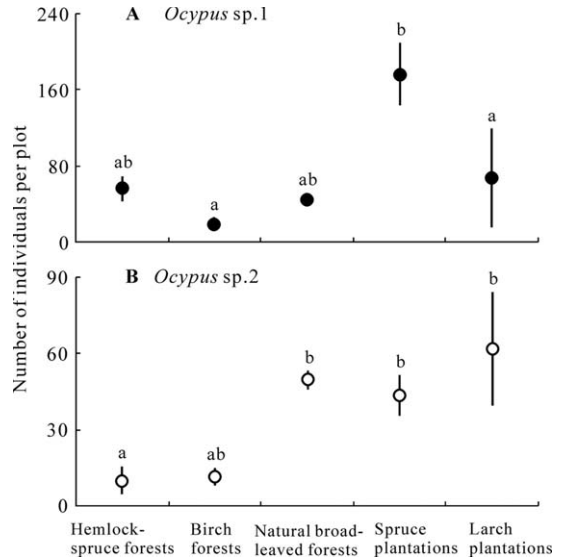


Fig. 2. Mean ( $\pm$ SE) number of individuals per plot of two abundant staphylinid beetle species with marked difference among the five forest types.

There were statistically significant differences in species richness among the five forest types ( $F = 3.94$ ,  $df = 4, 10$ ,  $P = 0.036$ ). According to LSD post hoc test, more species were found in natural broad-leaved forests than in hemlock-spruce forests and spruce plantations ( $P < 0.05$ ) (Fig. 1a). Staphylinid abundance was greater in spruce plantations than the four other forest types, but only a marginal significant difference was shown among the five forest types ( $F = 3.12$ ,  $df = 4, 10$ ,  $P = 0.066$ ) (Fig. 1b). Shannon diversity did not show significant differences among the five forest types, although spruce plantations exhibited a lower value than the four other forests did ( $F = 2.68$ ,  $df = 4, 10$ ,  $P = 0.094$ ) (Fig. 1c).

When the abundant species with  $>50$  individuals were tested, most species (11 of 13 species) were captured in all forest types. Only two species showed significant habitat preference among the five forest types (Fig. 2): i.e., *Ocyopus* sp. 1 was more numerous in spruce plantations than those in four other forest types ( $F = 3.53$ ,  $df = 4, 10$ ,  $P = 0.048$ ); *Ocyopus* sp. 2 was caught predominately in the traps of three younger forests ( $F = 3.93$ ,  $df = 4, 10$ ,  $P = 0.036$ ).

**Staphylinid Beetle Assemblage Structure.** NMDS ordination separated staphylinid beetle assemblages among the five forest types based on the successional stage along axis 1, and the staphylinid samples of two old-growth forests were clustered in the left of axis 1, and nearly all staphylinid samples of young-growth forests in the other end of axis 1. According to vegetation type (the proportion of broad-leaved trees), the staphylinid samples of spruce plantations could be separated from those of natural broad-leaved forests by axis 2. In addition, except the staphylinid samples of larch plantations, the beetle assemblages of other four forest type samples clustered independently, but

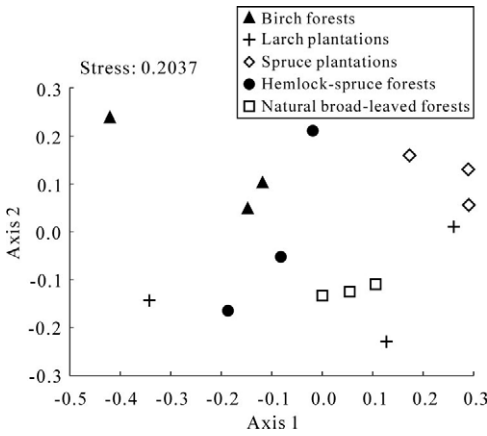


Fig. 3. Ordination plot (nonmetric multidimensional scaling, NMDS) of the range of pitfall catches of staphylinid beetle assemblages per sample within the five forest types.

birch forests and hemlock forests were not tightly clumped like the broad-leaved and spruce forests. Thus, successional stage and vegetation type (broad-leaved forests versus conifer forests) played important roles in species composition and distribution of staphylinid beetles among the five forests (Fig. 3).

**Staphylinid Beetle Occurrence and Environmental Variables.** In the redundancy analysis (RDA), the eigenvalues for the first four gradients were 0.201, 0.164, 0.128, and 0.085, respectively (Fig. 4). The first two axes explained 36.5% of the cumulative variance

of the species dataset and 50.9% of the species–environment relationship. The statistical significance of the axes by Monte Carlo randomization showed that the trace value of all axes was 0.718 ( $F = 1.909$ ;  $P = 0.016$ ; 4,999 permutations), indicating that the environmental variables and beetle species had a highly significant relationship.

The first axis of the ordination indicated that a division between trap samples of the five forests by the vegetation type (indicated by the proportion of broad-leaved trees), which correlated strongly and positively with this axis (right side of ordination space: broad-leaved forests; left side: conifer forests) ( $F = 1.86$ ,  $P = 0.025$ ) (Fig. 4). The second axis seems to indicate the successional sere from young forests to older forests, and the quantity of coarse woody debris that usually are found easily in older forests (Table 1) was greatest in the lower right side of the ordination space ( $F = 2.23$ ,  $P = 0.002$ ) (Fig. 4). In addition, elevation also contributed a lot to the variation of staphylinid beetle structure and showed a significantly negative correlation with the first axis ( $F = 2.28$ ,  $P < 0.001$ ).

Eleven taxa were plotted to the right side of the ordination, showing a preference for broad-leaved forests (Fig. 4). Of these species, three species of *Tachinus* (*Tachinus* sp. 3, *Tachinus* sp. 4, and *Tachinus* sp. 6) and *Oxytelus* sp. 1 plotted to the lower right of the ordination space and far away from samples of older forests. *Paederus chinensis* Berhauer, which was located in the lower right of the ordination space and near to axis 2, rarely was found in spruce plantations, but abundant in four other forests. Five species, *Ano-*

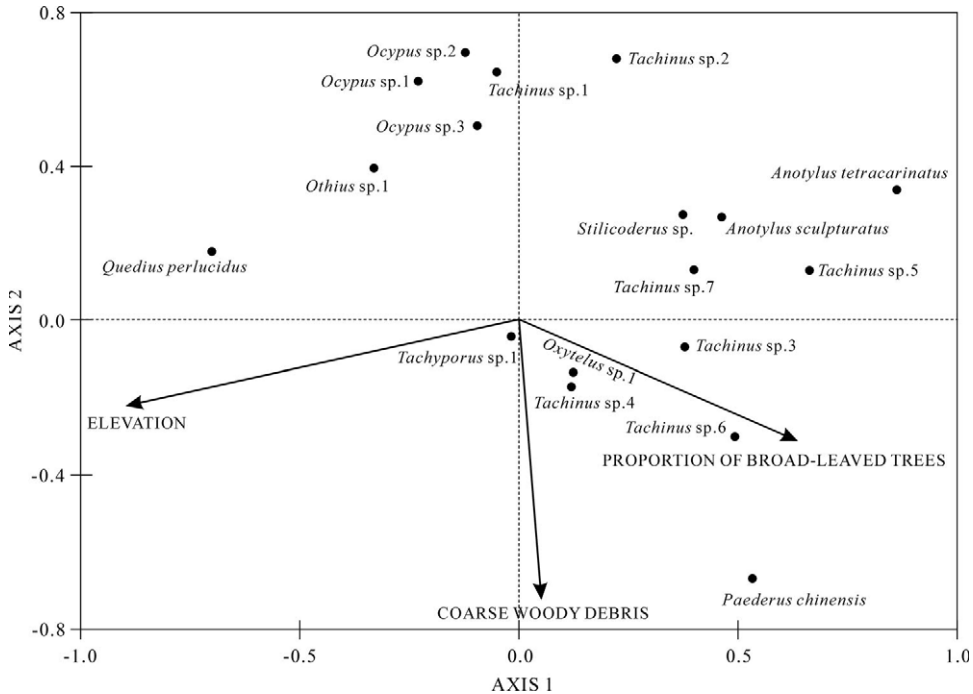


Fig. 4. Redundancy analysis (RDA) for staphylinid beetle species and four environmental variables which were the most important in shaping the beetle-abundance patterns. Only species with at least 14 individuals are presented.



*tylus sculpturatus* (Gravenhorst), *A. tetracarinatus* (Block), *Stillicoderus* sp., *Tachinus* sp. 5, and *Tachinus* sp. 7, were located in the upper right of the ordination space and near to axis 1. These species easily were found in the samples of forests with high proportion of broad-leaved trees, especially for the natural broad-leaved forests.

In contrast, only seven species clustered in the left side of the ordination space, representing a preference for conifer forests (Fig. 4). Five species, *Ocypus* sp. 1, *Ocypus* sp. 2, *Ocypus* sp. 3, *Othius* sp. 1, and *Tachinus* sp. 1, were located in the upper left of the ordination space and far way from the origin, showing a preference for younger forests. *Quedius perluvidus* Zhao et Zhou plotted to the upper left side of the ordination space and near the axis 1 preferred larch plantations, whereas *Tachyporus* sp. 1 was near the origin and abundant in larch plantations and two broad-leaved forests.

### Discussion

**Staphylinid Assemblage Structure.** Our results suggest that the establishment of conifer plantations can change the composition and distribution of staphylinid beetle assemblages when compared with the older mature forests. The variations in beetle fauna were attributed to vegetation type, elevation, and successional stage (e.g., coarse woody debris).

The heterogeneity of the species composition or spatial pattern of an assemblage among the young forests and older forests corresponded to the differences in microhabitat between the studied forests. The two older forests in this study shared similar microhabitats with dense coarse woody debris and sparse canopy trees and grasses (Table 1), thus resulting in a very homogeneous assemblage between them. On the other hand, high similarity in microenvironments were found among three young forests, e.g., high density in herbaceous layer and low density in shrub layer, except the difference in canopy tree species. Thus, three young forests showed high similarity in staphylinid assemblages, especially between two conifer plantations.

Moreover, according to the definition of forest stand dynamic stages by Oliver and Larson (1996), three 40-yr-old young stands are approaching the stem exclusion stage, closing the canopy with minimal die-off of neighboring trees, and the two 100-yr-old forests are at the stage of old-growth forests. Therefore, the characteristics of canopy layer and leaf litter layer of them in young forest stands were similar to those in the older forests, but some characteristics such as sparse subcanopy layer, shrub layer and coarse woody debris, and dense herbaceous layer, composed significantly different microenvironments in young forests from older forests, resulting in different distribution patterns of staphylinid beetle assemblages in older forests from those of young forests.

**Direct Effects of Plantations on Diversity of Staphylinids.** Compared with the older forests, the overall abundance of staphylinids increased in young forests

slightly, whereas species richness did not show obvious variations. However, when mean richness and abundance of staphylinids per trap location were considered, forest age and vegetation type played important roles. The former determined the abundance of staphylinids, which showed more individuals in younger conifer plantations (especially in spruce plantations), and the latter influenced the diversity of species and resulted in more species caught in two broad-leaved forests.

The close-canopy of old-growth forests and conifer plantations might be a reasonable explanation for the above result. When the well-developed forests reach the stem exclusion stage with a close-canopy, because the disappearance of open-habitat species occurred in the early succession stage and the recolonization of forest specialists, beetle assemblages would be more stable and changes in the regenerating community might generally shift in abundance only (Buse and Good 1993, Paquin and Coderre 1997, Spence et al. 1997, Buddle et al. 2006, Yu et al. 2006, Pohl et al. 2007). Compared with the old-growth forests, the young broad-leaved forests and conifer plantations in our study might bring about a drastic change in richness and abundance when they were in an early successional stage (e.g., 20 yr ago) as our previous study suggested (Yu et al. 2006). However, when these younger forests reached the stem exclusion stage with a close-canopy, there might be no significant differences in overall diversity of species between two old-growth forests and three young forests.

**Species Responses to Plantations.** Although most abundant species were captured in most forest types, many staphylinid species still showed obvious habitat preferences based on the RDA analysis (Appendix 1, Fig. 4). Most of these species were caught predominantly in younger forests, i.e., one species (*Quedius perluvidus*) could be considered as forest specialist associated with larch plantations, five species (*A. sculpturatus*, *A. tetracarinatus*, *Stillicoderus* sp., *Tachinus* sp. 5 and *Tachinus* sp. 7) with natural broad-leaved forests, and five species (*Ocypus* sp. 1, *Ocypus* sp. 2 and *Ocypus* sp. 3, *Othius* sp. 1 and *Tachinus* sp. 1) with three younger forests. In contrast, only five species (*Tachinus* sp. 3, *Tachinus* sp. 4 and *Tachinus* sp. 6, *Oxytelus* sp. 1 and *P. chinensis*) were abundant in two older forests.

These results were consistent with the findings about staphylinid beetle assemblages in foothills forests and arthropod responses (including staphylinid beetles) to harvesting reported in Canada, which also showed significant habitat preferences of staphylinid beetles among young regenerating and mature forests (Buddle et al. 2006, Pohl et al. 2007). However, as the previous studies suggested, a closed-canopy and similar microhabitats to old-growth forests might be the requirement for forest specialists to survive, so many species associated with old-growth forests would recolonize in the regenerating forests as they aged in a close-canopy (Buddle et al. 2006, Pohl et al. 2007). In our current study, three young forests (40 yr old) at the stem exclusion stage have a closed-canopy and similar dominant tree species composition to the old-

growth forests. Thus, most forest specialists in older forests could adapt to the younger forests. Of course, similar to the studies in Canada (Buddle et al. 2006, Pohl et al. 2007), there was also some forest specialists found only in old-growth stands, e.g., *Tachinus* sp. 3, *Tachinus* sp. 4, and *Tachinus* sp. 6, suggesting that the beetle assemblages from young-growth plantations became more similar to those from old-growth forests as they aged, but still differed considerably from them 40 yr after logging.

**Comparison to Results Based on Carabidae (Yu et al. 2008).** Different from staphylinids in this study, carabids in the same trapping regime exhibited significantly increased abundance in the younger stands, and the ordination plot of carabid catches exhibits tighter groupings, particularly for the younger stands (Yu et al. 2008). This suggests that forest successional stage is a key determinant of the carabid community, but that the staphylinid community may be additionally responding to other factors (e.g., coarse woody debris, vegetation type, density of mushroom and moss) as stands develop the complex characteristics of older forests. Moreover, the finding based on multivariate analyses (RDA) that some staphylinid beetle species had significant habitat preferences for particular vegetation type, indicates that subtle ecological differences are important to them, and that they respond to a finer scale of habitat variation than carabid beetles, most of which were habitat generalists and abundant in many forests. The feeding habit difference between these two families might be reasonable explanation. Most carabids are predators and are not restricted within a specific habitat (Thiele 1977). However, staphylinids depend on all kinds of foods and their feeding habits can be predaceous (e.g., Paederinae, Pselaphinae, Pseudopsinae, Staphylininae, Steninae, Tachyporinae), mycophagous (Omaliinae, Tachyporinae), saprophagous (Apateticinae, Oxytelinae, Tachyporinae), and phytophagous (Omaliinae, Staphylininae, Tachyporinae) (Thayer 2005). Therefore, except the predators, the staphylinids of three other feeding habits usually might depend on specific habitats such as mushrooms, decaying animals, fungi or woods, and plants, which are always heterogeneously distributed among the five forest types. However, more information on the feeding habit of rove beetles is needed to support the above deduction.

**Implications for Conservation.** Our results show, although the establishment of conifer plantation did not bring about a drastic change in the diversity of staphylinids when the plantation reached at the stem exclusion stage with a close-canopy, the composition and distribution of staphylinid assemblages in young conifer plantations are significantly different from those in old-growth forests. Moreover, young-growth forests shared most staphylinid species with old-growth forests, but some species only occurred in old-growth forests. In addition, compared with even-aged conifer plantations, a landscape with a patchwork of forest stands that are of various age classes and forest types should increase the diversity of staphylinids, as well as carabids (Yu et al. 2008). Thus, to protect

the biodiversity of staphylinid assemblages, forest management plans should be made carefully and avoid extensive establishment of even-aged conifer plantations, even if reforestation after harvest will be planted with some native tree species after natural succession.

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## Appendix 1. Staphylinid beetle species captured within five forest types

Species	Hemlock-spruce forests	Birch forests	Natural broad-leaved forests	Spruce plantations	Larch plantations	Total
<b>Apateticinae</b>						
<i>Apatetica</i> sp.	0	0	1	0	0	1
<b>Omalinae</b>						
<i>Unamis</i> sp.	0	1	0	0	2	3
<b>Oxytelinae</b>						
<i>Anotylus sculpturatus</i> Gravenhorst	63	80	87	98	66	394
<i>Anotylus tetracarlinatus</i> (Block)	3	16	101	20	1	141
<i>Anotylus</i> sp.1	0	1	0	0	0	1
<i>Anotylus</i> sp.2	0	0	0	1	0	1
<i>Anotylus</i> sp.3	1	0	1	0	0	2
<i>Anotylus</i> sp.4	0	2	0	0	0	2
<i>Anotylus</i> sp.5	0	0	1	0	0	1
<i>Oxytelus lucens</i> Bernhaur	0	1	0	0	0	1
<i>Oxytelus</i> sp.1	1	6	3	1	4	15
<i>Oxytelus</i> sp.2	0	1	0	0	0	1
<i>Platystethus erlangshanus</i> Yan, Li et Zheng	0	0	1	0	0	1
<b>Paederinae</b>						
<i>Paederus chinensis</i> Berhaur	30	33	22	7	39	131
<i>Stilicoderus</i> sp.	0	9	7	4	6	26
<b>Proteininae</b>						
<i>Megarthus</i> sp.	0	1	0	1	0	2
<b>Pselaphinae</b>						
<i>Saltysedes</i> sp.	0	0	0	0	1	1
<i>Anthophagini</i> , sp.	0	0	0	0	1	1
<i>Batrisini</i> , sp.1	1	1	0	0	1	3
<i>Batrisini</i> , sp.2	0	0	1	0	0	1
<i>Tyrini</i> , sp.	0	6	3	3	2	14
<b>Pseudopsinae</b>						
<i>Pseudopsis</i> sp.	0	1	5	0	0	6
<b>Staphylininae</b>						
<i>Craspedomerus gigante</i> Li & Zhou	0	1	0	0	0	1
<i>Dinothenarus sagaris</i> Smetana	2	1	2	1	3	9
<i>Eucibdelus</i> sp.1	1	0	0	0	0	1
<i>Eucibdelus</i> sp.2	2	0	4	0	3	9
<i>Gabrius fimetarioides</i> (Scheerpeltz)	0	0	0	1	1	2
<i>Miobdelus</i> sp.	0	2	5	1	1	9
<i>Ocypus</i> sp.1	169	57	133	529	201	1089
<i>Ocypus</i> sp.2	30	34	149	131	186	530
<i>Ocypus</i> sp.3	46	26	59	55	50	236
<i>Ocypus</i> sp.4	0	0	1	0	0	1
<i>Ocypus</i> sp.5	1	0	0	0	1	2
<i>Othius</i> sp.1	4	7	5	37	11	64
<i>Othius</i> sp.2	0	1	1	0	0	2
<i>Othius</i> sp.3	0	0	1	2	0	3
<i>Othius</i> sp.4	0	0	1	1	0	2
<i>Philonthus saphyreus</i> Schillhammer	0	0	8	0	0	8
<i>Philonthus</i> sp.	0	1	2	0	1	4
<i>Quedius calvus</i> Zhao et Zhou	0	0	2	0	0	2
<i>Quedius dispar</i> Zhao et Zhou	0	0	1	0	0	1
<i>Quedius perlucidus</i> Zhao et Zhou	3	0	1	1	9	14
<i>Quedius</i> sp.1	0	1	0	0	5	6
<i>Quedius</i> sp.2	1	0	3	2	1	7
<b>Tachyporinae</b>						
<i>Ischnosoma</i> sp.1	0	1	3	0	1	5
<i>Ischnosoma</i> sp.2	1	1	1	0	0	3
<i>Lordithon</i> sp.	1	0	1	1	0	3
<i>Parabolitobius</i> sp.1	0	0	0	0	1	1
<i>Parabolitobius</i> sp.2	0	0	0	1	0	1
<i>Sepedophilus</i> sp.1	0	0	1	0	1	2
<i>Sepedophilus</i> sp.2	0	1	0	0	0	1
<i>Sepedophilus</i> sp.3	1	0	0	0	1	2
<i>Tachinus</i> sp.1	12	12	8	71	16	119
<i>Tachinus</i> sp.2	2	3	8	5	7	25
<i>Tachinus</i> sp.3	42	98	31	36	26	233
<i>Tachinus</i> sp.4	47	29	6	34	14	130
<i>Tachinus</i> sp.5	6	15	4	30	3	58
<i>Tachinus</i> sp.6	9	7	7	2	0	25
<i>Tachinus</i> sp.7	7	19	11	7	6	50
<i>Tachinus</i> sp.8	1	0	4	0	1	6
<i>Tachinus</i> sp.9	0	0	0	1	0	1

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## Appendix 1. Continued

Species	Hemlock-spruce forests	Birch forests	Natural broad-leaved forests	Spruce plantations	Larch plantations	Total
<i>Tachinus</i> sp.10	0	0	1	0	0	1
<i>Tachinus</i> sp.11	1	0	1	2	0	4
<i>Tachinus</i> sp.12	3	0	3	1	1	8
<i>Tachinus</i> sp.13	0	1	2	3	0	6
<i>Tachinus</i> sp.14	0	2	0	0	0	2
<i>Tachinus</i> sp.15	0	0	1	0	0	1
<i>Tachyporus</i> sp.1	8	65	45	13	46	177
<i>Tachyporus</i> sp.2	0	0	0	0	1	1
<i>Tachyporus</i> sp.3	0	1	0	0	0	1
<i>Tachyporus</i> sp.4	0	1	0	0	0	1
Subtotal abundance	499	546	749	1103	721	3618