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Effects of dwarf bamboo, *Fargesia nitida* (Mitford) Keng f. ex Yi, on bark stripping by ungulates in a subalpine *Abies faxoniana* Rehder & E. H. Wilson forest, southwest China

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ABSTRACT

Incidence and intensity of bark stripping of trees by ungulates was investigated at no bamboo (*Fargesia nitida* (Mitford) Keng f. ex Yi) (B–) site and understory bamboo dominant (B+) site of a subalpine *Abies faxoniana* forest, southwest China. The percentage of damaged trees in B– site was higher than in B+ site. Bark stripping obviously occurred more frequently on *Abies faxoniana* Rehder & E. H. Wilson compared to other tree species. Appearance of stripped bark and dead stems of the trees in different size-classes of *A. faxoniana* strongly depended on the density of dwarf bamboo at the site, and also on the size and bark structure of the trees, with highest damage rates occurring on the smaller DBH classes (10–40 cm) in B– site. The bark stripping intensity of *A. faxoniana* decreased significantly with higher density and coverage of *F. nitida* around damaged trees. Therefore, there is an indirect negative effect of the distribution of dwarf bamboo, *F. nitida*, on bark stripping of tree species. We suggest the indirect effects of dwarf bamboo species should be taken into account while considering the succession and regeneration of natural forests.

Key words: bark stripping, *Fargesia nitida*, ungulates activity, regeneration, subalpine forest.

Dwarf bamboos were recognized as a determinant of the forest structure and dynamics in East Asia for their wide distribution and high density in understories [1, 2]. They could inhibit survival and regeneration of tree seedlings, saplings [3] and mature trees [4] in many forests.

However, some studies found that a certain density of dwarf bamboo could inhibit the activity of forest ungulates (deer) and reduce the damage to tree seedlings, providing a safe site for regeneration of understory trees [5]. Bark stripping by ungulates was the major hazard for tree regeneration in subalpine forests [6, 7]. Trees that incurred heavy damage from bark stripping were likely to die, which could have a profound impact on plant populations, forest structure and ecosystem processes [8, 9]. In subalpine *Abies faxoniana* Rehder & E. H. Wilson forest of southwest China, dwarf bamboo, *Fargesia nitida* (Mitford) Keng f. ex Yi, was widely distributed in the forest understory. Bark stripping of trees species by ungulates (*Budorcas taxicolor* Milne-Edwards and *Naemorhedus goral* Hardwicke, etc.) was commonly observed in this region. Thus, it was significant to discuss the relationship between the distribution of dwarf bamboo and activity of ungulates and bark stripping intensity, and also further relationship between the distribution of dwarf bamboo and trees survival in this subalpine forest.

This study aims to clarify the effects of bamboo density on bark stripping of trees species in a subalpine forest, southwest China. We address the following questions: What is the extent of bark stripping damage to trees caused by ungulates in the areas with different bamboo density? What are the determinants of the extent of bark stripping? Is there an indirect negative effect of the distribution of dwarf bamboo, *F. nitida*, on bark stripping of tree species?

MATERIAL AND METHODS

Study site. The field work was conducted in July 2006 in the subalpine dark coniferous forest near the Wolong Subalpine Dark Coniferous Forest Ecosystem Research Station (102°58′21″ E, 30°51′41″ N, 2 800 m a. s. l) in the southwest of Wolong Nature Reserve, Sichuan Province, China. The climate is warm, and the annual mean temperature is 4,3 °C and the annual precipitation and annual evaporation capacity are about 848,9 mm and 772,5 mm respectively. The annual sunshine duration is approximately 1185,4 h. The forest on the site mainly consists of evergreen coniferous tree species *A. faxoniana*, with sporadic distribution of deciduous broadleaved trees such as *Acer caudatum* G. Nicholson and *Betula utilis* D. Don. The forest floor is mainly covered with *F. nitida* [2].

Field investigation. Measurement of community was mainly conducted in subalpine forest in midsummer 2006 by comparing *F. nitida* (bamboo dominated, B+) site (4800 m^2) with No *F. nitida* (no bamboo, B−) site (4800 m^2). *F. nitida* site (B+) − average bamboo density ≥ ≥ 15 culms/m^2, and bamboo cover 40−85 %; No *F. nitida* site (B−) − the distribution of *F. nitida* was dispersed, average bamboo density < 1 culm/m^2, and bamboo cover < 2 %. Both B+ and B− site consisted of three 40 × 40 m plots. Each plot was composed of adjacent 5 × 5 m quadrats. In each quadrat, height and diameter at breast height (DBH) of each tree (height > 1,3 m and DBH > 5 cm), ramet number and coverage of *F. nitida* were measured.

Bark stripping by ungulates (*B. taxicolor* and *N. goral*) can be observed widely in this area. Therefore, records were maintained of each tree that suffered bark stripping [6], and did or did not encounter death due to bark stripping [9]. The occurrence of bark stripping by ungulates was classified visually as the percentage of maximum width of barked part to stem circumference in four classes: 25 %, 50, 75, and 100 %. The density and coverage of *F. nitida* in a 2 × 2 m circle around the central bark stripping tree was measured in order to analyze the further effect of distribution of bamboo on bark stripping. Frequency and intensity of ungulates activity in the quadrat with bark stripping damage were estimated using the number of paths, signs and feces left by ungulate animals. Micro-topographical factor, elevation difference, slope and position (upper, middle, lower, and flat slope) were also recorded in the quadrat with damaged trees. The description of categories and evaluation were based on our previous studies [2, 10].

Data analysis. Figures were drawn by Origin 7.0, and stepwise multiple regression was employed to find the main factors influencing bark stripping intensity of *A. faxoniana* by SPSS 11.0 statistical package (SPSS 11 Copyright: SPSS Inc.).

RESULTS AND DISCUSSION

Structure of *Abies faxoniana* in B− site and B+ site. The size-distribution of *A. faxoniana* revealed a lower age of no bamboo (B−) site and a higher age of bamboo dominant (B+) site, which was reflected by a larger relative abundance of size classes 5-30 cm DBH (smaller trees) in B− site and of 30−50 cm DBH (larger trees) in B+ site (Fig. 1). Mean tree DBH in B− site and B+ site was 28,21 and 32,84 cm respectively.

Incidence of bark stripping. *Abies faxoniana* along with other two coniferous tree spe-

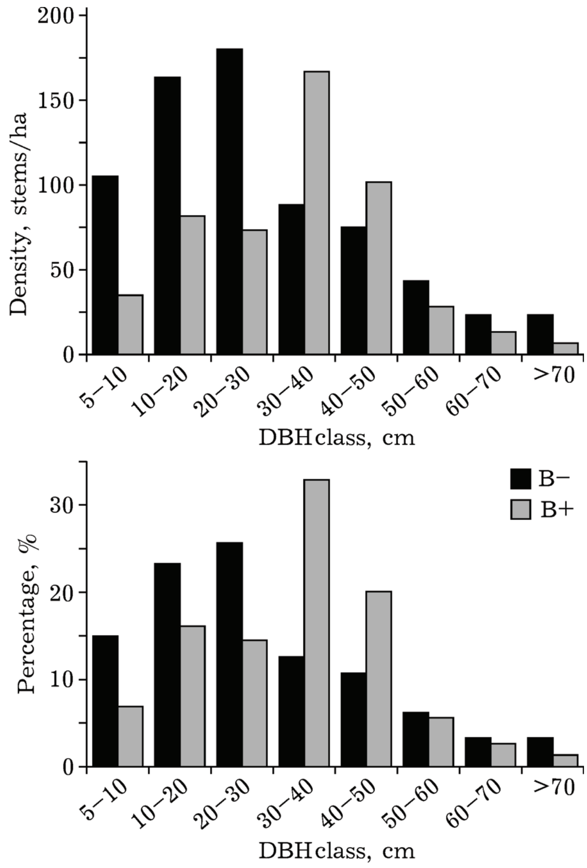

Fig. 1. Size-classes distribution (DBH) in density and percentage of *Abies faxoniana* in B− and B+ site in a subalpine forest, southwest China

cies and four deciduous tree species were observed at two sites (Table 1). The density of both coniferous and deciduous species in B− site tended to be higher than in B+ site. Only coniferous species suffered bark stripping by ungulates, and *A. faxoniana* obviously suffered more than other coniferous species. In general, the percentage of damaged trees was higher in B− site than in B+ site. Incidence of stem damage was dependent on understory bamboo density of *F. nitida*, and amounted to 11,63 % in B− site and 1,65 % in B+ site. Bark stripping mortality was highest with *A. faxoniana* of B− site. Instances of bark stripping of other coniferous tree species, *Larix kaempferi* (Lamb.) Carr., however occurred at very low densities and were scattered at both sites.

Bark stripping and death of trees in different size-classes of *A. faxoniana* were in the first place conditions-dependent, and at B− site these incidents occurred more frequently than at B+ site (Fig. 2). Stem damage and death of trees were also highly dependent on tree size (DBH). Incidences of damage were found for the size-classes DBH > 10 cm and 10−30 cm. Another significant factor affecting the amount of damage was bark structure. Young coniferous trees have smoother bark than old trees; moreover coniferous species have monolayer bark, while deciduous species, such as *Betula* genus, have multilayer bark.

The bark stripping intensity of *A. faxoniana*, decreased significantly with higher density and coverage of *F. nitida* around damaged trees, and increased significantly with ungulates activity (Table 2). It also had some relation to slope in micro-topography ($P = 0{,}051$).

Table 1

***Abies faxoniana* and other tree species in B− and B+ site, with total number per species, number of trees with stripped bark (Damaged) and trees that died due to bark stripping (Dead) in B− and B+ site**

Tree species	Number of trees per ha in B− site			Number of trees per ha in B+ site		
	Total	Damaged (%)[a]	Dead (%)	Total	Damaged (%)	Dead (%)
Coniferous species						
Abies faxoniana	717	83 (11,63)	15 (2,03)	506	8 (1,65)	2 (0,41)
Tsuga chinensis (Franch.) Pritz.	15	0	0	10	0	0
Larix kaempferi	25	2 (8,33)	0	4	0	0
Deciduous species						
Acer caudatum var. *prattii*	67	0	0	21	0	0
Betula utilis	323	0	0	44	0	0
Betula albo-sinensis Burk.	17	0	0	10	0	0
Betula luminifera H. Winkl.	10	0	0	–	–	–

[a] Percentage to total number of trees in parentheses.

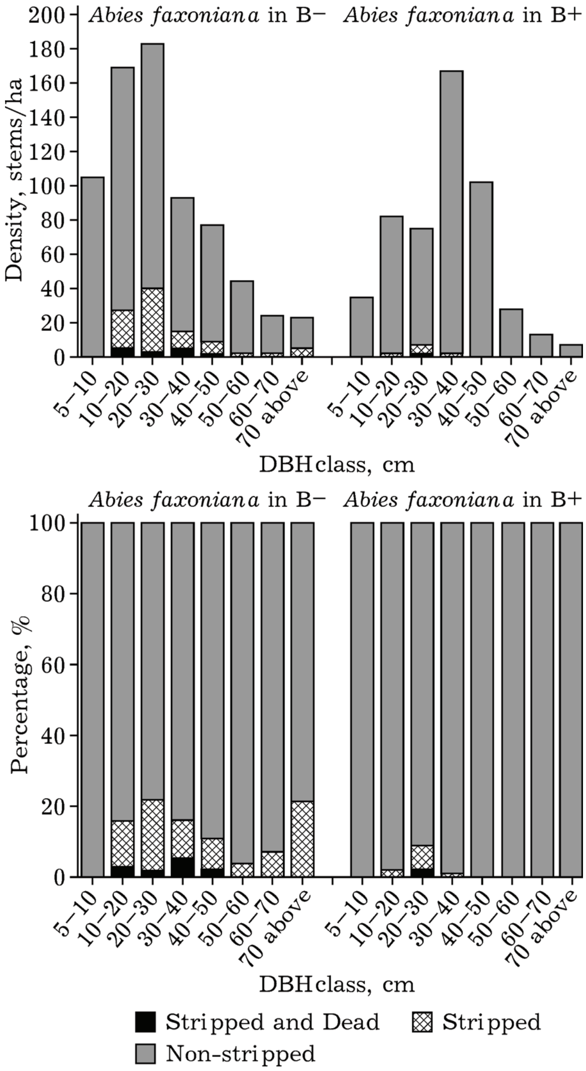

Fig. 2. Size-classes distribution (DBH) in density and percentage of Non-stripped, Stripped, and Stripped and Dead stems of *Abies faxoniana* in B− site and B+ site in a subalpine forest, southwest China

CONCLUSIONS

A. faxoniana exhibited to be much more susceptible to bark stripping than any other tree species, which confirmed the fact, also noted in other studies [9], that coniferous trees suffer more severe bark stripping than deciduous broadleaves trees. Other common trees in subalpine forest, such as *Betula* genus, showed no damage at all [6, 11]. Other species which was found debarked to some extent by ungulates was *L. kaempferi*. Selective bark stripping is a well known phenomenon, found also among other ungulates and small mammals. Ungulates were often found to prefer the bark of coniferous species, as was observed for *Abies alba* Mill., *Abies homolepis* Sieb. et Zucc, *Picea jezoensis* var. *hondoensis* Rehd., and *L. kaempferi* [12].

We found stem damage to be dependent on the size of the tree. Ungulates preferred to debark the trees of smaller size-classes (10–40 cm DBH); apparently the animals tended to select fast growing trees with smooth stems. It might be resulted from high level of stem-sap contents in young trees and corresponding high growth rate. Thus, small trees died very quickly as they tend to die soon after being completely barked. Larger stems were barked little-by-little and died only when they were 100 % barked [6, 11].

Another significant factor affecting the damaging of *A. faxoniana* was bark structure. Some studies pointed out that physical characteristics of bark, such as smoothness, thickness and hardness are more important than its chemical characteristics in explaining why

Table 2

Stepwise multiple regression analysis, conducted for bark stripping intensity of *Abies faxoniana* (data from all bark stripping trees in both sites and factors in their located quadrats), using the Standardized coefficients (with *P* values in parentheses) for the selected variables, *P* value of the model and r^2 are shown for each model

Bark stripping of *Abies faxoniana*	Disturbance	Distribution of *Fargesia nitida* around damaged trees		Topography			P	r^2
	Ungulates activity	Density	Coverage	Elevation difference	Slope	Position		
Intensity	0,405 (0,001)	−0,314 (0,015)	−0,352 (0,007)	–	−0,145 (0,051)	–	<0,01	0,654

ungulates prefer smaller size-class coniferous species [9]. Young coniferous trees have smoother bark than old trees; moreover coniferous species have monolayer bark, while deciduous species, such as *Betula* genus, have multilayer bark.

The observed differences in susceptibility to debarking between trees in no bamboo (B–) site and in bamboo dominant (B+) site of a subalpine forest were mainly related to understory bamboo (*F. nitida*) density and trees density. Stepwise multiple regression analysis also indicted that the bark stripping intensity of *A. faxoniana* was negatively related to density and coverage of *F. nitida* around damaged trees. A certain density of dwarf bamboo could inhibit the activity of ungulates (deer) and thus reduce the damage to trees' bark [5]. We found that the number of paths and feces left by animals was much smaller in B+ site, which could have influenced the activity and density of ungulates. Thus, the smaller bark stripping damage in B+ site also might be resulted from lower deer density. Stands with dense tree stems have been found to be more susceptible to debarking since understory bamboo inhibited trees regeneration thus influencing the trees' size-classes and density [11].

Bark stripping might occur at a relatively constant level at only a few trees. However, damaged trees are more likely to be damaged again, and trees stems that were being barked little-by-little might finally die when ring barked. In addition, micro-climatic conditions of the region lead to high infection rates among the trees with stripped bark which results in further reduction of the trees' density in future. Bark stripping also causes trunk decay and results in broken trunks and trees uprooted by wind [13], finally leading to a general reduction in yield of the stand [14]. Therefore, bark stripping can have a significant impact on plant populations, forest structure and ecosystem processes [8, 9].

However, at the sites without *F. nitida* growing around the trees there are higher threats to tree survival than in the B+ situation. Susceptibility to bark stripping was found to be strongly species-dependent, size-dependent, and conditions-dependent, as almost all bark stripping targets were large trees of *A. faxoniana* (DBH > 10 cm) in B– site. Microclimate (i. e., temperature, humidity, and light conditions) and habitats of B+ plots were hard for ungulates (*B. taxicolor* and *N. goral*) to live in, it was also hard for them to move around because of the dense bamboo clumps. Dwarf bamboos, having positive, indirect effects on survival of *A. faxoniana* resulted from hindering ungulates activity and lowering the ungulates disturbance risk for the trees [5].Therefore, there is an indirect, negative effect of the distribution of dwarf bamboo, *F. nitida*, on bark stripping of tree species.

F. nitida contributes to the reductions in the death ratio and bark stripping intensity of *A. faxoniana*. Maybe the density of *F. nitida* is a key determinant in the process of forest cycle succession. We suggest the indirect negative effects of dwarf bamboo species should be taken into account while considering the succession and regeneration of natural forests. Further studies on the dynamics of bamboo density (questions of growth, sporadic flowering and damage from animals) can be helpful for understanding understory bamboo dynamics and regeneration of *A. faxoniana* forest in this region.

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