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Citation	Eurasian Journal of Forest Research, 6(2), 111-115
Issue Date	2003-09
Doc URL	<a href="https://hdl.handle.net/2115/22166">https://hdl.handle.net/2115/22166</a>
Type	departmental bulletin paper
File Information	6(2)_P111-115.pdf



## Damage Caused by Sika Deer (*Cervus nippon yesoensis*) at a Young Larch Stand in Eastern Hokkaido, Northern Japan

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### Abstract

Conifer plantations have suffered serious damage by sika deer (*Cervus nippon yesoensis*) in Hokkaido. We surveyed damage caused by the deer at a young Japanese larch (*Larix kaempferi*) stand and clarified some of its characters. The main type of damage was bark stripping on trunks and branches. New damage of this type was observed in the surveys in May and June, while it was never observed in October and November. Wounds on trunks and branches were observed at heights lower than 200 cm above the ground, and they were especially concentrated between 60 and 140 cm high. A lot of the wounds were xylem-exposed ones, and as a result, almost all of the debarked trees had exposed-xylem. We did not find any trunks that had suffered complete girdling by sika deer. The percentage of debarked trees in each DBH class suggested that bark stripping by sika deer occurred mainly on trunks when larches were small in DBH (mainly 2-6 cm), and that the damaged part gradually changed from trunks to branches as the larches became larger in DBH. Few fraying and no browsing damage were observed at the stand in any season.

*Key words:* bark stripping, *Cervus nippon yesoensis*, forestry damage, *Larix kaempferi*, sika deer

### Introduction

Forest damage caused by sika deer (*Cervus nippon yesoensis*) has been severe in Hokkaido since the late 1980s (e.g. Takayanagi *et al.* 1991, Takahashi *et al.* 1997, Sakabe *et al.* 1998, Orihashi *et al.* 2002). Young Japanese larch (*Larix kaempferi*) stands suffered serious damages by the deer in eastern Hokkaido. Browsing damages occurred at the stands younger than six years old (Akashi 1999), and bark stripping and fraying damages occurred at the stands younger than 16 years old (Akashi 1999, Mabuchi *et al.* 2001). Understanding characters of those damages is increasingly important to consider effective protection of young larch stands against sika deer. In the present study, therefore, we surveyed damage caused by sika deer at a young larch stand (around 10 years old) to clarify some of its characters.

### Study site

The study site was a young Japanese larch stand located in the Kyushu University Forest in Hokkaido, Ashoro, eastern Hokkaido (43° 17' N, 143° 29' E, 0.3 ha, established in 1989). Around this site, there were other Japanese larch stands (established between 1966 and 1990) and an *Abies sachalinensis* stand (established in 1973). Some of these stands suffered severe damage by sika deer (Mabuchi *et al.* 2001, Orihashi *et al.* 2002).

In the University Forest, deer control measures have

permitted up to 100 deer to be hunted per winter season since the season of 1997-1998. The results were as follows (the number of sika deer hunted / the amount area of stands where the deer were hunted): 65 deer / 1,181 ha in the 97-98 season; 55 / 936 in the 98-99 season; 44 / 1,262 in the 99-00 season (Mabuchi, the Kyushu Univ. For. in Hokkaido, personal communication).

According to the meteorological observation of the University Forest between 1952 and 1991, the climate around the Forest is outlined as follows. The annual average temperature and the annual precipitation are 5.9°C and 782 mm. Snow begins to fall in the mid-November and the annual maximum snow depth is 42 cm. The temperature can reach above 35°C in summer and below -30°C in winter (The Kyushu University Forests 2000).

### Methods

We surveyed a total of 351 larches at the study site. The survey was conducted six times between 1997 and 2000 (early in June and mid-November 1997, early in May 1998, mid-May and mid-October 1999, and early in June 2000).

In the surveys, each larch was first checked whether it was alive or not. When it was dead, its mortal factor was estimated: a) bark stripping by sika deer; b) bark stripping by gray-sided voles (*Clethrionomys rufocanus bedfordiae*); and c) others (e.g. windblow and disease).

Dead larches were excluded in the subsequent surveys.

Second, each larch was checked whether it had new wounds or not. When it had new wounds, the larch was counted in the category 'new damage'. At the first survey, larches that had older wounds were counted in the category 'old damage'. Some larches that had both new and old wounds were counted in both (new and old) categories.

Third, the following six items were surveyed for each wound. 1) *Type of wound*: bark stripping or fraying or browsing. 2) *Wounded region*: trunk or branch. 3) *Depth of wound*: xylem-exposed or not. 4) *Height of wound*: the height of each wound from the ground was measured. The unit of measurement was 1 cm. 5) *Length and width of wound*: the central length and width of each wound was measured. The unit of measurement was 0.1 cm. 6) *Wound area index (WAI, length × width)*: it was calculated for each wound. For the wounds on branches, those six items were surveyed only at the last survey (in June 2000).

In addition to the above works, the girth at breast height was measured for each larch to calculate its DBH. This was conducted three times (once in June 1997, and again in May and October 1999). The unit of measurement was 0.1 cm. The DBH data in October 1999 was substituted for the data in June 2000. The frequency distribution of DBH (classified by 2 cm) was determined for each time (June 1997, May 1999, June 2000), and then the cumulative frequency distribution of DBH was calculated. For each DBH class of this cumulative distribution, the percentage of debarked trees was analyzed.

## Results

### 1 Incidence of deer related damage

As of June 2000, bark stripping was the main type of damage, and it was observed both on trunks and

branches (Table 1). Only three larches suffered fraying damage on their trunks, and no browsing damage was observed at the study site (Table 1). We found 64 dead larches by the end of the survey series (Table 1). Only two larches died from bark stripping by sika deer. Severe bark stripping damage by gray-sided voles occurred in the winter season of 1998-1999 at the study site (Orihashi *et al.* 2000). The death of 41 larches was due to complete girdling (or stripping large amounts of bark) by the voles. The other 21 larches died mainly due to other factors such as windblow or disease.

Bark stripping on trunks and branches was recorded in the surveys in May and June, while it was never found in October and November (Table 1). The percentage of trees that suffered bark stripping on their trunks (trunk debarked trees, hereafter) was high in June 1997 and May 1998 (Table 1). The percentage, however, dropped to about 5 % in May 1999 and June 2000. The percentage of trees that suffered bark stripping on their branches (branch debarked trees, hereafter) gradually increased year by year, and it was higher than that of the trunk debarked trees in May 1999 and June 2000 (Table 1).

### 2 Bark stripping damage on trunks: total damage up to June 2000

Up to June 2000, a total of 2,486 wounds were observed on the trunks surveyed. Seventy-four percent of them were xylem-exposed wounds, and as a result, 95 % of the trunk debarked trees (294 of 311 trunk debarked trees) had exposed-xylem. The height distribution of wounds was bell-shaped, and the concentrated range of them was from 60 cm to 140 cm high (Fig. 1a). The maximum and minimum height of wounds was 195 and 5 cm, respectively. The mean  $\pm$  SD, maximum and minimum length of wounds were  $9.3 \pm 7.8$ , 72.0 and 0.5 cm. The mean  $\pm$  SD, maximum and minimum width of wounds were  $3.5 \pm 2.1$ , 27.0 and

Table 1. Transition of deer related damage at the study site.

Survey time (month/year)	New/Old damage	Type and region								Dead		
		Bark stripping				Fraying						Browsing
		Trunk		Branch		Trunk		Branch		No. <sup>a</sup>	% <sup>b</sup>	
No. <sup>a</sup>	% <sup>b</sup>	No. <sup>a</sup>	% <sup>b</sup>	No. <sup>a</sup>	% <sup>b</sup>	No. <sup>a</sup>	% <sup>b</sup>	No. <sup>a</sup>	% <sup>b</sup>			
June/1997	Old	165	47.0	11	3.1	0	0	0	0	0	-	-
June/1997	New	225	64.1	23	6.6	0	0	0	0	0	1 (0)	0.3
November/1997	New	0	0	0	0	0	0	0	0	0	0 (0)	0
May/1998	New	134	38.2	48	13.7	2	0.6	0	0	0	4 (1)	1.1
June/1999	New	22	6.3	27	7.7	1	0.3	0	0	0	14 (0)	4.0
October/1999	New	0	0	0	0	0	0	0	0	0	30 (0)	8.5
June/2000	New	15	4.3	99	28.2	0	0	0	0	0	15 (1)	4.3
		No. <sup>c</sup>	% <sup>b</sup>	No. <sup>c</sup>	% <sup>b</sup>	No. <sup>c</sup>	% <sup>b</sup>	No. <sup>c</sup>	% <sup>b</sup>	No. <sup>c</sup>	No. <sup>c</sup>	% <sup>b</sup>
Total up to June 2000		311	88.6	150	42.7	3	0.9	0	0	0	64 (2)	18.2

<sup>a</sup> Numbers of the damaged or dead trees observed in each survey. Numbers of the dead trees due to bark stripping by sika deer in parentheses. <sup>b</sup> Percentages to the 351 trees surveyed. <sup>c</sup> Number of the trees which had been damaged or had died until the last survey in June 2000. Number of the dead trees due to bark stripping by sika deer in parentheses.

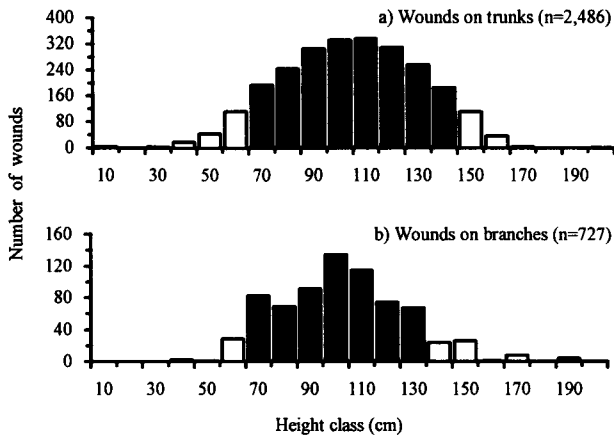


Fig. 1. Frequency distributions of height for the wounds caused by bark stripping by sika deer. The distributions are classified by 10 cm. a) The total wounds up to June 2000. b) The wounds that were newly observed in June 2000. Height class 10, for example, shows  $0 \text{ cm} \leq H < 10 \text{ cm}$ . In each figure, the height classes that have 5% or more of total wounds are shown with black bars. The range indicated by the black bars is regarded as a wound concentrated range in this study.

0.5 cm. Percentage of the wounds belonging to each WAI (wound area index) class is shown in Fig. 2a. Sixty-nine percent of the xylem-exposed wounds and 94% of the wounds with no exposed-xylem were WAI < 50. In the surveys, we did not find any trunks suffering from complete girdling by sika deer.

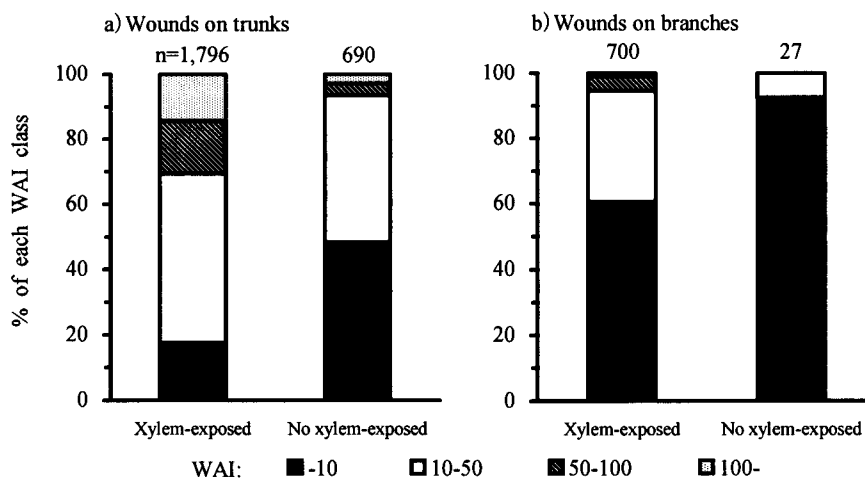


Fig. 2. Percentages of the wounds belonging to each WAI class. The wounds are due to bark stripping by sika deer. WAI, wound area index (wound length  $\times$  width). a) The total wounds up to June 2000. b) The wounds that were newly observed in June 2000. WAI class 10-50, for example, shows  $10 \leq \text{WAI} < 50$ .

### 3 Bark stripping damage on branches: new damage observed in June 2000

In the survey of June 2000, a total of 727 wounds were recorded on the branches surveyed. Those wounds were generally observed near the trunk region. Ninety-six percent of them were xylem-exposed wounds, and as a result, 99% of the branch debarked trees (98 of 99 branch debarked trees) had exposed-xylem. The height distribution of wounds was bell-shaped, and the concentrated range of them was from 60 cm to 130 cm high (Fig. 1b). The maximum and minimum height of wounds was 181 and 35 cm, respectively. The mean  $\pm$  SD, maximum and minimum length of wounds were  $1.8 \pm 0.7$ , 7.5 and 0.5 cm. The mean  $\pm$  SD, maximum and minimum width of wounds were  $6.6 \pm 7.4$ , 54.0 and 0.5 cm. Percentage of the wounds belonging to each WAI class is shown in Fig. 2b. Sixty-one percent of the xylem-exposed wounds and 93% of the wounds with no exposed-xylem were WAI < 10.

### 4 Percentage of debarked trees and DBH class

The cumulative frequency distribution of DBH (that was composed of the DBH data in June 1997, May 1999 and June 2000) was bell-shaped with its peak at the DBH class of 6-8 cm (Fig. 3). For each DBH class of this distribution, the percentage of debarked trees is shown in Fig. 4. Concerning trunk debarked trees, the percentage was large between 2 and 6 cm, and gradually decreased at the subsequent classes. On the other hand, the percentage of branch debarked trees became larger as the DBH class rose. The distribution of percentage was significantly different between the trunk debarked trees and the branch debarked ones (Kolmogorov-Smirnov test,  $P < 0.001$ ).

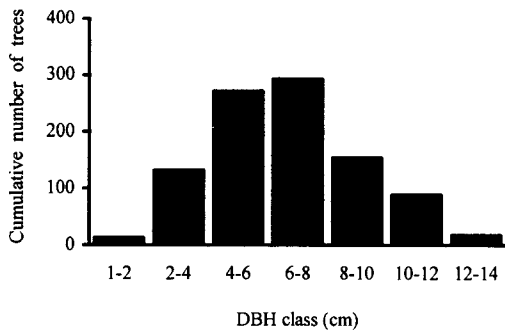


Fig. 3. Cumulative frequency distribution of DBH. The distribution is composed of the DBH data in June 1997, May 1999 and June 2000 ( $n = 971$ ). DBH class 1-2, for example, shows  $1 \text{ cm} \leq \text{DBH} < 2 \text{ cm}$ .

### Discussion

Bark stripping on trunks and branches was the main type of damage at the study site (Table 1). New damage of this type was observed in the surveys in May and June, while it was never observed in October and November. This result suggests that bark stripping by sika deer usually occurs between late autumn and early spring (probably in winter) at the study site. It agrees with the result reported in previous studies (Orihashi *et al.* 2002).

Old bark stripping was recorded in the first survey in June 1997 (Table 1). Deer related damage may have started in the early or mid-1990s around the study site (Mabuchi, the Kyushu Univ. For. in Hokkaido, personal communication).

Xylem deterioration such as breakage, discoloration and decay can occur and develop from xylem-exposed wounds (Gill 1992a, Tokuda 1998). Almost all of the debarked trees had xylem-exposed wounds on their trunks and/or branches at the study site. This result is probably due to the thin bark of those regions. The prospective xylem deterioration on the debarked trees may result in a serious forestry loss in future.

Concerning the bark stripping on trunks at the study site, the width of wounds tended to be small, and no trunk suffered complete girdling by sika deer. Also, few fraying damage was found on the trunks surveyed (Table 1). Lateral branches can physically obstruct deer from bark stripping on tree trunks (Welch *et al.* 1988, Gill 1992b). No artificial pruning had been conducted at the study site, and the larches surveyed had whorls of lateral branches along their trunks. Those whorls, therefore, may have limited the width of wounds, complete girdling and fraying on the trunks.

Wounds from bark stripping on trunks and branches were observed at heights lower than 200 cm (Fig. 1). Those wounds were concentrated approximately at the same height range. Thus, we concluded that the concentrated range of wounds was from 60 cm to 140 cm high. Previous studies near the study site have

reported similar results (Mabuchi *et al.* 2001, Orihashi *et al.* 2002). In the vastly snowy areas in Hokkaido, wounds from bark stripping were found at heights over 200 cm from the ground level (e.g. Orihashi *et al.* 1999). Compared to that fact, relatively low snow depth (The Kyushu University Forests 2000) seems to be responsible for the wounds that were concentrated at lower heights at the study site.

The percentage of debarked trees in each DBH class (Fig. 4) indicates that deer's preference for trunks was higher than that for branches when larches were small in DBH, and that the preference gradually changed as the larches grew larger. Morphological characteristics such as bark thickness and roughness are important determinants of bark stripping by deer (Gill 1992b). Also, chemical compounds such as terpenes and phenolic compounds affect feeding choice by cervid species (Schwartz *et al.* 1980, Elliott and Loudon 1987, Duncan *et al.* 1994, Jia *et al.* 1997, Vourc'h *et al.* 2002). In relation to the deer's preference, bark morphological and chemical properties should be compared between trunks and branches covering various DBH classes.

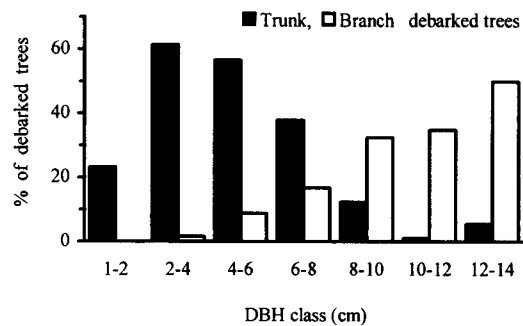


Fig. 4. Percentages of debarked trees for each DBH class. DBH class 1-2, for example, shows  $1 \text{ cm} \leq \text{DBH} < 2 \text{ cm}$ .

### Acknowledgement

We would like to thank Mr. T. Mabuchi (The Kyushu Univ. Forest in Hokkaido) for his helpful information on this study. We also thank staffs of the Kyushu Univ. Forest in Hokkaido and students of Dept. Forest Science, Fac. Agr., Hokkaido Univ. for their assistance in this study.

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