Effects of pruning and brush clearing on debarking within damaged conifer stands by Japanese black bears

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Debarking of conifers by American black bears (*Ursus americanus*) has been documented in the western United States (Ebert 1979, Parsons 1979, Poelker and Parsons 1980, Dyke 1993, Barnes and Engeman 1995, Ziegltrum and Nolte 1997, Stewart et al. 1999). Debarking by Japanese black bears (*Ursus thibetanus japonicus*) in plantations of conifers such as hinoki cypress (*Chamaecyparis obtusa*) and Japanese cedar (*Cryptomeria japonica*) has also seriously affected forestry in southwestern Japan (Watanabe and Komiyama 1976, Torii 1978, Azuma and Torii 1980, Furubayashi et al. 1980, Watanabe 1980, Yoshimura and Fukui 1982). In southwestern Japan, many cage-traps have been set for bears, and a great number of bears have been killed, both legally and illegally (Torii 1978, Shibata and Kofune 1984, Yamada et al. 1990, Hazumi 1994). Debarking has also been reported in the Okutama Mountains of central Japan, near where I have studied bears for 10 years. This short paper provides preliminary data comparing characteristics of damaged and undamaged trees and stands within areas known to be subject to bear damage.

Study area and methods

My main study area was located in the Mine area of Okutama Town where the Forestry Owners' Association and forest workers reported that most of the bear debarking has occurred (Fig. 1). I also set up a supplemental study area in the Nippara area of Okutama, approximately 4 km north of the main study area.

The topography of the overall study site varies steeply from 500 to 1,500 m. Existing vegetation was classified at approximately the 1,000 m contour by the Japanese Environment Agency (1988). The Japanese beech (*Fagus crenata*)–mizunara oak (*Quercus crispula*) vegetation category was predominant >1,000 m, and the konara oak (*Quercus serrata*)–Japanese chestnut (*Castanea crenata*) category was predominant below that elevation. The proportion of planted hinoki cypress and Japanese cedar has been expanding since 1960s, and as of 2000 occupied about 50% of the forest area (Okutama Forestry Owners' Association, Okutama Town, Japan, unpublished data, 2000). In Okutama, the area in cedar plantations was about 2.5× greater than the area of cypress plantations (Okutama Forestry Owners' Association, Okutama Town, Japan, unpublished data, 2000).

During winters in 1992 and 1993, I conducted preliminary transect surveys within stands known to have bear damage in the Mine area to obtain a general understanding of the situation. Following this, during the winter of 1993, I non-randomly selected 4 quadrats (3 in mixed cypress–cedar stands, 1 in a pure cypress stand), each 0.16 ha in size (40 × 40 m). Selection was biased to areas where I had earlier found a large number of debarked trees and toward stand edges (Fig. 2). Quadrat elevations varied from 950 to 1,050 m. I recorded the species and diameter at breast height (dbh) for all trees within selected quadrats and measured the debarked portion for all trees exhibiting any bear damage. I also counted the number of existing branches under the *chikara* (a Japanese term for low lying branches that participate in photosynthesis) branches of each trees. Normally, forest owners prune all branches under the *chikara* branches to obtain high quality timber with fewer knots as well as to ventilate the stand.

For the supplemental study area in Nippara (spring 2001), I selected one 0.16 ha quadrat (elevation 1,035 m) within a pure cypress stand in Nippara area that had been substantially pruned and thinned. However, in contrast to the Mine quadrats, this stand was characterized by thick growth of asebi (*Pieris japonica*), an evergreen broad-leaved brushy species, on the stand floor. Therefore, in addition to a count of branches under the *chikara* branches, I documented undergrowth density via a visual obstruction index. To produce this index, I first I divided the entire quadrat into 64 smaller grids (5 × 5 m each). I then located each asebi group to the nearest meter within the grid and measured the branch volume of each. Volume was calculated as a sphere, with radius equal to 2/3 of the asebi's height. I excluded from this volume the portion of the asebi ≥220 cm, which was the maximum height for debarking by a bear

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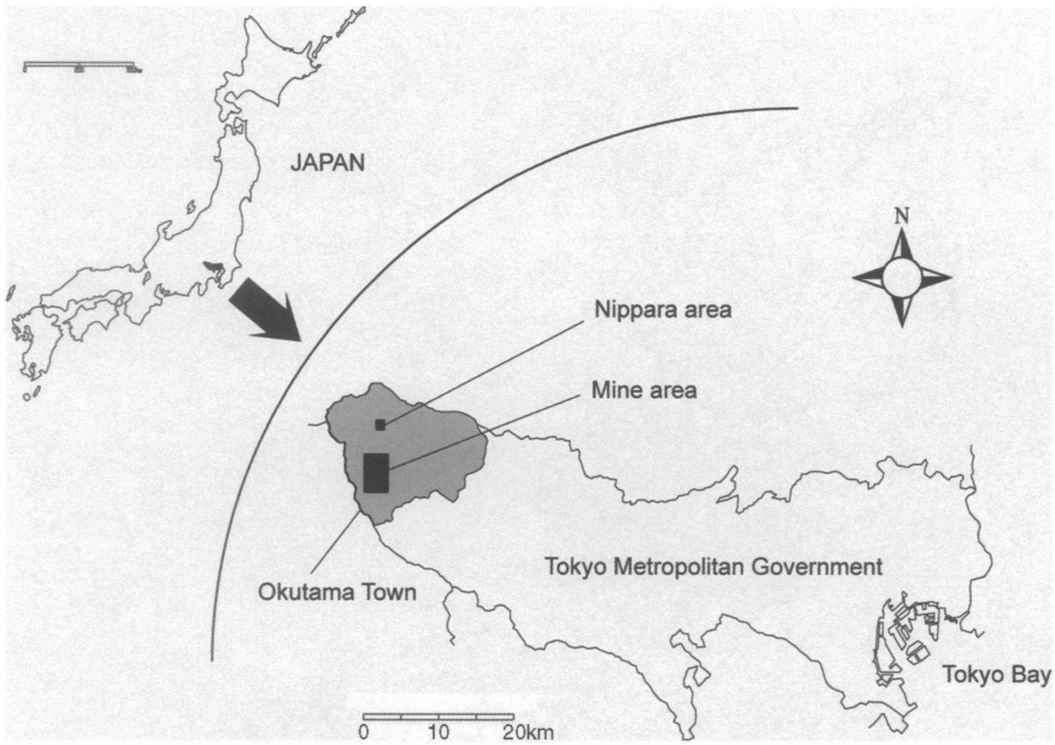

Fig. 1. Location of the Mine and Nippara areas within Okutama Town, Tokyo, central Japan.

recorded in this stand. The obstruction index was defined as asebi volume divided by asebi height (with a maximum of 220 cm). I also recorded dbh for all cypress trees and measured the debarked portion for damaged cypresses.

I compared dbh between damaged and undamaged conifers separately for each quadrat using Mann-Whitney U tests. I tested the hypothesis that bear damage was independent of conifer species using Fisher's exact test separately for each quadrat. At Nippara, the Kruskal-Wallis rank test was used to test for a relationship between bear damage occurrence and obstructed view within each grid. Differences were considered significant at $P < 0.05$.

Results

Within the Mine study area, quadrats with more branches below the *chikara* tended to have a higher percent of trees damaged than did those with more pruning (Table 1). Bears significantly selected cypress over cedar for debarking in quadrats 1 and 3 (Fisher's exact probability test, $P < 0.0001$), but not in quadrat 4 ($P =$ 1.0000). Damaged trees had thicker mean dbh than undamaged trees for all comparisons within the Mine areas for which sample size for both samples was >5 (Table 2).

For the Nippara area surveys, no trees had branches under the chikara branches (about 7 m in height). However, asebi occurred 34.4% of the 64 grids, and all of the asebi grids were adjacent. The dbh did not differ between damaged and undamaged trees (Table 2). Grids with greater Asebi volume had higher proportion damage than grids with less asebi (Kruskal-Wallis rank test, $H = 27.26$, $P < 0.0001$; Table 3).

Discussion

Debarking of conifers has been a concern by local people and foresters in the Okutama Mountains of central Japan. In my preliminary surveys, however, I found the density of damaged trees to be only 1.50 trees/ha (K. Yamazaki unpublished data) even where people had expressed concerns about damage. Because trees debarked by bears were relatively rare in my study area, I was only able to investigate a few quadrats and thus

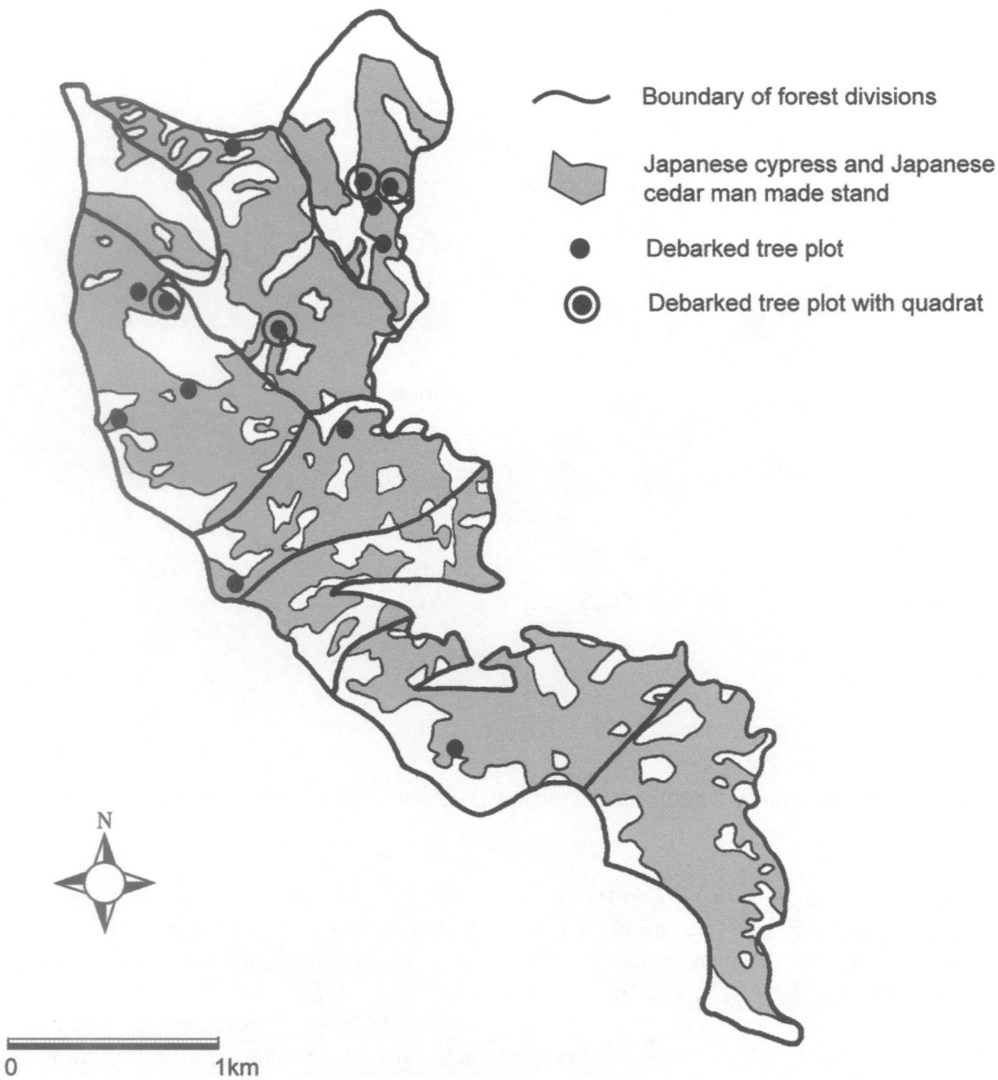

Fig. 2. Location of quadrats as well as pilot study plots in the Mine area relative to plantation boundaries, in the Okutama Town, Tokyo, Japan, 1992–93.

cannot account for all the variables that might be important. However, these results suggest the possibility that, at least within stands known to have some damage, debarking was concentrated in stands with higher understory density and on trees with greater dbh. I speculate that these stands were selected by bears because they seemed to offer more protection from humans (due to the obstructed view caused by obstacles such as unpruned branches and undergrowth) than more open stands. Bears probably debarked trees with thicker dbh because of their interest in feeding on the cambium layer. They therefore selected trees with relatively more growth. Similar tendencies were noted by Watanabe and Komiyama (1976), Shibata and Kofune (1984), and Yamada (1990) in Japan and by Barnes and Engeman (1995) in North America. However, in the Nippara quadrat where the stand was characterized by thick undergrowth, bears did not select thicker trees. Here, bear feeding selection may have been limited by the distribution of undergrowth, in contrast to stands that with more homogeneous floor cover.

It is unclear why bears selected cypress over cedar in my study area, although cedar has been commonly debarked in other areas of Japan (Watanabe and Komi-

Table 1. Characteristics of quadrats in the Mine (numbers 1–4) and Nippara (number 5) area, Okutama Town, Tokyo, Japan in 1993 (Mine) and 2001 (Nippara).

	Mine				Nippara
Quadrat	1	2	3	4	5
Elevation (m)	1050	1041	1000	950	1035
Stand age (yr)	25	18	38	27	29
Shrub existence at stand floor	no	no	no	no	yes
Tree density (trees/ha)	2543.8	2375.0	2250.0	2568.8	1035.7
Hinoki cypress (trees/ha)	1012.5	2375.0	162.5	2281.3	1035.7
Japanese cedar (trees/ha)	1531.3	NA	2087.5	287.5	NA
Average number of branches below the chikara (SD)	25.2 (20.8)	34.1 (20.3)	5.2 (6.3)	57.4 (15.6)	0.0 (0.0)
Damaged trees (%)	14.0	21.8	3.1	6.8	26.2
Hinoki cypress (%)	35.2	21.8	23.1	6.8	26.2
Japanese cedar (%)	0.0	NA	1.5	6.5	NA
Average debarked degree, % (SD)	39.7 (46.3)	51.3 (34.0)	32.1 (24.4)	30.0 (26.1)	48.3 (25.8)

yama 1976, Torii 1978, Watanabe 1980, Yoshimura and Fukui 1982, Shibata and Kofune 1984, Yamada 1990). Yoshimura and Fukui (1982) suggested that bear feeding selection on cambium could be affected by the amount of alpha-pinene, which is a type of monoterpene. Differences in such chemical composition, timing of sap flow of the conifers, or both could affect bear selection, but further research is needed.

Supplemental feeding (Ziegltrum and Nolte 1997) may be an option for reducing bear damage in some places, but it may not be suitable in the Okutama Mountains due to limited land area and the overlapping and use of land by bears and humans (K. Yamazaki, unpublished data). If bears are habituated to feeding spots, it may increase the risk of bear–human encounters. Damage control by hunting (Poelker and Parsons 1980) is also not a suitable option due to the low density of bears in the Okutama Mountains. Therefore, in plantation forests with low bear densities, I propose that pruning and thinning to maintain open stands offers promise to reduce bear debarking.

For the same reason, undergrowth should be reduced. In the Okutama Mountains, the sika deer (*Cervus nippon*) population has erupted in recent years (Okutama Town Office, Japan, unpublished data), and their feeding pressure has damaged undergrowth. However, asebi contains substances toxic to herbivores such as asebotoxin, and thus is relatively unaffected by deer. Unless foresters cut asebi, it will grow to provide thick cover. Yamanaka et al. (1991) and Takayanagi et al. (1992) reported that winding a polyethylene tape around a tree trunk about 1.3 m in height effectively stopped bear depredation.

Table 2. Summary statistics for mean dbh, comparing damaged and undamaged trees within 4 quadrats in the Mine area and 1 in the Nippara area, Okutama Town, Tokyo, 1993 (Mine) and 2001 (Nippara).

		Damaged			Undamaged			
Quadrat no.[a]		Mean dbh (cm)	±SD	*n*	Mean dbh (cm)	±SD	*n*	*P*[b]
1	all trees	15.6	2.4	57	13.3	4.2	350	<0.0000
	cypress	15.6	2.4	57	12.0	3.2	105	<0.0000
2	all trees	16.4	2.5	83	12.1	2.7	297	<0.0000
3	all trees	21.9	5.0	11	16.8	5.7	349	0.0033
	cedar	21.9	3.2	5	16.8	5.7	329	NA[c]
	cypress	22.0	6.5	6	15.8	5.5	20	0.0206
4	all trees	18.9	4.5	28	13.0	4.7	383	<0.0000
	cedar	27.1	2.9	3	17.0	5.8	340	NA
	cypress	17.9	3.6	25	12.5	4.4	29	<0.0000
5	all trees	19.3	3.4	38	20.1	3.0	107	0.5266

[a]No.1–4 were in the Mine area in 1993, and no. 5 was in the Nippara area in 2001.
[b]Test statistic based on Mann-Whitney's *U* test.
[c]The statistical test could not be applied due to small sample size.

Table 3. Number of grids with bear damage, categorized by an index of view obstruction in a Japanese cypress stand, Nippara area, Okutama Town, Tokyo, Japan, 2001.

	Index of view obstruction using asebi			
	0	<0.217[a]	>0.217	Total
Damaged grids	4	7	9	20
Undamaged grids	38	4	2	44
Total	42	11	11	64

[a]The index is classified by the median (0.217, $n = 22$).

A combination of the taping in the potential damaged areas and trimming of asebi should be also considered.

The above management suggestions could be adapted to areas with lower bear densities such as my study area, but they require further examination in areas with higher bear densities where food resource availabilities are more restricted.

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