BRUSHTAIL POSSUM DAMAGE AND ABUNDANCE IN A NEW ZEALAND *PINUS RADIATA* PLANTATION

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ABSTRACT

During summer 1996/97, a *Pinus radiata* D. Don plantation (9000 ha) near Whangamata, New Zealand, was sampled to assess how intensity and distribution of brushtail possum (*Trichosurus vulpecula* Kerr) damage were related to stand maturity. Based on a review of previous surveys, a new damage-scoring system was developed. Using this system, the overall proportion of pine trees greater than 3 years of age with possum damage was found to be very low (3.6% of 1244 trees surveyed) despite possums being present in substantial numbers (mean catch of 28.1 possums per 100 trapnights; range 12.0–54.9). Damage levels varied markedly (0%–30%) between 36 plantation blocks. The majority of possum damage involved needle clipping and damage to lateral branches. All damage types showed negative correlations with tree maturity. Given the low damage levels recorded, the cost-effectiveness of current possum-control efforts in pine plantations of this type is uncertain and would benefit from further economic analysis.

Keywords: plantation forest; impact assessment; damage assessment; *Trichosurus vulpecula*; *Pinus radiata*.

INTRODUCTION

The extent and significance of damage by brushtail possums on *Pinus radiata* plantations in New Zealand are unclear. Previous studies range from reports of a 50% loss of 3-year-old seedlings (Warburton 1978), to highly variable browse damage (Pracy 1981), and no economic damage (Warburton 1978). Clout (1977) and Keber (1987) both reported possum damage at their sites to be low overall, but with some areas suffering extreme possum damage.

Possums inflict various forms of damage on *P. radiata* plantations (Clout 1977; Keber 1987), the majority of which occurs when the plants are young. Most damage can be categorised as needle clipping, bark stripping (= ringbarking), and leader/lateral breakage. In addition, possum damage can allow entry to pathogenic fungi, especially *Diplodia pinea* (Desm.) Kickx, which can reduce tree vigour (Weston 1957; Gilmour 1966).

Needle clipping most commonly occurs on the leader and reduces the vigour of the tree rather than causing malformation or death (Keber 1987). It generally occurs at low levels but increases sharply during autumn (Harvie 1973; Pracy 1981; Warburton 1978), when needles can contribute over 40% of possums' diet (Clout 1977). Needle clipping is more damaging to seedlings than to mature trees because it affects their subsequent growth and form (Clout 1977). Although needle clipping of terminal and lateral shoots typically has little economic effect on mature stands (Keber 1987), trees damaged when they are young often die (Warburton 1978) or are removed in subsequent thinning operations.

Bark stripping is the form of possum damage that has been of most widespread concern to foresters (Clout 1977) as possums bite bark either to consume it or to access the soft cambial layer underneath (Fitzgerald 1981). Basal ringbarking that girdles trees (particularly when young) can either kill them or cause malformation (Fitzgerald 1981) that converts dominant trees into subordinate ones (through stunting, dieback, and possible windblow) which are then likely to be thinned out (Clout 1977; McNally 1955). However, it is uncommon for bark stripping damage to completely girdle limbs or stems (Clout 1977).

Foraging possums can cause secondary damage by breaking or damaging limbs or the leader, particularly when consuming pollen (Harvie 1973; Warburton 1978). Male cones are fed on from mid-July through to late October and female cones are consumed in their first year from late summer to autumn. Typically, the broken leader : broken lateral ratio is about 1:3 (Clout 1977; Warburton 1978). Over time, leader damage stimulates lateral growth and so trees become forked, short, and bushy. This has potential economic consequences if it occurs when the tree is young (5–10 years), because leader damage at this time can cause malformation of the trunk wood (termed a "hockey stick") or forking of the main stem, both of which reduce millable timber length (Clout 1977; Keber 1987). However, in trees <3 years of age this "hockey stick" is often so low in the tree that it has negligible economic significance.

Four Australasian studies have quantified *P. radiata* damage by possums. Clout (1977) classified damage, but did not differentiate between different types of possum damage. Ringbarking by deer and possums was also not distinguished. Barnett *et al.* (1977) classified damage more specifically but did not measure the extent or position of damage (such information is needed for any economic assessment to be made). If a tree endured more than one type of damage, only the highest damage classification was recorded. Possum damage was defined as damage above 2 m in height. Damage occurring to trees less than 3–4 years old was therefore disregarded. Natural forking occurs in nature and this type of forking was not distinguished from possum-induced forking. Griffith's (cited by Keber 1987) damage scoring system built upon the previous two systems by combining both damage type and extent of damage. The damage records did not distinguish between possum and other sources of injury, and so economic thresholds for possum populations could not be accurately established. This system is more useful in terms of an economic evaluation yet still lacks

detail. Keber's (1987) system was the most extensive of the four methods, classifying tree dominance, number and status of leaders, and the age, type, and extent of possum damage. However, this system lacked information on the height and severity of damage, which is important for an economic analysis. Keber's system was used as a starting point for the scoring system developed for this study.

It is unclear why possum damage levels vary markedly between plantations, partially because no standard quantitative method for assessing possum damage is currently in use. This lack of consistency between studies means that economic damage thresholds for implementing possum control have not yet been established and possum control in pine plantations is usually undertaken on an ad hoc basis. The loss in forestry revenue through a reduction in wood quality, and the benefits (if any) of expenditure on possum control, are uncertain. The influence of tree maturity and location on possum damage is also unclear; such information would allow vulnerable blocks to be targeted with more-intensive possum control.

This study required a quantitative method for measuring the type, extent, certainty, and age of possum damage, which the existing methods did not provide. Such a scoring system was therefore developed.

Using the scoring system we then measured the magnitude, nature, and distribution of possum damage in a *P. radiata* plantation at Tairua Forest on the Coromandel Peninsula during summer 1996/97, and investigated the relationship between damage levels and stand maturity.

METHODS
Study Site

This study was conducted in Tairua Forest, Whangamata, Coromandel Peninsula, New Zealand (lat. 37°10′S, long. 175° 51′ E; NZMS260 T12 620400). Tairua is a low-elevation (0–200 m) plantation forest of 9000 ha of *P. radiata* varying in age from 1 to 27 years. The forest is divided into 112 compartments with each compartment divided into blocks averaging 25 ha in size (range 0.3–122 ha). Block boundaries are relatively independent of the contours and aspects of the land.

Tairua Forest is planted on variable slopes (0–40°) with a wide diversity of understorey vegetation. Commonly, the land between ridges and valleys is steep with flat ridges and marshy valley bottoms. Most ridges have tracks and clearings on them, allowing for easy animal and human access. On steep land the understorey is dominated by pampas grass (*Cortaderia* spp.), fireweed (*Senecio diaschides* D.Drury), and kanuka (*Kunzea ericoides* (A.Rich.) J.Thompson), whereas the predominant understorey species on open ridges are grasses, lotus (*Lotus pedunculatus* Cav.), and pampas grass. Forestry plantings are absent from a riparian zone of 5–30 m, so the larger valley bottoms are dominated by native species such as mahoe (*Melicytus ramiflorus* Forst.), broadleaf (*Griselinia littoralis* Raoul), and kanuka. Flat valley bottoms are commonly marshy, with rushes (*Juncus* spp.) being the predominant species.

The climate is considered warm temperate (Meurk 1984), with a mean annual temperature of 14.5°C and an annual mean rainfall of 1530 mm (based on New Zealand Meteorological Service data from 1975 to 1985).

Jacometti (1997) measured possum abundance in the forest using leghold traps and obtained a mean catch of 28.1 possums per 100 trapnights (range 12.0–54.9) measured at 20-m intervals on randomly located transects in six randomly selected blocks.

Sampling Strategy

Possum damage assessment was restricted to stands of *P. radiata* aged between 3 and 20 years, although this will under-estimate total damage. Trees under 3 years of age are vulnerable to mammalian (rabbit (*Oryctolagus cuniculus* L.), hare (*Lepus europaeus* Pallas), pig (*Sus scrofa* L.), goat *(Capra hircus* L.), and deer (*Cervus* spp.)) damage and the dense palatable understorey in such stands is also attractive to possums, thus relieving the browse pressure on the trees. Furthermore, when young trees are damaged they recover quickly by growing new leaders. Trees over 20 years of age have been found to have a low susceptibility to possum damage as toxin levels (alkaloids, terpenes—Cates & Orians 1975; essential oils—Clout 1977) in these trees make the foliage unpalatable to possums (Cates & Orians 1975; Clout 1977; Keber 1987). Blocks less than 1 ha in size, which made up less than 1% of the forest area, were also excluded from the survey. Small blocks bordering roads and clearings have a high boundary to area ratio and, as boundaries are believed to suffer high possum damage/density, this has the potential to over-estimate damage. All blocks were stratified into four stand age-classes (3–5, 6–10, 11–15, and 16–20 years) prior to selection. A total of 36 blocks were randomly selected, seven from each of age-classes 3–5 and 16–20, and 11 from the two middle age-classes. The 36 blocks were selected from a total of 239 eligible known-aged blocks in the forest.

A randomly located transect was established through each block from an easily located position, the bearing determined by a randomly selected number between 1° and 360°. If the resulting transect reached the block edge in less than 250 m, then additional transects were run through the block until the accumulated length exceeded 250 m (Fig. 1). Individual trees were sampled every 10 m along the transect, using a hipchain, to obtain a minimum sample size of 25 trees per block. Altogether 1244 trees were sampled.
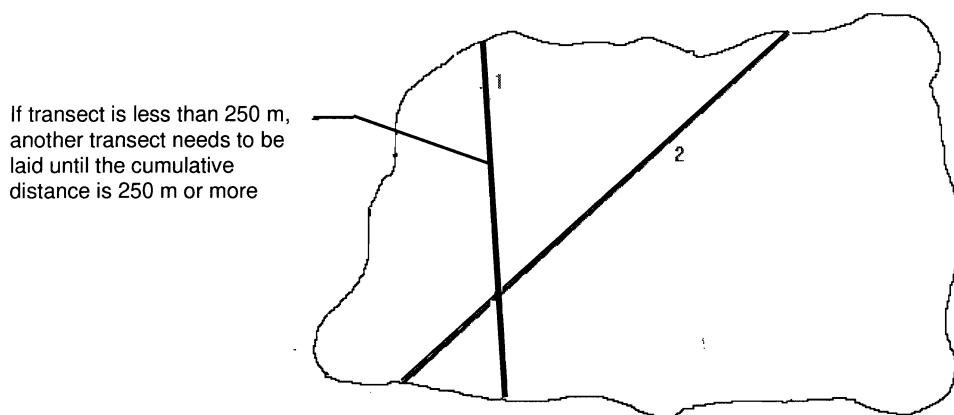

If transect is less than 250 m, another transect needs to be laid until the cumulative distance is 250 m or more

FIG. 1–Example of how transects were established within a block. Transect 2 is required in addition to Transect 1, as 1 is shorter than 250 m.

Damage Assessment

For each tree sampled, diameter at breast height (dbh), height (measured with a vertex), and damage type, severity, and age were measured, together with an estimate of the certainty that possums were responsible for the damage.

Bark stripping

Bark stripping was scored as basal stripping, stem stripping, and leader stripping and classified according to the height at which it occurred in the tree. Severity was scored on a 5-point scale with 0 = undamaged, 1 = less than a quarter of the tree diameter damaged, and every point thereafter indicating damage to another quarter of the diameter.

Needle clipping

This was scored on a 4-point scale, with 0 = no damage and 1, 2, and 3 = light, medium, and heavy damage. An example of code 3 is illustrated in Fig. 2a.
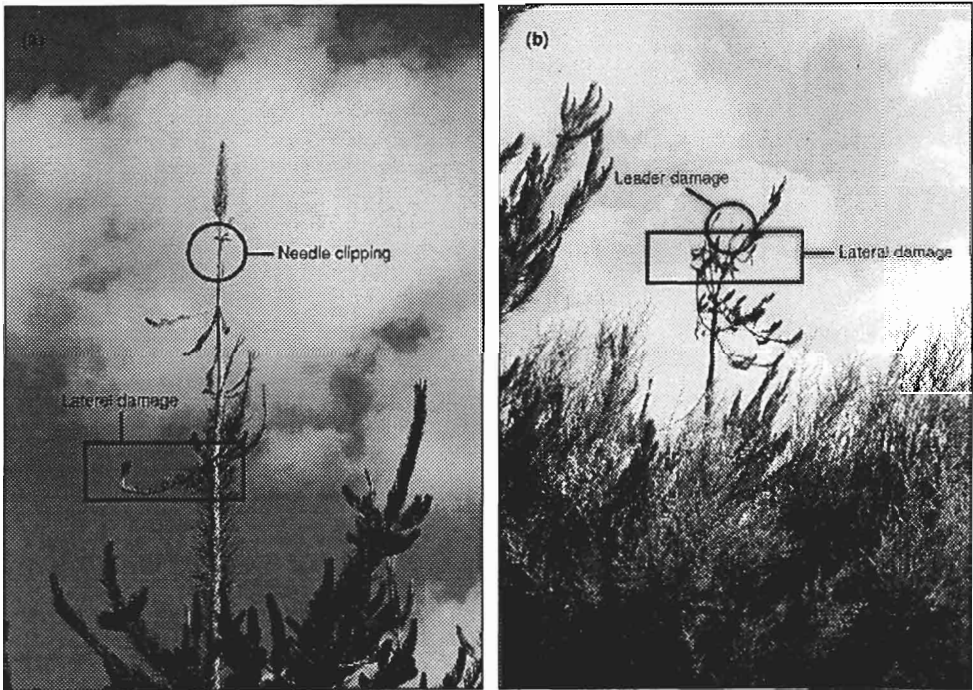

FIG. 2—Examples of (a) needle clipping, code 2; lateral damage, code 3; (b) lateral damage, code 4; leader damage, code 4. Circles highlight new damage; squares highlight old damage.

Lateral damage

This was scored on a 7-point scale, with 0 = no damage and 1 and 2 equating to laterals sitting above and below the horizontal plane respectively. Codes 3, 4, 5, and 6 equated to 0–20%, 21–40%, 41–99%, and 100% of laterals in a whorl being broken or dead. Examples of codes 3 and 4 are illustrated in Fig. 2a and b respectively.

Leader damage

Leader damage, unlike the other damage types, was scored by the type of damage rather than the extent of damage that had occurred. Thus, 0 = no damage, 1 = the presence of ramicorns *, and 2, 3, 4, 5, and 6 = damaged†, changed‡, broken, missing, and dead leaders, respectively. An example of code 4 is illustrated in Fig. 2b. If the tree was multi-leadered, the number of leaders was also recorded.

Age coding

All damage types were scored for the age of the damage. This was coded into two classifications—(1) under 6 months old, and (2) more than 6 months old. Age of damage was determined largely on the basis of dead needles and the reddening/darkening of the colour of the sap/damaged wood. When stem stripping was over 6 months old, the colour of the sap darkened and reddened, while the wood lightened as it dried out. When needle clipping was over 6 months old, the needles that had been damaged appeared to be brown, dead, or burnt off at the tips. Laterals with damage codings of 1 or 2 became curved as they aged (the tree alters its growing habit to push the damaged laterals back towards the sunlight) (Fig. 2a). Old laterals with damage codings of 3–6 could be distinguished by the brown colour of the needles on the dead laterals or, if the branch was absent, by the reddening of the sap and lightening of the exposed wood at the wound (as in stem stripping). Old damage to broken or dead leaders (codes 2, 4, and 6) was determined by the presence of brown, dead needles. Missing leaders were sometimes hard to age when damage was close to 6 months. When a leader is lost the growth of the top whorl of laterals increases, giving trees with old damage a bushy appearance. It was assumed that if the leader was missing and the growing habit of the laterals had not altered, then the leader damage was less than 6 months old. The age of multiple leaders was determined by noting the position of the start of the multiple leader in the tree and the size of the competing leader. Old damage began low on the tree and produced two leaders of similar size.

Certainty of possum damage

The certainty that damage was related to possums (rather than rabbits, deer, goats, wind, hail, etc.) was coded as follows: 4 = high, 3 = likely, 2 = unsure, 1 = unlikely, 0 = not possum-related.

Certainty of damage was influenced by other possum sign in the tree or on other species (such as claw scratches, lateral bending, needle clipping, faecal pellets, damage to adjacent trees and understorey, possum/animal tracks, etc.).

Statistical Analysis

Analysis was undertaken only on damage that was considered likely (certainty score >2) to have been caused by possums. Some of the damage omitted may have been due to

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* A ramicorn is a lateral branch that becomes dominant and competes with the leader.
† Damaged leaders were malformed, twisted, or with low vigour.
‡ A changed leader is where the initial leader has lost dominance (predominantly through death or loss of the leader).

possums, so the results of our analysis are conservative. Trees with more than one occurrence of a certain damage type were scored with the most severe damage score.

Overall damage levels were obtained by deriving counts and percentages for all the trees, for each of the different severity scores for the four different damage types (n = 1244). As the sampling was stratified by stand age, the overall estimate of damage was calculated as a weighted average of the damage estimates for each age stratum, using the known proportions of each stand age-class within the whole forest.

The different damage types were plotted against each other for all 36 blocks, with the significance of each relationship tested using Spearman's rank correlation coefficient.

The block characteristics (block size; stand age; height and dbh of sampled trees) were compared with the damage types for the 36 blocks, with the significance of the relationship tested using Spearman's rank correlation coefficient.

RESULTS

A total of 59 of 1244 trees (4.7%) had some possum damage. Allowing for stand age stratification in sampling, the weighted estimate for the whole forest was 3.6%. Although possum damage was low overall, it was variable between blocks; damage levels as high as 30% were found in certain parts of the forest. Lateral damage was the most frequent damage type, occurring in 3.5% of trees (Table 1).

Only one tree had multiple leader damage and only one had stripped bark; these two rare damage types were excluded from the subsequent analyses.

Lateral damage was positively correlated with needle clipping (Fig. 3) and leader damage ($r = 0.80$, $p < 0.001$; $r = 0.33$, $p < 0.05$ respectively). Needle clipping and leader damage were uncorrelated ($r = 0.25$, $p > 0.05$).

Most of the lateral and leader damage was old, whereas needle damage was predominantly new (Table 2).

TABLE 1–The proportion of possum damage in each of six severity classes at Tairua Forest (counts in parentheses).

Damage type	Damage severity							Total
	0	1	2	3	4	5	6	(%)
Needle (%)	97.6 (1214)	1 (12)	0.9 (11)	0.6 (7)				2.4 (30)
Lateral (%)	96.5 (1200)	0.3 (4)	0.5 (6)	1.1 (13)	0.7 (9)	0.3 (4)	0.6 (8)	3.5 (44)
Leader (%)	98.9 (1230)	0.2 (2)	0.1 (1)	0.1 (1)	0.2 (2)	0.5 (6)	0.2 (2)	1.1 (14)

TABLE 2–Old and new possum damage in Tairua Forest.

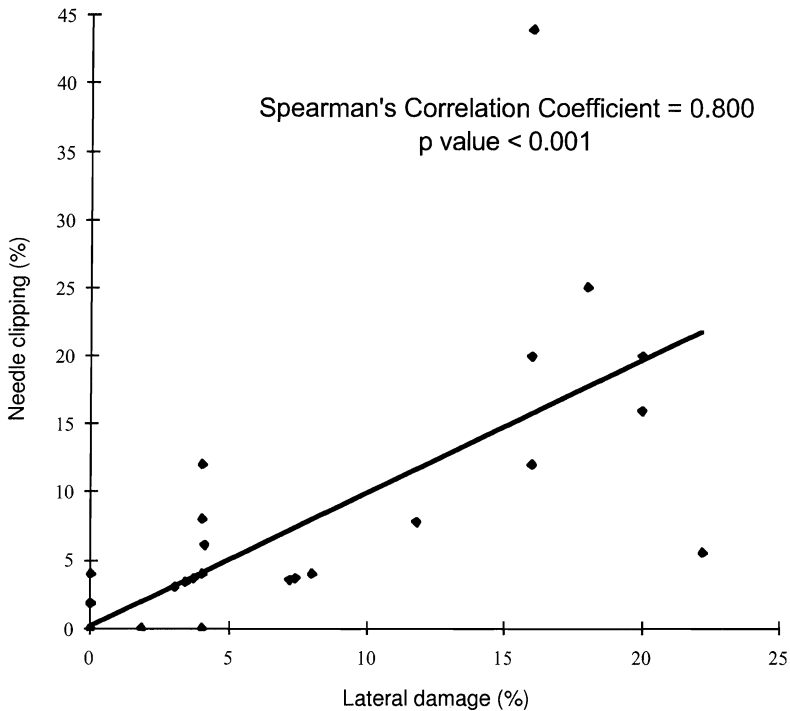| Damage type	Damaged trees	Percentage with new damage
Needle	30	56.6
Lateral	44	34.2
Leader	14	14.3

FIG. 3–Correlation between lateral damage and needle clipping in 36 forest blocks.

All types of damage tended to be lower in blocks where the *P. radiata* were mature (Spearman's correlation coefficients between stand age, height and dbh, and damage, ranged from −0.631 to −0.412, all $p < 0.05$). The correlation between tree height and damage (Fig. 4) was the highest of the three maturity measures (tree age, height, and dbh), with r values ranging from −0.631 to −0.554. There was no significant association between stand size and any of the damage types ($p > 0.05$), with values ranging from 0.110 to 0.285.

DISCUSSION

Possum damage in Tairua Forest was very low overall (3.6%). This could represent a slightly conservative estimate as trees under 3 years old were not included in the survey. This low level of damage was despite relatively high possum densities in the plantation (28.1 possums/100 trap nights). Damage levels varied up to 30% in certain parts of the forest. This seems typical for possum damage in *P. radiata* plantations; Clout (1977) and Keber (1987) both found damage levels low overall but patchy, with some areas receiving high damage. Beaumont (1974, cited by Keber 1987) conducted a survey over heavily damaged compartments (not a random survey of damage levels) in Kaingaroa Forest and found 7% of planted stems overall, and up to 50% of planted stems locally, had possum damage.

In Tairua Forest, the majority of damage consisted of needle clipping and lateral damage (50.8% and 74.6% of damaged trees respectively). This type of damage is more likely to
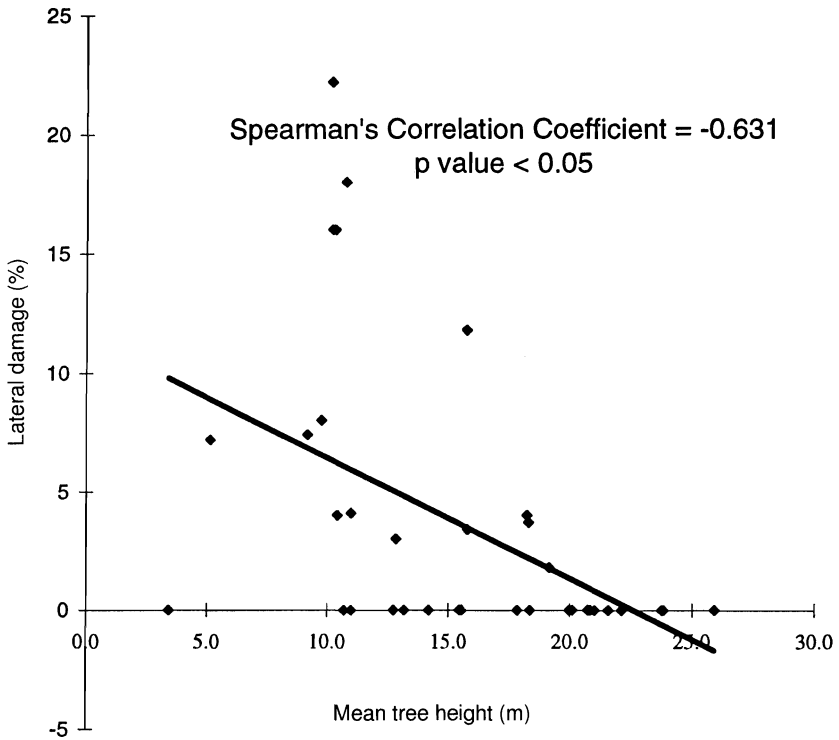
FIG. 4—Correlation between lateral damage and mean tree height in 36 forest blocks.

decrease vigour than to cause any long-term structural damage to the milling timber. Leader damage, which can cause malformations that shorten the final millable timber length, is relatively uncommon (only 23.7% of damaged trees) in Tairua Forest. Barkstripping was observed on only 1 of 1244 trees sampled so is virtually non-existent in Tairua Forest. This differs from previous surveys, which found barkstripping to be prevalent in some patches, although not in young stands (Clout 1977).

The three damage types measured showed some degree of correlation. This would be expected for lateral damage and needle clipping, because when possums are browsing needles they stand on the laterals, damaging them as well. Leader and lateral damage showed a weaker correlation, in part because there was little leader damage. Needle clipping and leader damage showed no statistically significant correlation as needle clipping occurred predominantly on the leader and so was often not observable when the leader was not present or was broken.

The majority of lateral and leader damage was considered to be over 6 months old as this damage tends to remain visible and thus accumulates over time. Conversely, the visual effects of needle clipping are only temporary as the needles can grow back, and so the majority of visible needle damage was considered recent.

As the trees matured (with correlated increases in height and girth) the levels of all types of possum damage decreased despite the temporary accumulation of effects mentioned above. This is consistent with previous studies (Clout 1977; Keber 1987), and is believed to be related to the heightened plant toxins in mature trees and the sparse understorey in these blocks (Cates & Orians 1975; Clout 1977; Keber 1987). Huges & O'Connor (1976, cited by Keber 1987) suggested that consumption of *P. radiata* by possums is a reaction to seasonal dietary deficiencies or to the timing of vegetative flush (when it is most nutritious). In contrast, Freeland & Winter (1975) speculated that toxic or indigestible compounds produced by *P. radiata* placed severe limitations on the quantity of such leaves a possum is capable of consuming (Green 1984) and that they need to dilute the toxins by eating a variety of other plant species. The concentration of these secondary compounds changes seasonally, regulating the possums' consumption of pine needles and bark (Clout 1977). Needle and bark palatability also changes with age; chemical defence mechanisms are not fully developed in the younger needles so that most new growth is palatable (Cates & Orians 1975; Clout 1977; Keber 1987).

Implications for Future Management

This study suggests that possums at abundance levels sufficient to cause extensive damage in a northern North Island indigenous forest (28.1 in this study, cf. 22.0 possums/100 trapnights at Waipoua—Payton *et al.* 1997) are unlikely to severely damage *P. radiata* stands in forests similar to Tairua. They damage few trees over 3 years old and most of the damage that does occur is unlikely to cause structural defects in the final milling log. Thus it seems likely that, from a forestry perspective, expenditure on possum control cannot be justified in blocks of trees over 3 years old. However, this remains speculative without an appropriate economic analysis that uses forestry models to "grow through" the damage recorded here to determine its implications in terms of lost millable timber. Once that is known, the optimum level of expenditure on possum control could be determined. In a subsequent paper we will address the extent to which possum abundance and habitat factors could be used to identify high-risk blocks. If high-risk blocks could be identified in this way, possum control could be better targeted. Furthermore, it is recognised that possum control may be required in some plantation forests to prevent possum movement from the plantation to neighbouring land where they may have an adverse impact on crops, conservation values, and livestock health.

This study did not assess the impact of possums on trees under 3 years of age, nor the seasonality of possum damage to *P. radiata*. Previous studies suggest that pine is a more important component of the possums' diet in winter than summer. Future work could address this point. If damage does intensify in winter, substitute plant species could perhaps be planted to take over this seasonal role of the pine in the possums' diet.

ACKNOWLEDGMENTS

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