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SEASONAL VARIATION IN THE IMPACTS OF BRUSHTAILED POSSUMS (*TRICHOSURUS VULPECULA*) ON FIVE PALATABLE PLANT SPECIES IN NEW ZEALAND BEECH (*NOTHOFAGUS*) FOREST

Summary: The seasonal variation in possum browse and foliage cover of five possum-preferred species was quantified and studied in northern Westland, New Zealand over a 24 month period. Four of the five species (*Pseudopanax simplex, P. colensoi, Aristotelia serrata,* and *Elaeocarpus hookerianus*) showed marked seasonal patterns in both browse and foliage cover, with maximum browse evident in winter/spring when foliage cover was at a minimum. There was very little browse and no seasonal pattern in foliage cover for the fifth species, *Pseudopanax crassifolius*. In the season of maximum browse there were significant negative correlations between browse and foliage cover for the four impacted species suggesting that the changes in foliage cover were caused by possum browsing. Mortality was highest in the two most heavily browsed species (*P. simplex* and *P. colensoi*). This seasonality in possum browse needs to be accommodated when designing long-term surveys of possum impacts.

Keywords: Possum; *Trichosurus vulpecula*; browse, seasonal impacts; damage; indicator species.

Introduction

Brushtailed possums (*Trichosurus vulpecula* Kerr) are a widespread introduced marsupial in New Zealand. Their selective browsing of plant foliage, flowers, and fruit (Cowan, 1990a) and predation on native fauna (e.g., James and Clout, 1996) has had considerable impact on native ecosystems. About $10 million is spent annually on controlling possum populations in an attempt to alleviate these impacts on conservation values (Parkes, Baker and Ericksen, in press).

To justify continued expenditure the agency responsible, the New Zealand Department of Conservation (DoC), will require evidence that control is benefiting vegetation. However, until recently the only techniques available for assessing vegetation recovery have been designed for measuring forest composition and structure, particularly as they are affected by ungulates (Allen 1992, 1993). These methods are time consuming, expensive, require complex analyses, and it is often difficult to separate the effects of possums and possum control from the effects of other pests and natural changes.

Since 1992 we have been developing a standard methodology for assessing possum impacts on the forest canopy (Payton, Pekelharing and Frampton,

1997). The method is based on the subjective assessment of the percentage of foliage cover in individual tree canopies (giving a Foliage Cover Index, FCI) by ground based observers. Species known to be browsed by possums are chosen as indicator species, and the foliage cover in the canopy of a sample of permanently marked and numbered trees of each species is monitored through time to determine what changes (if any) have occurred as a result of possum control (or the lack of it). Because possum diet varies seasonally (Fitzgerald, 1976) it is likely that the degree of browse also varies seasonally. If it does, comparison of FCI's between and within areas would require either that all assessments be carried out at the same time of the year, or that we have a clear understanding of variation in the indices between seasons. The primary aim of this study was therefore to determine whether browsing intensity and FCI's varied between seasons for five possum-palatable plant species in a southern alpine beech (*Nothofagus* spp.[1]) forest. A subsidiary aim was simply to document the impact of possums on the survival of the trees studied.

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[1] Botanical nomenclature follows Allan (1961) and Connor and Edgar (1987).
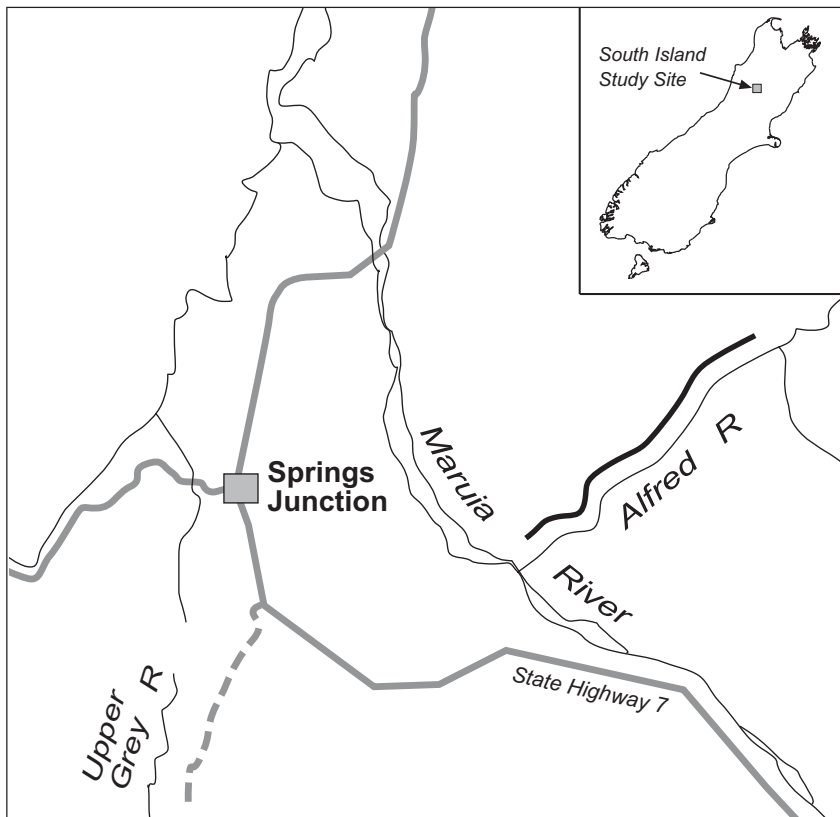
Figure 1: *Location of the study area. The transect line alongside the Alfred river is in bold.*

Methods

Study area

The study area is situated in northern Westland along the north bank of the Alfred River (42°20'S: 172°15'E), a tributary of the Maruia River running adjacent to State Highway 7 (Fig. 1). It contains relatively simple forests dominated by silver beech (*Nothofagus menziesii*) and red beech (*N. fusca*), with an understorey of broadleaf (*Griselinia littoralis*), *Coprosma foetidissima*, and *Pseudopanax simplex* (Wardle,1984). *Elaeocarpus hookerianus* and the semi-deciduous small tree *Aristotelia serrata* were occasionally encountered along the vegetation transect in the study area, and are locally common. During the establishment phase of the study occasional, recently dead specimens of *P. simplex, P. colensoi*, and *E. hookerianus* were noted along the vegetation transect. *Fuchsia excorticata* was also present in the study area but

was not encountered along the vegetation transect. It was seen occasionally along the river flats on the opposite side of the river and most specimens seen were heavily browsed.

Possums in the study area probably originate from a liberation made sometime after 1952 in the nearby upper Grey River (Pracy, 1974). The Alfred River population therefore is of relatively recent origin and likely to be near peak density as it takes colonising populations about 25-35 years to reach peak densities (Boersma, 1974; Pekelharing and Reynolds, 1983; Thomas *et al.*, 1993). No official possum control has been conducted in the area and during the study there was no evidence that any possums were killed by fur hunters.

Field methods and analyses

A total of 216 trees were permanently marked on 32 plots along a vegetation transect alongside the Alfred River between 500 and 600 m a.s.l. Plots

were located at 50m intervals along the transect unless there were no individuals of the indicator species present within 20m of the plot centre in which case sampling continued at the next plot 50m further on. Only living trees with a canopy height above 2 m (i.e., above ungulate browse level) and with a diameter at breast height over bark (dbh) > 5 cm were selected. The five indicator species chosen were *Pseudopanax simplex* (n = 40), *Aristotelia serrata* (n = 51), *Pseudopanax crassifolius* (n = 49), *Pseudopanax colensoi* (n = 26) and, *Elaeocarpus hookerianus* (n = 50). All five plant species have been recorded in the leaf-diet of possums (Kean and Pracy, 1953; Mason, 1958; Fitzgerald, 1976; Fitzgerald and Wardle, 1979; Coleman *et al.*, 1985; Cowan, 1990a, 1990b).

To determine the seasonality of impacts, each marked tree was assessed bi-monthly, from August 1993 to August 1995, with an additional assessment a year later in August 1996. For each tree we used the methods described in Payton *et al.* (1997) to estimate:

(a) The percentage foliage cover in the crown, the Foliage Cover Index (FCI). This is the amount of light occluded by the canopy foliage as observed from directly below the tree. The observed degree of occlusion is visually assessed by comparison with a card containing a set of standard silhouettes in 10% classes (from 5% to 95%).

(b) The amount of possum browse in five classes (0 = none discernible, 1 = light with 1-25% of the leaves browsed, 2 = moderate with 26-50% of the leaves browsed, 3 = heavy with 51-75% of the leaves browsed, and 4 = severe with 76-100% of the leaves browsed).

(c) The abundance of fruit in the crown in five classes (0 = none discernible, 1=rare, 2=occasional, 3=common, and 4 = abundant/ heavy crop, fruit on most branchlets).

Where trees were defoliated during the study, death was ascertained by cutting the bark with a knife to check whether sap flow still occurred. Heavy snow halfway through the August 1994 sampling period prevented completion of the assessment of *Aristotelia serrata*, *Pseudopanax crassifolius*, and *Elaeocarpus hookerianus*. In August 1996 only the FCI and the status (alive or dead) of each tree was recorded. The inter-observer variation in the FCI indicates that two observers scoring the same 50 trees will, with 95% confidence obtain mean scores of +/- 2.5% of each other (data reported in Payton, Pekelharing and Frampton, 1997). To remove observer variability as a source of variation from this study CJP made all observations.

The statistical significance of observed differences (in mean FCI's and degree of browse in browsed trees) between species, seasons and years, and the overall comparison of the severity of impact for each species were tested by ANOVA for repeated measurements. The proportion of trees browsed was compared between seasons and years using McNemar's Chi-square test (Selvin, 1995). The browse score and FCIs of individual trees were correlated at the time of maximum browse (winter/ spring, 1994) using Pearson's correlation coefficient. The seasons were defined as winter/ spring (= July/August /October) and, summer/ autumn (= December/February/April) for *Aristotelia serrata, Pseudopanax colensoi*, *P. crassifolius*, and *P. simplex*. Because possums consistently browsed *Elaeocarpus hookerianus* later in the season than the other species throughout the study, the season definitions were adjusted for this species to late winter/spring/early summer (=August/October/ December) and, summer/autumn/early winter (= February/ April/July). The study period was divided into two full calendar years: the first - from August 1993 to June 1994 and, the second - from July 1994 to June 1995. Data for July and August 1995 were not included in the analysis.

Results

Browse

Proportions of trees browsed
For two of the three *Pseudopanax* species (*P. colensoi* and *P. simplex*) possum browse was observed on 80-100% of the trees throughout the study (Fig. 2). In contrast, only 3 out of 49 trees of *P. crassifolius* were browsed, and only in winter/ spring of 1994.

The proportion of *Elaeocarpus hookerianus* and *Aristotelia serrata* trees browsed varied markedly between seasons (Fig. 2), and was significantly higher in winter/spring than summer/autumn (*P*<0.001 for both species). For *A. serrata,* browsing varied between years as well as seasons with a significantly higher proportion of trees being browsed in 1993/94 than 1994/95 (*P*<0.001). However, for *E. hookerianus* the proportion browsed did not vary significantly between years.

Intensity of browse in the browsed trees
The intensity of browse (the mean browse recorded in browsed trees) changed significantly between seasons for *Aristotelia serrata, Elaeocarpus hookerianus, Pseudopanax colensoi* and *P. simplex* (Fig. 3). Impact on the foliage was greater in winter/
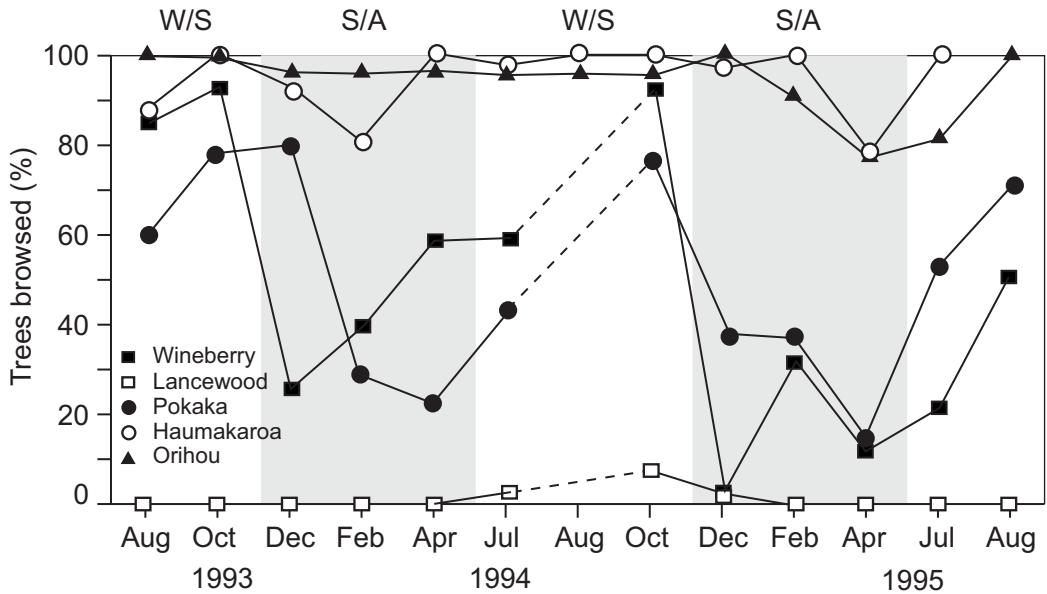
Figure 2: *Percentage of trees browsed for each of the five indicator species for each assessment period from August 1993 to August 1995. W/S = winter/spring, S/A = summer/autumn (the shaded area).*
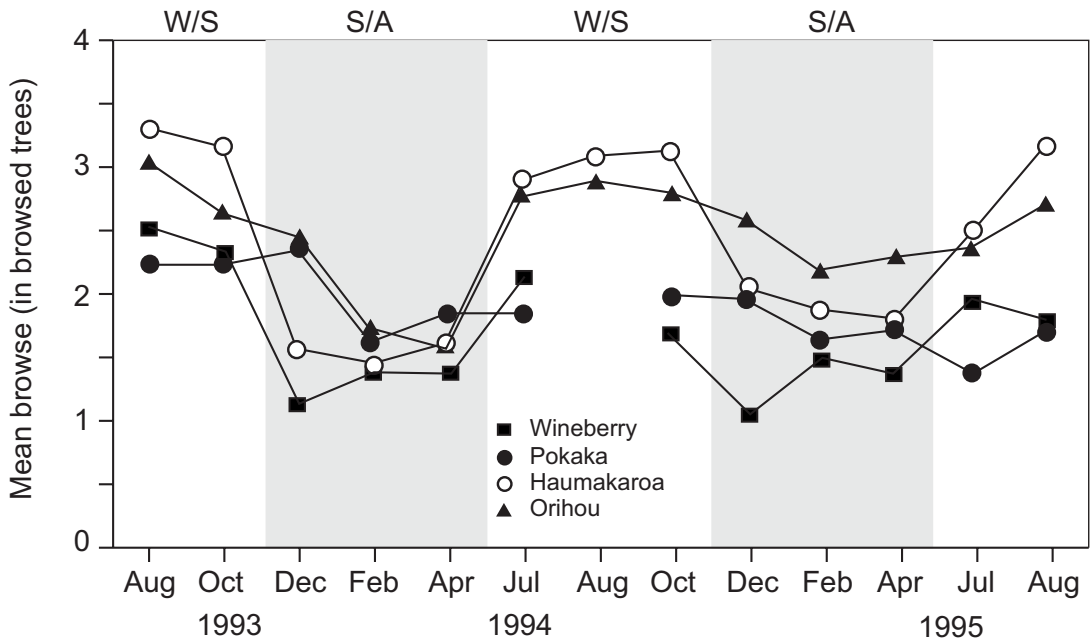

Figure 3: *Intensity of browse in the browsed trees for each assessment period from August 1993 to August 1995. For differences in mean intensity of browse between seasons and years for each species refer to Table 1. W/S = winter/spring, S/A = summer/autumn (the shaded area).*

spring when all trees were moderately to heavily browsed than in summer/autumn, when browsing pressure had declined to light/moderate ($P<0.001$, for all species, Table 1). *P. crassifolius* was lightly browsed only in the winter/spring of 1994.

The intensity of browse also varied significantly between years for *E. hookerianus* where overall mean browse declined between the first and second year of the study ($P<0.05$, Table 1).

In *Pseudopanax simplex* and *P. colensoi* (the species with the highest proportion of browsed trees, and the highest incidence of browse in both seasons and years (Fig. 3)) the difference between summer/autumn and winter/spring browse intensity increased significantly during the study, from the first to the second year ($P<0.05$).

Overall ranking

The highest mean overall browse (for both seasons and years combined) was recorded for *Pseudopanax simplex* (2.53) and *P. colensoi* (2.50). They were not significantly different from each other ($P>0.05$), but were significantly more browsed than the other species ($P<0.01$). Of the other species, *Aristotelia serrata* (1.72) and *Elaeocarpus hookerianus* (1.69) were not significantly different from each other. Only three *P. crassifolius* trees were browsed, so the mean was not calculated.

Foliage cover index (FCI)

The highest FCI was recorded for the least browsed species (*Pseudopanax crassifolius*, Fig. 4) and the lowest for the two most heavily browsed species (*P. colensoi* and *P. simplex*). For all species (excluding *P. crassifolius*), the trees with the highest FCI had the least browse (*Aristotelia serrata* r = -0.418; $P<0.01$; *Elaeocarpus hookerianus* r = -0.705; $P<0.001$; *P. colensoi* r = -0.745; $P<0.001$ and *P. simplex* r = -0.353; $P<0.05$). *P. simplex* trees were almost totally defoliated making the degree of browse difficult to detect, and so the correlation for this species was weaker than for others.

The mean FCI varied significantly between seasons for four of the browsed indicator species ($P<0.001$ for each species, Table 1), but not for the largely unbrowsed *Pseudopanax crassifolius* ($P>0.05$). Not surprisingly the FCI for *Aristotelia serrata* (semi-deciduous), *Elaeocarpus hookerianus*, *P. colensoi* and *P. simplex* was significantly higher in summer/early autumn (coinciding with bud burst noted in December, and shoot elongation in February), than in winter/spring. The mean FCI of *A. serrata* and *P. colensoi* did not vary significantly between years ($P>0.05$), but declined for *E. hookerianus* and *P. simplex* ($P<0.001$) and increased for *P. crassifolius* ($P<0.001$).

Fruiting

Aristotelia serrata trees bore fruit in December of both the first and second year, but the intensity of fruiting appeared to vary between years. In the summer of 1993/94 (December) sixty percent of the trees bore fruit and fruit intensity was recorded as occasional (1.9). In 1994/95 eighty percent fruited and fruit intensity was recorded as common (2.9). The proportion of fruiting trees and intensity of fruiting declined in both years to 1.2 in April of 1993/94 and 1.5 in April of 1994/95. Few

Table 1. *Mean browse in all trees with some browse and mean Foliage Cover Index for each species in each season over 2 years for 5 indicator species*. Pseudopanax crassifolius *is excluded for the browse data because only 3 trees were browsed. P-values are generated by repeated measures ANOVA testing the significance of mean differences between seasons and years*.

| Species | Year 1 | | Year 2 | | P values: | | |
	Win/Spr	Sum/Aut	Win/Spr	Sum/Aut	Year	Season	Year*Season
Mean Browse							
Aristotelia serrata	2.41	1.56	2.50	1.38	0.702	<0.001	0.148
Elaeocarpus hookerianus	2.64	1.77	2.24	1.56	0.043	<0.001	0.428
Pseudopanax colensoi	2.77	1.80	2.80	2.27	0.177	<0.001	0.018
Pseudopanax simplex	3.10	1.49	2.98	1.91	0.073	<0.001	0.003
Mean FCI							
Aristotelia serrata	22.8	46.4	27.1	43.0	0.630	<0.001	<0.001
Elaeocarpus hookerianus	44.6	51.6	43.1	46.2	<0.001	<0.001	0.007
Pseudopanax colensoi	30.0	39.5	29.8	36.5	0.391	<0.001	0.185
Pseudopanax simplex	21.5	32.0	19.7	26.5	0.001	<0.001	0.015
Pseudopanax crassifolius	46.2	48.3	50.0	50.3	<0.001	0.069	0.054
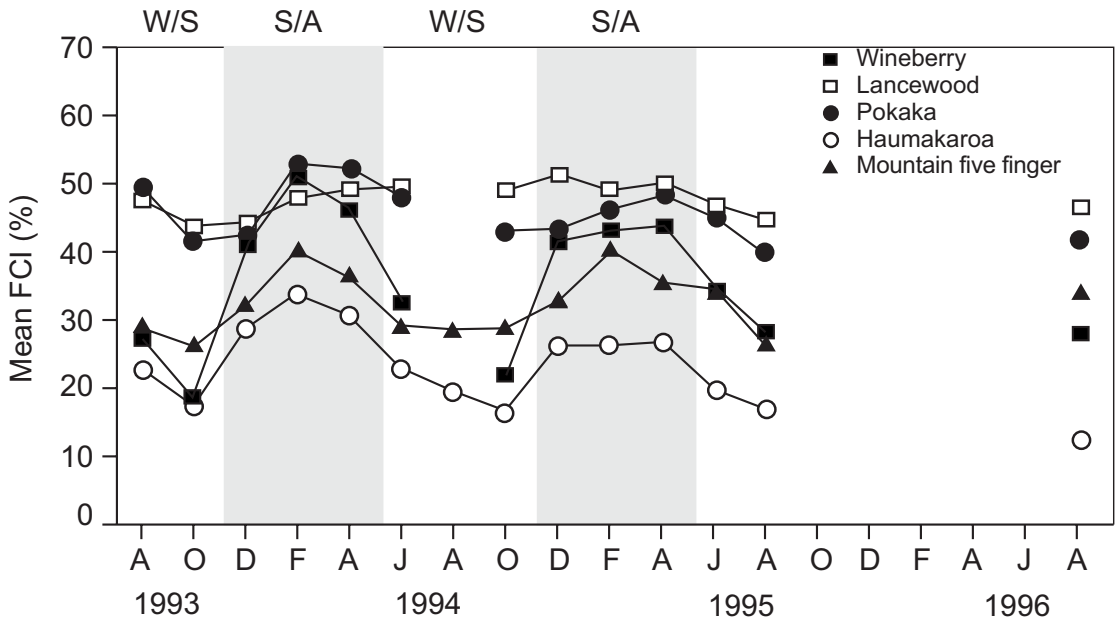
Figure 4: *The mean index of foliage cover (FCI) for each assessment period from August 1993 to August 1996. For differences in species mean FCI between seasons and years refer to Table 1. W/S = winter/spring, S/A = summer/autumn (the shaded area).*

Elaeocarpus hookerianus and *Pseudopanax crassifolius* trees bore fruit in the first year (1993/94; <15%), but about sixty percent of the trees bore fruit in the second year (in February for *E. hookerianus*, with an intensity of 1.6, and in April for *P. crassifolius* with an intensity of 2.6). In the two most heavily browsed species (*P. simplex* and *P. colensoi*), less than 10% of the trees bore fruit in both years.

Mortality

The two most heavily browsed species, *Pseudopanax simplex* and *P. colensoi*, showed the highest mortality rates. At the end of the study (after 37 months) 42.5% of the *P. simplex* and 34.6% of the *P. colensoi* trees had died, compared to 2% for *Aristotelia serrata*, 4% for *Elaeocarpus hookerianus,* and 6% for *P. crassifolius*. This relatively high mortality rate, together with the declining trend in percent foliage cover of the surviving population, and the continued high level of possum browse, indicates that these two species were being targeted by possums. Two severely browsed *E. hookerianus* (FCI = 0 and 5% before death) and one *A. serrata* tree died during the study period as did three apparently healthy *P. crassifolius* trees. Unlike the possum induced

mortality of *P. simplex, P. colensoi*, and *E. hookerianus* which were all consistently severely browsed and defoliated before death, *P. crassifolius* trees appeared to die from some other cause, as indicated by their sudden collapse.

The mean dbh of *Pseudopanax simplex* (7.7 cm) and *P. colensoi* (12.1 cm) at the beginning of the study was not significantly different from that of the dead component at the end (8.9 and 10.4 cm, respectively, $P>0.05$)), suggesting that possums were not targeting a particular size class. The initial mean dbh of *Aristotelia serrata* (7.7 cm), *Elaeocarpus hookerianus* (15.1 cm) and *P. crassifolius* (14.7 cm) was also similar to that of the dead component at the end (5.0, 18.5 and 13.5 cm, respectively), but sample sizes of the dead component for these species (< 3) were too small for statistical comparisons.

Discussion

In beech forests the canopy is less susceptible to possum browsing than conifer-broadleaved forests (e.g., Coleman, Green and Polson, 1985; Rose, Pekelharing and Platt, 1992) because the beech species that form most of the canopy are not

preferred foods for possums (Wardle, 1984). Despite that, some canopy and understorey species characteristic of beech forest are preferred foods for possums, and there is considerable potential for possum-induced effects on forest composition and biodiversity (Wardle, 1984; Rose *et al*., 1993). *Pseudopanax simplex* and *P. colensoi* (of relatively low preference in south Westland, Fitzgerald and Wardle, 1979) were the most heavily browsed species during this study, followed by *Elaeocarpus hookerianus* and *Aristotelia serrata*. *A. serrata* was also recorded as having a relatively low browse index in other studies (e.g., Mason, 1958; Gilmore, 1967; Fitzgerald and Wardle, 1979, Coleman *et al.,* 1985).

Other studies have also found that the impact of possums on the foliage was highest and heaviest in winter/spring and lowest and lightest in summer/autumn. Mason (1958) recorded highest levels of impact (as determined from stomach contents and field observations) in winter and early spring in a more mixed beech-hardwood forest. Fitzgerald and Wardle (1979) and Coleman *et al*. (1985) found the highest percentage of *Pseudopanax* spp. leaves in possum faeces in autumn and winter in rata/kamahi forests. In summer, food sources other than leaves are available (for example, introduced broadleaved herbs and grasses in clearings, Gilmore, 1967; Coleman *et al.,* 1985).

The significant negative correlations between browse and foliage cover at the time of maximum browse suggest that possums are primarily responsible for the damage and death of many trees. To some degree this correlation could reflect the fact that new replacement leaves are less likely to be browsed than older leaves that have been around longer. However, the relative seasonal changes in FCI and mean browse indicate that this can only explain some of the observed effect. A feature of this study was the resilience displayed by most of the heavily browsed species. Many of the trees were severely defoliated during the first winter/spring (to 0 and 5% FCI in most cases) but slightly increased in foliage cover over the summer/autumn months (to 15% FCI). They were again severely defoliated in the following winter/spring months and then died. Some survived for up to 11 months with a FCI of 5% before dying. Little sign of epicormic recovery was noted in *Pseudopanax simplex* and *P. colensoi*, although coppicing from the base was recorded for some (this foliage was also heavily browsed).

Extensive ringbarking was observed on *Elaeocarpus hookerianus* in spring (when sap flow is presumably greatest) causing conspicuous dieback of large branches, especially in the upper canopy. In subsequent assessments epicormic recovery was evident, originating from just below the ringbarked area.

In the absence of comparative data from possum-free areas the fruiting incidence and intensity recorded during this study cannot be evaluated, but it is highly probable that current levels of possum browse are negatively influencing flowering and fruiting. Flowers and/or fruits of *Pseudopanax* spp., *Aristotelia serrata,* and *Elaeocarpus hookerianus* have been recorded in the diet of possums elsewhere in New Zealand (Kean and Pracy, 1953; Mason, 1958; Cowan, 1990b).

This study indicates that *Pseudopanax simplex* and *P. colensoi* were most at risk in this forest type and were obviously declining in their distribution and abundance, indicating an ongoing decline in the species richness of these forests.

Surveys to determine the level of possum impact in forests should be carried out in late winter/spring when impact on foliage is highest.

Acknowledgements

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