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POSSUM *(TRICHOSURUS VULPECULA)* DENSITIES AND IMPACTS ON FUCHSIA *(FUCHSIA EXCORTICATA)* IN SOUTH WESTLAND, NEW ZEALAND

Summary: To assess the effect of possum browse on plant growth, an index of the amount of foliage on about 50 trees of *Fuchsia excorticata* and the number of trees that died or were completely defoliated was measured at five sites in South Westland over 5 years. This index was compared to possum density indices taken at each site each year. At one site, possums were reduced from a high density about 6 months before the final measurement. The degree of defoliation of fuchsia was significantly related to the density of possums at each site. Possums defoliate and kill fuchsia within two years once the catch-rate index of their density exceeds about 25%. However, this impact can be halted and quickly reversed by reducing possum density.

Keywords: Brushtail possums; *Trichosurus vulpecula*; impacts; browse; animal density; pest control; *Fuchsia excorticata*; mortality rates.

Introduction

Browsing by brushtail possums (*Trichosurus vulpecula* Kerr) is claimed to be a major cause of defoliation and mortality to many plant species in New Zealand indigenous ecosystems, particularly in forests (e.g., Payton, 1987; Rose *et al.,* 1993a). Browsing may reduce the diversity of the ecosystems (e.g., Ecroyd, 1996), and can be particularly critical where the affected species are the dominant canopy trees in the forest, resulting in the total collapse of the forest canopy (e.g., Rose, Pekelharing and Platt, 1993b). It is estimated that at least 17 600 km^2 (21%) of New Zealand's remaining indigenous forests are particularly vulnerable to damage by possums (Parkes, Baker and Ericksen, 1997). Currently possums are controlled for conservation purposes in about 13 000 km^2, mostly in these vulnerable indigenous forests (Parkes *et al.*, 1997). The benefits of this control are sometimes measured using an index of canopy tree condition reported by Pekelharing (1996) and Payton, *et al.* (1997).

The extent of damage or mortality caused by possums in any population of a plant species is not simple and may depend on many factors. Those suggested in previous studies include the density of possums and the length of time they have been present at each site (e.g., Batcheler, 1983), the intensity and frequency of any control of the possums (Pekelharing and Batcheler, 1990), the palatability of the plant species relative to others in the area (Brockie, 1992; Allen, Fitzgerald and Efford, 1997), the species composition and age structure of the plant population (Payton, 1987, 1988), other environmental stresses (Stewart and Veblen, 1982), plus the interactions between all these. Despite this complexity managers need some simple "rule-of-thumb" measures of impacts or of possum densities that they can use as intervention thresholds for initial or repeated control.

Tree fuchsia (*Fuchsia excorticata* J.R. et G. Forst.) is eaten by possums in south Westland (Owen and Norton, 1995), and is susceptible to possum damage (Rose *et al.*, 1993b). Its condition in these forests can therefore act as a bioindicator or early warning of the need for possum control.

In this paper we compare the amount of damage and mortality to fuchsia over 5 years at five sites in south Westland where possum densities varied from near-zero to high (trap-catch rates of over 40%) and where the sites each had different colonisation and control histories. The hypotheses tested were that possums defoliate and kill fuchsia, and that more possums kill fuchsia more quickly. We tested these hypotheses by comparing the condition of fuchsia canopies, indexed by an estimate of their foliage cover, with an index of possum density, and by one "experiment" where possum densities at one site were markedly reduced by a commercial fur trapper.

Methods

Study sites and possum histories

Five sites were selected south of the Paringa River in south Westland (Fig. 1), all in forests dominated by beech (*Nothofagus* spp.):

- "Moeraki" , in the upper Moeraki River (NZMS 260 G37 250 035) is along a dissected toe-slope opposite the Middle Head Hut at 400 m a.s.l.
- "Windbag" in the Windbag Creek, Lake Paringa (NZMS 260 G37 185 085) is located along the toe-slope of the hill between Windbag and Hostel Creeks at 180 m a.s.l.
- "Kea Stream", at Kea Stream, Landsborough River (NZMS 260 G37 498 000), is located on the boundary between a terrace and a toe-slope at 500 m a.s.l.
- "Lower Waipara", in the lower Waipara River below its confluence with the Arawhata River (NZMS 1 S106 524 650) is a river terrace at 50 m a.s.l.
- "Upper Waipara", also in the Waipara River (NZMS 1 S106 520 650) but on the debris cone of a large slip at 300 m a.s.l. and on a steeper slope (35°) than the other sites (all < 10°).

Possums colonised Moeraki and Windbag in *c*. 1959 (Rose *et al*., 1993a) from a liberation made at Bruce Bay (Pracy, 1974). Possum densities at both these sites have always been low (see Figs. 2a and 2b) and remained low throughout our surveys because of control operations by the Department of Conservation (DoC) in the late winters of 1990 and 1993 (T. Farrell, *pers. comm*.; DoC, Hokitika). Possums colonised Kea Stream in *c*. 1959 from a liberation at Makarora (Pracy, 1974). Initial ground control in Kea Stream was done as part of a larger operation in the Landsborough River in summer of 1994 but to date no maintenance control has been conducted. Possums colonised the Waipara River in the 1980s via the Waiototo Valley from a liberation to the east in the Wilkin Valley (Rose *et al*., 1993a). No official control has been conducted in the Arawhata catchment, although one fur trapper took

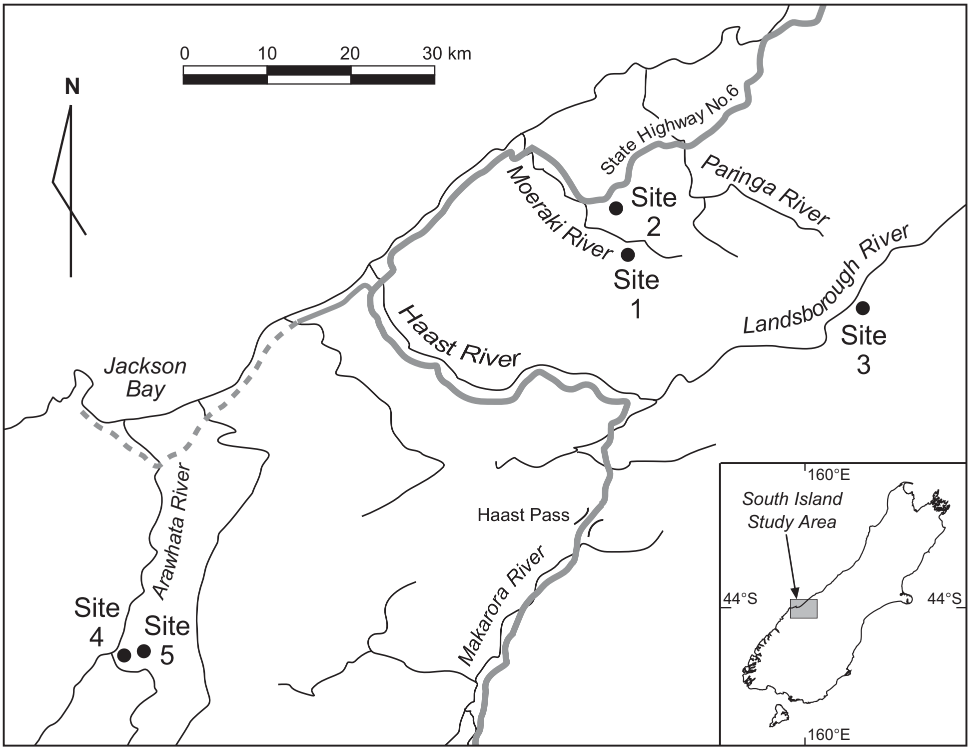


Figure 1: *Location of study sites. Site 1 = Moeraki, Site 2 = Windbag, Site 3 = Kea Stream, Landsborough, Site 4 = Lower Waipara, Site 5 = Upper Waipara.*

about 1000 possums from the valley flats in the lower Waipara River during winter 1995 (F.Wolfe, *pers. comm.;* Haast). In the absence of control in this area, possum densities should still be increasing, and we have used this commercial harvest as an experimental reduction in possum density. Preliminary aerial surveys of the Arawhata River in 1992 recorded no conspicuous dieback (Rose *et al.*, 1993a). Thus, our first surveys of fuchsia in 1992 were made before much possum-induced mortality was expected. Possums were also removed from each site as part of our density index monitoring.

Mortality and foliage cover of fuchsia

At each site in 1991/92, 100 major branches (n = 496) on between 53 and 70 live fuchsia trees were located and tagged along a strip transect 20-m wide and up to 1-km long. Measurements were taken between November to January in each year from 1991/92 to 1994/95 for the Moeraki, Windbag and Kea Stream sites, and from 1991/92 to 1995/96 for the two Waipara sites.

Foliage cover index (FCI): The percentage of foliage cover in the crown of each trunk was subjectively scored by standing under the trunk and estimating the amount of foliage present in 10 classes from a low of 5% to a high of 95% (Pekelharing, 1996). In the first year (1991/92) only 5 classes were used (1-5%, 6-25%, 26-55%, 56- 75% and 76+%), and these data were not used in the analyses but are presented graphically.

Mortality/complete defoliation: The number of tagged branches that subsequently died or were completely defoliated was measured and the cause of mortality classed as either due to possum defoliation or to natural events (a flood removed trees at Kea Stream and snow damage killed trees at Moeraki and Windbag).

Possum density index

Possum densities were indexed using a trap-catch method. At each site, 20 Victor No. 1 leg-hold traps were set on the same 20 tagged fuchsias along the length of the transect for one fine night each year the trees were surveyed; the index is simply the percent of traps that caught a possum. The exception to this schedule was at the upper Waipara site where no trapping was conducted in 1995/96. All possums caught were killed.

Analysis

Because it is likely that current canopy condition on a plant will be related to past canopy condition, a repeated-measures model with autoregressive errors (Mansour, Nordheim and Rutledge, 1985) was fitted to the untransformed mean FCIs for all tagged trunks on each tree in each year. A description of the repeated-measures model is given in the Appendix to this paper. All tests were carried out using likelihood ratio tests (Larsen and Marx, 1986). In the lower Waipara River site, where possums were "controlled" by the commercial fur trapper between the 1994/95 and 1995/96 measurements, the FCIs between 1994/95 and 1995/96 were compared using a linear contrast of the year effects (Sauer and Williams, 1989).

Results

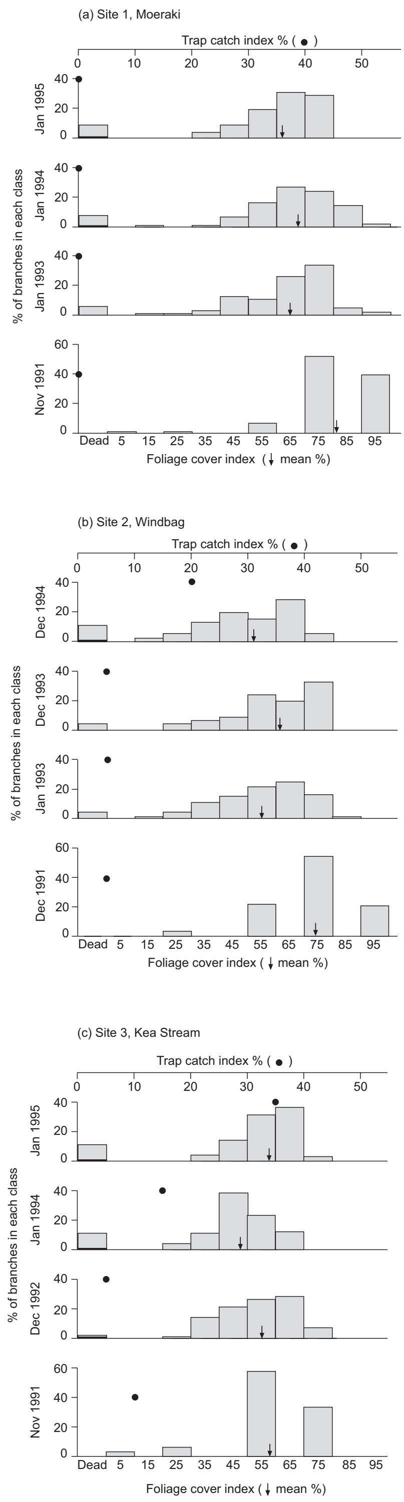
Mortality

The proportion of branches that died during the study varied between the five sites ($\chi^2_4 = 158.7$, $P < 0.001$) (Fig. 2). Over all sites 27 trunks (5.4 %) died from natural causes and 95 (19.2%) were killed by possums. At Moeraki and Windbag, with very low possum densities, only two branches died from defoliation by possums. At Kea Stream, with low but increasing possum densities, one branch was killed by possums. At lower Waipara, 11 branches had died by 1995/96, with seven of these dying after the removal of a large number of possums from the area in 1994/95. At the upper Waipara site, with high and increasing possum densities, 81 branches were killed by possums.

Canopy condition and possum densities

The condition of fuchsia at each site as measured by the FCI was related to the density of possums measured at the site (Fig. 3). The relationship between the condition of fuchsia and possum densities suggested in Fig. 3 is confirmed by the likelihood ratio tests which showed a significant effect of possum density indices on the annual FCIs at the four sites where we caught possums (Windbag; $\chi^2_1 = 31.0$, $P < 0.001$: Kea Stream; $\chi^2_1 = 18.3$, $P < 0.001$; lower Waipara; $\chi^2_1 = 50.3$, $P < 0.001$; upper Waipara; $\chi^2_1 = 74.8$, $P < 0.001$). Only one possum was caught at Moeraki (in 1991/92) so this site was not used in the test.

The FCIs at lower Waipara increased significantly between 1994/95 and 1995/96 after the removal of a large number of possums ($\chi^2_1 = 55.7$, $P < 0.001$), while the FCIs at the neighbouring site with no possum control, upper Waipara, continued to decline to near zero.



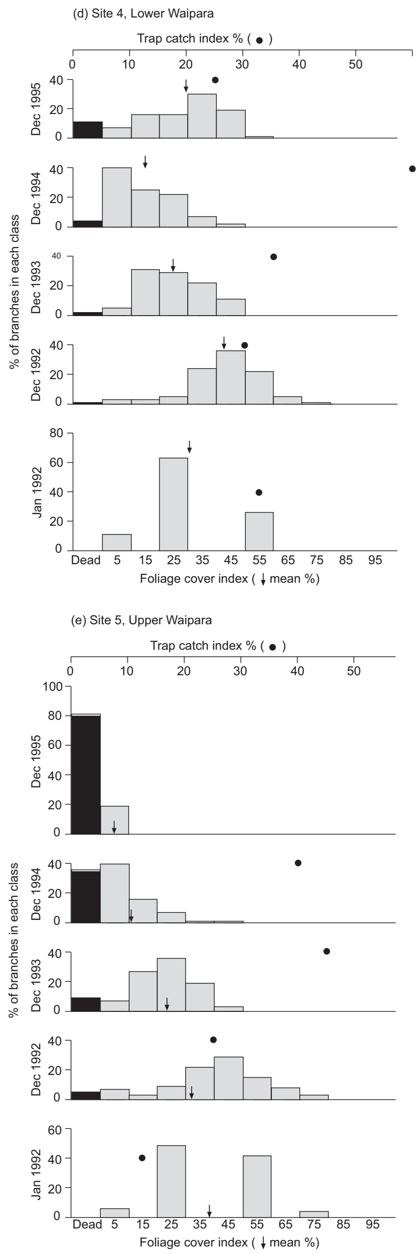


Figure 2: *Percent of 496 branches in 10 foliage cover classes, or completely defoliated or dead for five study sites over 4 or 5 years in south Westland. In the defoliated/dead (Dead) class, the frequency of branches killed by possums is shown in black and that of those that died from other causes is unshaded. The mean Foliage Cover Index is indicated by an arrow, and the index of possum density by a dot. (a) Moeraki, (b) Windbag, (c) Kea Stream, (d) lower Waipara, (e) upper Waipara.*

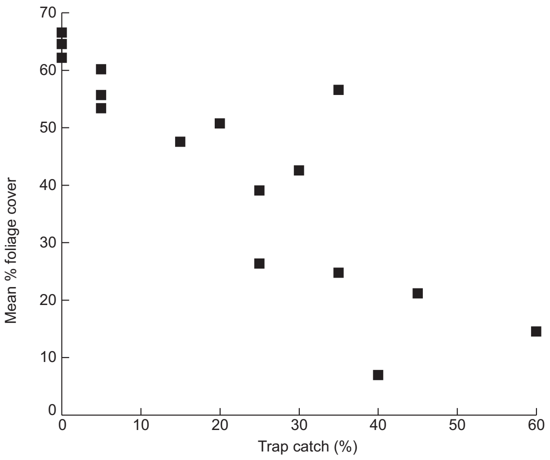


Figure 3: *Relationship between Foliage Cover Indices (FCI) and possum trap-catch rates for five study sites over 4 or 5 years. Note, the data for the first year were not used because different foliage cover index classes were used.*

At all sites there was also evidence of significant variation in annual FCIs that was independent of our measured possum density index (Windbag; $\chi^2_1 = 8.4$, $P < 0.05$: Kea Stream; $\chi^2_1 = 28.8$, $P < 0.001$: lower Waipara; $\chi^2_2 = 122.0$, $P < 0.001$: upper Waipara; $\chi^2_1 = 88.0$, $P < 0.001$). The importance of this effect is illustrated by Moeraki, where there were no possums trapped in any year but there was strong evidence of differences in the annual FCIs ($\chi^2_2 = 16.64$, $P < 0.001$).

Discussion

This study provides evidence of a density-dependent effect of possums on populations of a native plant. Previous attempts to demonstrate an effect have relied on coarse measures of impacts such as basal area (Pekelharing and Batcheler, 1990), or have measured mortality of trees in the absence of possums (by protecting individual trees) and compared this with tree mortality at carrying capacity (Meads, 1976), or have measured an index of possum density or use (browse) that may not be independent of the foliage density estimates (Leutert, 1988).

The correlation between the index of possum density and foliage cover and mortality at each site, and the improvement in foliage cover after possum control, support our hypothesis that possums defoliate and kill fuchsia and the severity of defoliation increases with increasing possum density at each site. At low possum densities, there is some defoliation but little mortality, but as possum densities increase the increasing defoliation causes increasing mortality that may lead to the local extinction of fuchsia (Rose *et al*., 1993a). As a rule of thumb, fuchsia will die within a few years without possum control once the mean FCI falls below about 25% or the trap-catch density index exceeds about 25% (Fig. 2). However, the limited evidence provided by the removal of *c*. 1000 possums from the lower Waipara River site in the winter of 1995 suggests that the trend can be reversed by timely control even when the fuchsia is nearly completely defoliated.

This density-dependent damage is apparent for fuchsia at each site (except Moeraki where we trapped no possums). We suspect all South Westland fuchsia might have similar palatability and the relationship might be general in the area, but we know fuchsia in other areas is less palatable to possums (P. Sweetapple, *pers. comm.*; Landcare Research, Lincoln) so the relationship will not be universal. The relationship between possum density and damage to plants is not necessarily true across a range of forest types even with in one area. At Mt Bryan O'Lynn in North Westland, possum damage was worse in the simplest forest types at mid-altitude with fewer possums than in more complex forest associations at lower altitudes (Coleman, Gillman and Green, 1980). Canopy recovery following possum control is also not universal. A recent study using a similar canopy assessment methodology (Payton, 1988) to investigate the effect of possum control on several tree species (but not fuchsia) in a complex forest in Northland failed to show a significant short-term response in canopy condition, although the control did halt the degradation that was occurring when possums were unmolested (Payton *et al*., 1997).

Variation in measured possum densities did not appear to be the only explanation for significant variation in foliage cover. One likely explanation is that our trap-catch index of density, only 20 traps set for one night each year, was an inadequate measure of the actual densities of possums.. However, given the strength of the relationship apparent in the scatterplot (Fig. 3) and the known palatability of fuchsia to possums, our analysis highlights the importance of possums in influencing changes in foliar density.

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Appendix

At each site, the repeated measures model with autoregressive errors used was:

$$Y_{ij} = m + a_i + T_j + e_{ij}$$

Where Y_{ij} is the canopy score for the i'th plant at the j'th time, μ is the overall mean FCI among all plants, a_i is the random effect for the i'th plant, and is assumed to be independent and identically distributed $N(0,\sigma_a^2)$, T_j is the fixed effect of the j'th time and e_{ij} is an error term that follows the first-order autoregressive model:

$$e_{ij} = f e_{ij-1} + m_{ij}$$

Where $u_{i,j}$ is independent and identically distributed $N(0,\sigma_e^2)$. The model was fitted by maximum likelihood using the GAUSS programming language. The parameter ϕ measures the strength of the relationship between measurements at adjacent time points, and if $\phi = 0$, we obtain the usual repeated measures model. Note that ϕ is *not* a correlation coefficient and can take any value in the range $(-\infty,\infty)$, however the time series is only stationary (i.e., well behaved) if $-1 < \phi < 1$. If $\phi < 0$, adjacent values are negatively correlated but are positively correlated otherwise. Note also that the time effect T_j, is a surrogate for factors which influence the FCI, since time itself can have no direct effect.

We tested the significance of the autoregressive parameter by comparing the full model to one where the parameter ϕ was constrained to zero. To test for the effect of possums, we compared three nested models.

Model 1: $T_j = 0$ for all j. This model assumes no effect of time.

Model 2: $T_j = \beta P_j$, where P_j is the density of possums at the study site at time j.

Because true density is unknown, trap catch was substituted for P_j.

Model 3: The full model as above.

There was strong evidence ($c^2_5 = 23.0$, $P < 0.001$) that the autoregressive parameter f, which in all cases was estimated to lie between 0 and 1, needs to be included in the model. The need for inclusion of the autoregressive parameter f illustrates the importance of modelling the dependency between successive observations within a plant. This dependency indicates that the effects of defoliation persist through time, i.e., the canopy state of the plant in any one year depends on its state in previous years. The model used to analyse these data is still a simplification of reality. For example, the time series model treats the categorical FCI data as continuous. One intriguing possibility would to model these categorical data using multi-state mark-recapture models which model plant death as well as transitions of plants from one FCI state to another.