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IMPACT OF INVADING BRUSHTAIL POSSUM POPULATIONS ON MIXED BEECH-BROADLEAVED FORESTS, SOUTH WESTLAND, NEW ZEALAND

Summary: The impact of browsing by introduced brushtail possums on mixed beech - broadleaved forests in South Westland was estimated from the amount of conspicuous canopy dieback present in 1989-1990. Aerial and ground-based reconnaissance in all catchments indicated most canopies (84%) were intact. The remaining 16% of canopies were affected by conspicuous dieback, principally of southern rata *(Metrosideros umbellata)* and/or fuchsia *(Fuchsia excorticata)*. Major dieback nuclei were located in the three areas with the longest history of browsing by possums, which had spread from three known liberation centres. At each dieback nucleus, the amount of dieback reflected the abundance of possum-preferred canopy species. Because South Westland forests contain lower proportions of such species, they are less susceptible to dieback than the conifer-broadleaved forests of central Westland. However, the present low amounts of dieback in South Westland mainly reflect low overall possum densities and a short period of occupation. The occurrence of key possum-preferred species indicates that about one-third of the forests could develop conspicuous canopy dieback if possum numbers increase and 44-94% are susceptible to canopy and/or understorey depletion. By 1992, the few areas selected for sustained possum control effort in Westland under-represented the range of forest composition. However, recently boosted funding for possum control has provided the opportunity to protect representative forest tracts before the onset of widespread ecosystem depletion in South Westland.

Keywords: Brushtail possums; canopy dieback; mixed beech-broadleaved forests; Westland; mapping; surveys.

Introduction

In many areas of New Zealand, prolonged browsing by the introduced Australian brushtail possum *(Trichosurus vulpecula* Kerr) has caused extensive defoliation and mortality of dominant canopy trees, such as southern rata *(Metrosideros umbellata*[1]*)*, kamahi *(Weinmannia racemosa)*, and Hall's totara *(Podocarpus hallii)*. Central Westland conifer-broadleaved forests dominated by southern rata and kamahi are one of the most seriously affected ecosystems, with canopy mortality conservatively estimated at 20% over the last 40 years (Rose, Pekelharing and Platt, 1992).

The boundary between central and South Westland (Fig. 1) marks a major discontinuity in forest composition. In central Westland, conifer-broadleaved forests predominate. In contrast, beech *(Nothofagus)* species are generally dominant or codominant in South Westland (Wardle, J., 1984), broadleaved canopy species are less abundant, and there are few reports of canopy dieback (Wardle, P., 1978, 1979). Two factors may underlie this difference in dieback. First, as brushtail possums appear to be still colonising the South Westland forests, populations may not yet be large enough to cause widespread dieback. Second, because beech species are not preferred foods for possums (Wardle, J., 1984), forest canopies containing beech may be less susceptible to browsing than those dominated by possum-preferred species.

However, many canopy and understorey species characteristic of mixed beech-broadleaved forests are preferred foods for possums, and the potential for possum-induced depletion has been recognised (Wardle, J., 1984). Despite this, the extent of depletion has received little attention. In 1990 the conservation value of the South Westland forests achieved global recognition when the area was designated a World Heritage Park. This study was prompted by the need for an overview of present and potential possum-induced depletion to assist development of an effective forest conservation strategy. Specific objectives were to:

[1] Botanical nomenclature follows Allan (1961), Moore and Edgar (1970), and Connor and Edgar (1987).

map the amount of canopy dieback present; assess forest susceptibility to depletion by possums; review present possum densities and population status; and assess likely future trends in forest depletion and their implications for conservation.

Study Area

The study area comprises 155 860 ha of lowland to subalpine forests between the Mahitahi and Arawata Rivers in South Westland (Fig. I). It consists of two major geomorphological zones separated by the Alpine Fault. To the east of the Fault, the landscape is dominated by mountainous catchments on schist bedrock, with their headwaters in the Southern Alps. To the west, the topography is less steep and is dominated by alluvial plains and moraines, apart from a central block of dissected hill country on breccia, sandstone, limestone and siltstone located between the Ohinemaka and Waita Rivers (Fig. 1; Fitzsimons and O'Loughlin, 1984; Fitzsimons, O'Loughlin and Eggers, 1985).

The study area lies immediately south of central Westland, and beeches, predominantly silver beech *(Nothofagus menziesii),* are generally dominant or codominant. However, forest composition is highly variable, often involving mixtures of beeches, conifers such as rimu *(Dacrydium cupressinum)* and Hall's totara, and broadleaved species such as southern rata and kamahi. Such variability often reflects gradients in elevation and soil factors associated with drainage, fertility, parent material, and landform stability (Wardle, J., Hayward and Herbert, 1973; Duncan, Norton and Woolmore, 1990).

History and origin of possum populations

Possum populations in the study area are probably derived from at least three authorised liberations; one in the north, at Bruce Bay and two in the south, in the Wilkin/Matukituki Valleys and the Makarora Valley (Fig. 1). Liberations at Jackson Bay in 1896 and the mouth of the Okuru River in 1926 were unsuccessful (Pracy, 1974; LT. Pracy, *unpublished data;* Tustin, 1972).

In the north, by 1950 possum populations resulting from liberations at Bruce Bay between 1925 and 1930 had spread southward througout the western front country between the Mahitahi and Paringa Rivers (Fig. 1). By 1959 they had dispersed further along the coast to the Moeraki River and eastward into the high country between the Mahitahi and Paring a, but were still scattered and at low densities (LT. Pracy, *unpublished data).* In 1984-1985, possum densities ranged from low (<45 faecal pellets ha^{-1}) to absent in the high country forests between the Mahitahi and Moeraki Rivers (New Zealand Forest Service, *unpublished data).*

In the south, by 1974 possums had become established in the headwaters of the Waiatoto River (unpublished Mount Aspiring National Park Board files), probably after dispersing over a low pass in the Southern Alps from the Wilkin Valley (where possums were liberated in 1932) and from the Matukituki Valley (where possums were liberated in 1916) (Pracy, 1974). In 1985, low possum densities *(c.* 45 faecal pellets ha^{-1}) were recorded in the headwaters of the Waiatoto (Willemse, 1985). By 1990, continuing dispersal had resulted in low to moderate possum densities on the east bank of the Arawata River, below the confluence with the Waipara (C.J. Pekelharing and K.W. Fraser, *unpublished data).*

Further eastwards, by 1959 possums had also migrated over the Southern Alps via Haast Pass (Fig. 1) from the Makarora Valley (where animals were released in 1914) (Pracy, 1974) and were spreading down the Haast Valley highway and up the east bank of the Landsborough Valley (LT. Pracy, *unpublished data).* By 1965 they had also spread part way up the Burke River, a tributary of the Haast (F. Woolf, possum trapper,*pers. comm.).*

Field inspections by Department of Conservation staff and ourselves, unpublished information, and anecdotes suggest that possums occupied at least two-thirds of the South Westland forests by 1990. Populations with predominantly *(c.* 75%) light-coloured coats south of the Moeraki River graded into predominantly dark populations further north. Although possums had been present in some locations for 50 years, over much of their range they were at low densities consistent with colonising populations (Fig. 1).

Methods

Forest susceptibility to depletion by possums

The overall composition of different forest types appears to be a major influence on their susceptibility to depletion by possums (Payton, 1987; Reif and Allen, 1988; Stewart and Rose, 1988). For example, possum-preferred canopy species, such as southern rata, are more susceptible to dieback in types that also contain abundant preferred subcanopy and seral broadleaved trees such as *Fuchsia excorticata* and *Aristotelia serrata.* Such forests are typical of relatively fertile, well-drained soils. In contrast, the susceptibility of preferred canopy species is lower in forest types on

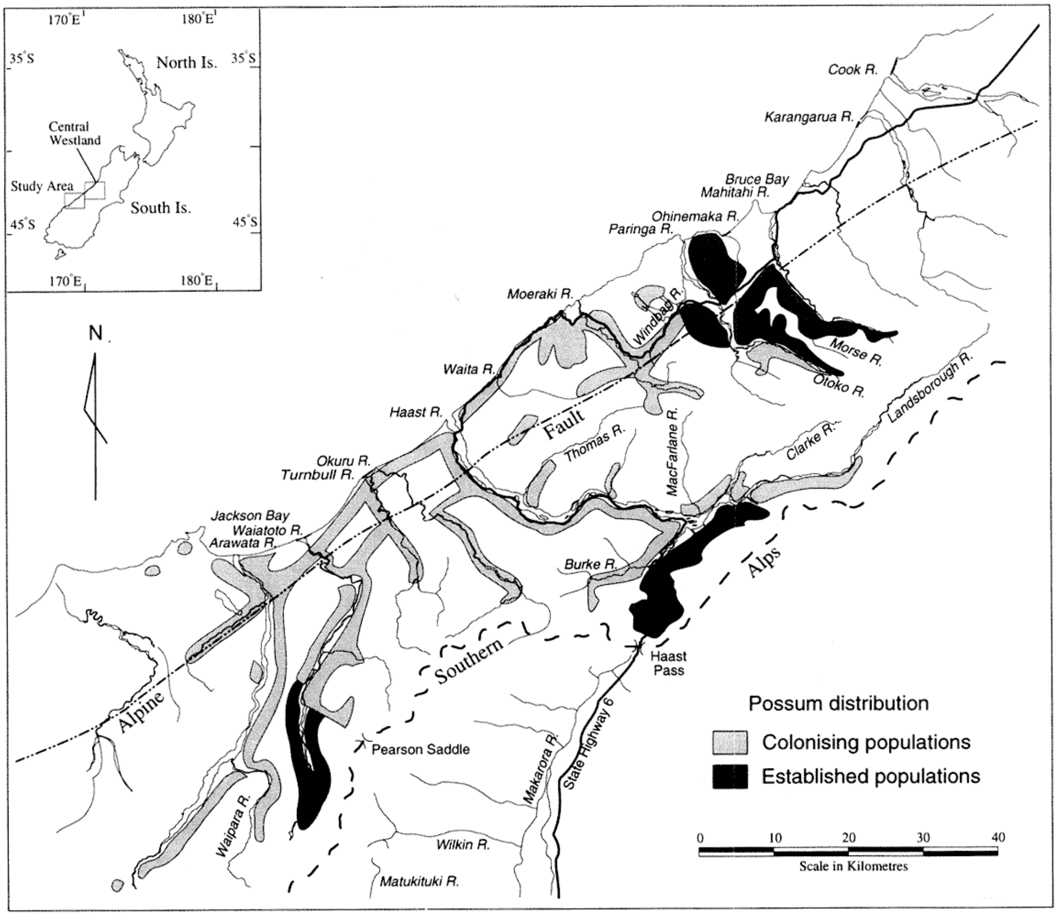

Figure 1: *Minimum distribution and status of brushtail possum populations, and location of the study area between the Mahitahi and Arawata Rivers, South Westland, 1989-1990. Possum population data are based on field inspections and a review of available information.*

very infertile/poorly-drained soils that lack preferred subcanopy species and are characterised by species such as *Phyllocladus aspleniifolius* and *Gahnia procera*. For this study, we used data on forest composition from previous forest surveys in five areas of South Westland to evaluate susceptibility to possum-induced depletion. Three areas west of the Alpine Fault were intensively surveyed in 1984-1986 (C. Woolmore, *unpublished data)*. The mountainous catchments east of the Alpine Fault have been less intensively surveyed: in the north (Karangarua - Moeraki catchments) in 1984-1985 (C. Woolmore, *unpublished data)* and in the south (Okuru - Arawata) in 1970-1971 (Wardle, J., *et al.,* 1973). Two surveys (Cook - Paringa and Karangarua - Moeraki) that included some forests just north of the study area were included in the analyses.

All surveys involved full vascular plant species lists recorded on 3916 unbounded plots using methods similar to those described by Allen and McLennan (1983). Fifty forest types had been identified by agglomerative cluster analysis using group average sorting strategy and Sorensen's K

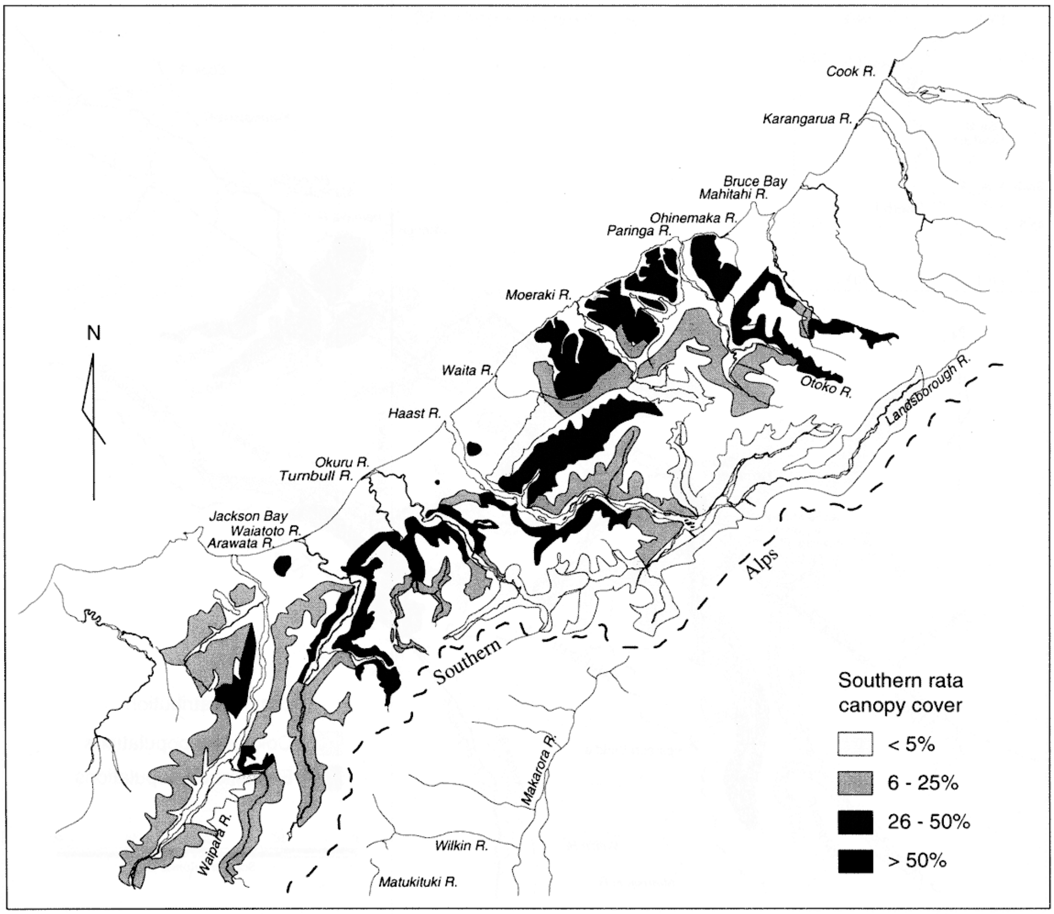

Figure 2: *Southern rata canopy cover (%) in the study area, determined from aerial or ground-based assessments of all catchments between the Mahitahi and Arawata Rivers, 1989-1990.*

similarity coefficient. For each forest type, we determined the percent frequency of occurrence for 18 key widespread plant species forming three groups that reflect likely susceptibility to depletion by possums (Payton, 1987; Reif and Allen, 1988; Stewart and Rose, 1988):

1. Possum-preferred canopy species, i.e., the trees *Metrosideros umbellata, Podocarpus hallii,* and *Weinmannia racemosa* and the mistletoe. *Peraxilla colensoi.*
2. Possum-preferred subcanopy and seral broadleaved trees (also typical of relatively fertile/well-drained soils), i.e., *Fuchsia excorticata, Aristotelia serrata, Schefflera digitata, Melicytus ramiflorus,* and *Hoheria glabrata.*
3. Non-preferred species (also indicative of infertile and/or poorly drained soils), i.e., *Lagarostrobus colensoi, Phyllocladus aspleniifolius, Elaeocarpus hookerianus, Leptospermum scoparium, Lepidothamnus intermedius, Cyathodes juniperina, Gahnia procera,* G. *xanthocarpa,* and *Halocarpus biformis.*

The susceptibility of each forest type to canopy and/or understorey depletion was assessed as:

Ä High, if ~70% of its plots contained possum-preferred canopy and/or subcanopy species and

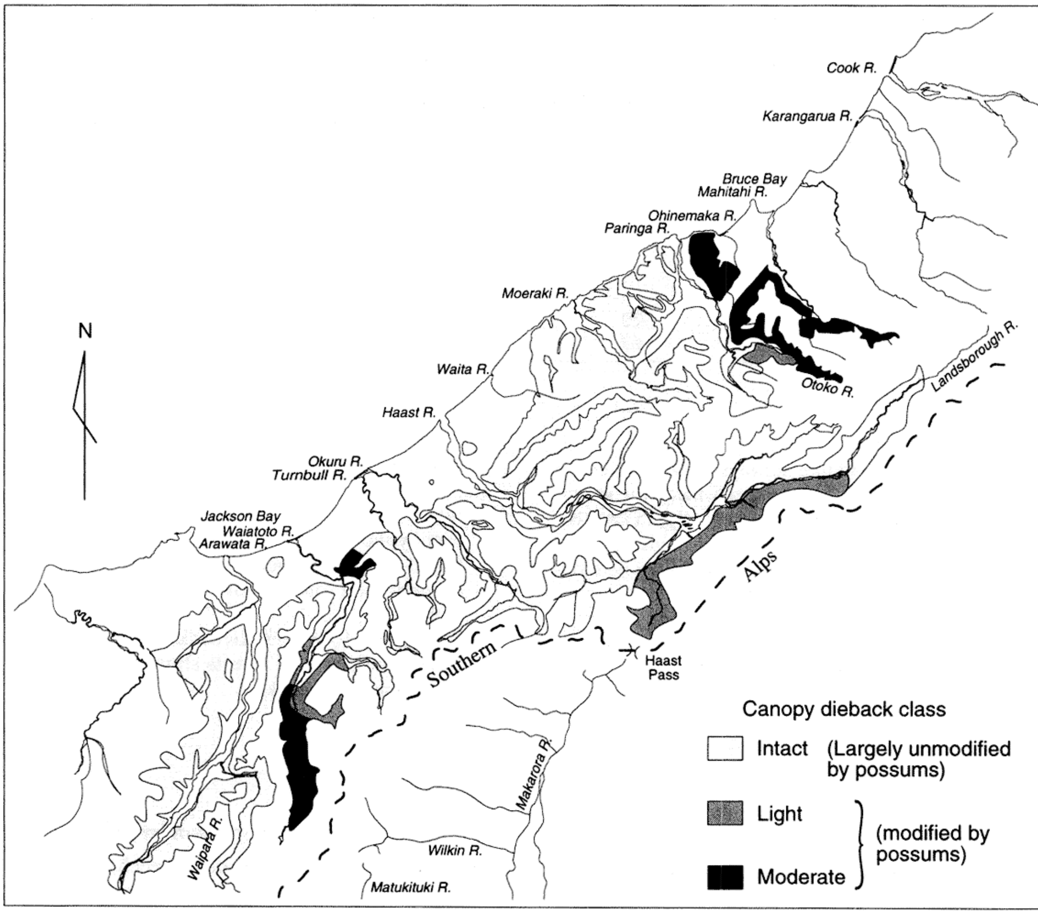

Figure 3: *Amount of visibly conspicuous canopy dieback in the study area, determined from aerial or ground-based assessments of all catchments between the Mahitahi and Arawata Rivers, 1989-1990. Dieback classes are: Intact (<10% dieback of mature forest, no dieback of seral forests); Light (<10% dieback of mature forest, conspicuous dieback of seral forests); and Moderate (10-30% dieback of mature forest, conspicuous dieback of seral forests).*

30% contained species characteristic of infertile/poorly drained soils.

Ä Moderate, if 40-60% of its plots contained preferred species and/or 40-60% contained species characteristic of infertile/poorly drained soils.

Ä Low, if >70% of its plots contained species characteristic of infertile/poorly drained soils and/or 30% contained preferred species.

For each of the five survey areas, overall forest susceptibility was calculated from the proportion of forest types in each susceptibility class. An example of these analyses is presented in Appendix 1.

Also for each area, a "Canopy Dieback Index" (CDI), representing the minimum likely extent of conspicuous canopy dieback, was calculated from the survey data, using the proportions of susceptible forest types that contained abundant southern rata and/or Hall's totara:

CDI = (% highly susceptible types with 50% frequency of southern rata and/or Hall's totara)
+ 0.5(% moderately susceptible types with ≥50%frequency of southern rata and/or Hall's totara).

Table 1: *Predicted forest susceptibility to possum-induced depletion in five areas of South Westland, calculated from the occurrence of key species on vegetation plots. Values represent proportions* (%) *of forest in each susceptibility class (see Methods and Appendix* 1). *Sources:* [1]*Wardle. J.,* et al., 1973; *otherwise* C. *Woolmore*. unpublished data.

	Overall susceptibility (%)			Canopy Dieback Index
	High	Moderate	Low	(%)
Forests west of the Alpine Fault				
Cook-Paringa	48	41	10	14
Paringa-Haast	55	39	6	34
Haast-Arawata	37	7	56	33
Forests of the major catchments east of the Alpine Fault				
Karangarua-Moeraki	70	21	11	46
Arawata-Okuru I	63	17	20	27

As the five vegetation surveys did not cover the full extent of the study area, we estimated the abundance of southern rata in the canopy to gain further information on the potential for conspicuous possum-triggered canopy dieback. Operating from a helicopter, or where practicable from the ground, two or three observers scored southern rata canopy cover in predetermined map units in all catchments. The map units were identical to those used for assessing canopy dieback (see below). Average rata cover values were mapped in four classes (≤5; 6-25; 26-50; >50%) using TERRASOFT Geographical Information System (Digital Resource Systems Ltd, Canada).

Canopy dieback

Little canopy dieback was evident on the most recent (1984-1985) aerial photographs, which covered part of the study area. The amount of conspicuous canopy dieback was therefore estimated and mapped from helicopter or ground-based inspections of all catchments between November 1989 and April 1990. Field methods were similar to those developed for central Westland (Rose *et al.,* 1992). For predetermined map units drawn on 1 : 250 000 maps, two or three observers independently scored the proportion of dead or conspicuously defoliated mature-forest canopy trees (primarily southern rata). In addition, presence or absence of conspicuous dieback of seral forests (primarily *Fuchsia excorticata* in gullies) was recorded. This proved a useful means of identifying possum-induced damage even when the surrounding mature forests were dominated solely by beech.

If major forest damage boundaries intersected a map unit, the unit was redefined. A few dieback estimates differed by more than about 10% between observers, and these map units were revisited and reassessed.

Average dieback estimates were used to map canopy dieback in three classes using TERRASOFT:

1. Intact: <10% dieback of the mature-forest canopy; no detectable dieback of seral forests.
2. Light: <10% dieback of the mature-forest canopy; seral forests showing conspicuous dieback.
3. Moderate: 10%-30% dieback of the mature forest canopy; seral forests showing conspicuous dieback.

Results

Forest susceptibility to depletion by possums

Despite widespread dominance of beech, possum-preferred canopy, seral, and understorey species were abundant in the study area. For example, the frequency of southern rata, Hall's totara, or kamahi exceeded 50% in 39 of the 50 forest types identified in the survey areas. Seral forests and mature-forest understoreys often contained high frequencies of possum-preferred small trees such as *Fuchsia excorticata, Aristotelia serrata,* and *Schefflera digitata*. In 24 forest types, such species exceeded 50% frequency (e.g., see Appendix 1).

West of the Alpine Fault, 37-55% of the forests surveyed were highly susceptible to canopy and/or understorey depletion because of high frequencies (≥70%) of possum-preferred species (Table I). The proportions of highly and moderately susceptible forests were similar for the Cook - Paringa and Paringa - Haast areas (totalling ≥90%) but were lower for the Haast - Arawata area (totalling 44%).

In the mountain catchments east of the Alpine Fault, 63-70% of the forests surveyed were highly susceptible, with a further 17-21 % being moderately susceptible (Table 1).

The potential for conspicuous possum-triggered canopy dieback was high. Aerial inspection indicated that southern rata canopy cover exceeded 25% in one-third of the forests of the study area. In only 29% of the forests was this species uncommon (≤5% canopy cover; Fig. 2). In some areas, e.g., Mahitahi, Okuru, and Turnbull catchments, southern rata cover exceeded 50%. For the five survey areas, 14-46% of the forests could potentially develop conspicuous possum-triggered dieback of southern rata and/or Hall's totara (Canopy Dieback Index, Table 1).

Canopy dieback

For 84% of the study area, forest canopies were considered intact in 1989-1990, with < 10% dieback of mature forest and no detectable dieback of associated seral forests (Fig. 3). For 7% of the area, although mature-forest canopies were intact (<10% dieback) associated seral forests (principally *Fuchsia excorticata* in gullies) showed conspicuous dieback. The remaining 9% of the forests showed moderate dieback (10-30% of the mature-forest canopy and conspicuous dieback or collapse of associated seral forests). Mature-forest dieback chiefly involved southern rata and was often in patches restricted to areas or altitudinal belts where this species was abundant.

Three major dieback nuclei were identified (Fig. 3), whose location reflected patterns of possum invasion and build-up from the three known liberation centres. At each dieback nucleus, the severity of dieback reflected the abundance of possum-preferred canopy species.

In the north, a nucleus of moderate dieback affected mature and seral forests between the south bank of the Mahitahi catchment and the north banks of the Otoko and lower Paringa (Fig. 3). This reflected prolonged browsing by possums originating from the Bruce Bay liberation. The mature forests had a relatively high component of southern rata (>25% canopy cover). On the south bank of the Otoko, seral forests showed conspicuous dieback, indicating that although the mature forests here were largely intact, dieback will develop as possum numbers build up.

In the south, a nucleus of moderate dieback affected the forests of the Waiatoto headwaters, reflecting dispersal of possums originating from the Wilkin-Matukituki liberations. Southern rata is moderately abundant in the mature forests of this area (6-25% canopy cover) and the severity of dieback (10-30%) indicated most rata trees were affected. Downstream, seral forest dieback indicated further dieback of the mature forest is imminent (Fig. 3). A localised area of moderate dieback was also recorded for forests adjacent to the Alpine Fault, between the Waiatoto and Turnbull Rivers.

In the east, a nucleus of dieback affected seral forests of the upper Haast catchment and the west bank of the lower Landsborough. This reflected the impact of possums originating from the Makarora liberation. Mature forests were largely intact, reflecting low proportions of southern rata (≤5% canopy cover) in these beech-dominated catchments.

Discussion

Relative susceptibility to possum-induced canopy and understorey depletion

In central Westland, a prolonged history of possum browsing has triggered canopy dieback of *c*. 90% of the highly susceptible southern rata-kamahi forests above 500 m elevation (Rose *et al.,* 1992). The potential for conspicuous dieback in South Westland would seem to be lower than this because of lower proportions of possum-preferred canopy species. Our study suggests about one-third of the South Westland forests could develop conspicuous dieback if possum numbers increase.

Although dieback of mature-forest canopies is an obvious visible symptom, it underestimates total forest depletion caused by possums. In an assessment based on the distribution of key possum-preferred species, 44-94% of the forests were rated as highly or moderately susceptible to canopy and/or understorey depletion. Depletion by possums already also involves conspicuous dieback of possum-preferred seral forests. Inconspicuous dieback of uncommon preferred canopy species (c.f. Rose *et al.,* 1992) will develop in otherwise beech-dominated forests, and preferred understorey species will become less abundant (Wardle, J., 1984). For example, we saw severe defoliation of subcanopy fuchsia in the mid Arawata and lower Waiatoto Valleys, two areas that lacked conspicuous canopy dieback. We also saw heavily browsed *Peraxilla colensoi* on the south bank of the Haast and in the Waipara catchment. These large mistletoes are highly palatable and may be heavily depleted, even at low, colonising densities of possums (Wilson, 1984; Farrell and Mead, 1990).

Trends and implications for conservation

Although the South Westland forests are less susceptible than the southern rata - kamahi forests of central Westland, the present low amount of visible dieback of mature and seral forest canopies (16%) mainly reflects overall low densities and a short period of occupation by possums. Because of wide variation in canopy composition and susceptibility, it is difficult to predict the likely rate of spread of dieback in South Westland. However, there is little doubt that the forests are becoming progressively depleted as possum populations continue to spread and build up. Our observations indicate that seral forest dieback had spread further at all possum invasion fronts by 1992 (Rose and Pekelharing, 1993). Dieback of the mature forest canopy is imminent, for example, in the Otoko tributary of the Paringa catchment, the lower Waiatoto, the lower-mid Haast, and the Turnbull (Fig. 3).

Sustained possum control has proven elusive on the mainland, despite extensive Government control operations and private trapping. Because of the expense of widespread possum control and the ability of possum populations to increase to high levels *c*. 10 years after control, an effective forest conservation strategy requires that representative tracts are selected in which to target repeated possum control indefinitely. In 1990, the New Zealand Department of Conservation identified 13 key areas that warranted sustained possum control effort in Westland (James, 1990). However, because of funding constraints only the four top-ranked areas were selected. The Moeraki/Windbag catchment, the only area then selected in South Westland, comprises only c. 5% of the forests of the present study area and is almost totally dominated by beech (Fig. 2). By 1992, two further areas had been selected, including the Turnbull catchment in South Westland, but the range of forest composition in Westland was still heavily under-represented (e.g., Wardle, J., *et al.,* 1973; Wardle, P., 1977; Reid and Allen, 1988). However in mid-1993, with increasing awareness of the threat to indigenous ecosystems from possums, Government funding for sustained possum control was boosted significantly. This should provide the opportunity to implement an effective strategy to protect representative forest tracts before the onset of widespread canopy dieback and associated ecosystem depletion in South Westland.

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Appendix overleaf

Appendix 1: *An example of estimated forest susceptibility to possum-induced depletion. Data are from a vegetation survey west of the Alpine Fault. between the Paringa and Haast Rivers* (C. *Woolmore and M. Bendall*. unpublished data; C. *Woolmore*. unpublished data). *Forest types are named after physiognomically dominant species (c.f. Atkinson. 1985*; *species with >50% canopy cover are underlined): PHI = Silver beech-rimu; PH2 = (Silver beech)/soft treefern.* Cyathea smithii *Hook. f.; PH3 = (Silver beech)/manuka; PH6 = Rimu-silver beech; PH7 = Rimu-kamahi; PH8 = ~ beech-kamohi; PH9 = Silver beech: PH1O = Silver beech/(manuka). Manuka-dominated swampland accounts for 8% of the area (types PH4. PH5. not included).*
For each forest type. the % frequency of occurrence of key species on vegetation plots is summarised: blank = absent or <1%; + = 1-4.9%; 1 = 5-14.9%; 2 = 15-24.9% ... 10 = 95-100%; n = number of vegetation plots. Highly susceptible forest types contain high proportions ´I!70%) of possum-preferred canopy and/or understorey species and are characteristic of relatively fertile/well-drained soils. Forests of low susceptibility contain low proportions (≥***30%)****of preferred species or are characteristic of very infertile/poorly-drained soils.*

	Susceptibility							
	High				Moderate		Low	
Forest type	PH8	PH9	PH2	PH7	PH6	PH1	PH3	PH10
% Forest (n = 1023)	8	6	6	35	37	2	4	2
Possum-preferred canopy species								
Metrosideros umbellata	5	6	2	2	7	5	3	4
Podocarpus hallii	2	2	1	3	8	4	6	
Weinmannia racemosa	10	4	10	10	10	10	8	
Peraxilla colensoi	2	1	1	1	2	4	2	2
Possum-preferred subcanopy species indicative of fertile/well-drained soils								
Fuchsia excortica	7	2	7	5	1		1	
Aristotelia serrata	3	+	6	3	1	1	1	
Schefflera digitata	7	1	10	7	1	+	1	
Melicytus ramiflorus	3	+	7	6	1	2	+	
Hoheria glabrata	1	1	1	+			+	
Non-preferred species indicative of infertile/poorly drained soils								
Lagarostrobus colensoi				+	1		2	2
Phyllocladus aspleniifolius		+		+	4	2	8	5
Elaeocarpus hookerianus	+	1	1	1	4	4	6	3
Leptospermum scoparium					1	+	7	4
Lepidothamnus intermedius					+		3	2
Cyathodes juniperina					1	4	3	3
Gahnia procera		2	+	+	2		3	7
Gahnia xanthacarpa			1	1	2	5	5	
Halocarpus biformis		+			+			6