Comparison of red deer and possum diets and impacts in podocarp-hardwood forest, Waihaha Catchment, Pureora Conservation Park

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CONTENTS

Abstract

The impacts of the two most widespread introduced herbivores in New Zealand (red deer and possums) were investigated to compare the relative importance of arboreal and terrestrial browsers, and to determine the likely relationships between pest density and their impacts. The study was conducted between 1990 and 1993 in podocarp-hardwood forest west of Lake Taupo, where the density, diet, and forage use of the two species was quantified and compared with quantitative estimates of forest composition, forage availability and production, and stem diameter and seedling height distributions. Deer density was stable at about c. 6 deer/km^2, and annual faecal output for deer was estimated at 14 kg (dry weight)/ha/yr. Possum density increased during the study to reach c. 3 possums/ha in 1993, with an estimated faecal output of 44 kg/ha/yr for that year. In the forest, pepperwood (*Pseudowintera colorata*) and *Neomyrtus pedunculata* were most abundant, but podocarps comprised nearly half the total basal area of 73 m^2/ha. About 2.5 tonnes/ha of foliage were produced annually, suggesting that c. 5 tonnes/ha of foliage were available to possums. In contrast, only 288 kg/ha of forage was available within the deer browse tier with just 9 kg/ha of that being comprised of the seven foods most important to deer. Deer and possums ate much the same range of about 100 plant species, but there was very little overlap in the main food used by each species. For deer, woody plants comprised 70% of the annual diet, ferns 17%, and grasses 10%, with broadleaf (*Griselinia littoralis*) and lancewood (*Pseudopanax crassifolius*) being the two most important foods. Most deer forage consisted of adult tree foliage, much of it obtained as litterfall. Woody plants also predominated (c. 80%) in possum diet, followed by herbs and ferns (c. 5% each). Possums relied heavily on fruit at times, but the foliage of Hall's totara (*Podocarpus hallii*) was their main food. Overall, possums and deer consumed about 88 and 30 kg of forage/ha/yr, respectively, equating to 3.3% of total annual foliage production (AFP) for possums and just 1.1% of AFP for deer. Possums used 16 of the 40 most common species or species groups, but ate less than 12% of AFP for all but three of those. Deer consumed far greater proportions of the much smaller quantities of AFP available to them and, as a consequence, prevented regeneration for many of their preferred species. In contrast, possums appeared to have relatively little influence on the seedling heights (i.e., regeneration) of common species. Overall, there appeared to be little competition for food between the species, and possum impacts were focused on fewer woody plants than were deer impacts. Deer had a greater impact on regeneration patterns within the browse tier than did possums on the forest as a whole. Because neither species removed much of the total annual foliage production, major dieback or changes in abundance of the most common species appeared unlikely. However, most podocarps (excluding Hall's totara) and other unpalatable species appeared likely to increase and many of the palatable species likely to decrease while deer and possums remained uncontrolled. A major reduction in deer density (i.e., to <2 deer/km^2) would be required to significantly alter present regeneration patterns. If deer numbers remain above this level, intensive possum control would have little

effect on regeneration patterns, but should benefit established specimens of Hall's totara and other possum-preferred species not accessible to deer. These results suggest the Department of Conservation should reassess present priorities in possum and ungulate (deer and goat) control for vegetation protection, giving greater consideration to the dominant influence of ungulates on patterns of ground-level regeneration.

1. Introduction

The diets of red deer and possums and their likely impacts on the vegetation were assessed in a podocarp-hardwood forest by Manaaki Whenua-Landcare Research, Lincoln, for the Science and Research Directorate, Department of Conservation (DoC) as a complementary part of a Foundation for Research, Science and Technology (FRST)-funded investigation to quantitatively define and compare forage utilisation and impact patterns for the two species. The project was initiated in July 1989, with a planned 5-year time frame consisting of both pre- and post-control phases. However, deer and possum control was not implemented until winter 1994, so this report covers only the pre-control phase.

2. Background

Red deer (*Cervus elaphus scoticus*) and possums (*Trichosurus vulpecula*) are the two most widespread introduced herbivores in New Zealand forests. Although they consume a similar range of plant species (Leathwick *et al*. 1983) there have been no direct studies of the dietary overlap between the two species. Our goal in this study was to determine the relative impacts of possums and deer on the native flora. We approached this by measuring deer and possum densities, diets, and forage consumption, and then relating the absolute amounts of forage consumed to the quantity available and the rate at which it was produced. From the inferred balances between forage production and animal consumption, we attempt to deduce which animal threatens which plant species and the likely nature of the various animal density - animal impact relationships.

We address two main arguments:

- The relationship between deer density and their impacts on regeneration of their food plants is non-linear, and this relationship differs between plant species.
- Deer, rather than possums, have the greatest long-term impacts on forest composition and structure because these are ultimately determined mainly by ground-level regeneration patterns, not by the fate of canopy trees.

Edible litterfall (the wind-broken or cast, but still edible, green or yellowed foliage) from selected tree species has been identified as the primary source of deer and goat forage in native forests (Nugent & Challies 1988; Nugent 1990; Fraser 1991; Nugent 1993; Cochrane 1994). As a result, we hypothesise that the relationship between deer density and the regeneration of their food plants is unlikely to be linear (Nugent 1990; Nugent 1992, unpubl. FRI contract report). Only a small reduction in deer density below carrying capacity is required to protect the least preferred deer foods because these are only eaten as a last resort. In contrast, near total removal of deer is required to protect the most highly preferred species, as once a forest is "eaten out" the seedling biomass produced annually is insigificant. Therefore, this hypothesis predicts that at intermediate deer densities the reliance on litterfall means that small reductions in deer density simply result in more litterfall being left uneaten and little change in the consumption of preferred seedlings. Further, at intermediate deer densities, seedling size and total biomass of plants present in the browse tier (<2 m above ground level) will be very low and independent of deer density for preferred species, and high (but still independent of deer density) for species not preferred by deer. For species of intermediate palatability, or with some degree of browse resistance, we predict a negative relationship between deer density and seedling size or biomass.

The argument that deer, rather than possums, are likely to be the principal determinants of ongoing modification in forests where deer and possums have been established for more than 20 years (Nugent 1992, unpubl. FRI contract report; Nugent & Fraser 1993) has important implications for DoC's priorities for animal control. At present, DoC spends in excess of $6 million annually controlling possums (Parliamentary Commissioner for the Environment 1994), but less than $100,000 on deer control. Our basic premise is that forest composition and structure will be determined ultimately by regeneration patterns in the ground-level browse tier where deer have most impact. In the long-term, mortality of established trees caused by possums is largely irrelevant if the species is not able to regenerate.

We tested the above predictions mainly by comparing sites within our study area. Our study was conducted on a geographic scale large enough to be meaningful in terms of whole animal populations and ecosystems. As a consequence, the study has resulted in large data sets that are not easily summarised. Some results are therefore preliminary, as not all statistical analyses have been completed. We also report some incidental technical developments of relevance to DoC (new methods for assessing possum diet and the clarification of some problems with faecal-pellet counts).

3. Objectives

- To quantify the composition and biomass of forage species within the browse tier and in the overstorey, and relate these to forage consumption.
- To determine and compare the diets of red deer and possums, including the species composition, the amounts consumed, and the probable source of forage items.
- To assess and compare deer and possum impacts in relation to animal density and feeding patterns.

4. Methods

4.1 STUDY AREA

A 4 × 4 km grid was established in a 25 km^2 area of podocarp-hardwood forest in the headwaters of the Waihaha catchment, Pureora Conservation Park (Fig. 1). Most data were gathered from plots in the vicinity of 25 "foci".

Altitude ranges from 650 a.s.l. in the north to 850 m a.s.l. in the south, and the area is characterised by low flat-topped (but sometimes steep-sided) ridges. A full description of the physiography, geology, recent vulcanism, and climate of the area is given in McKelvey (1963). The forest is dominated by emergent miro (*Prumnopitys ferruginea*), rimu (*Dacrydium cupressinum*), Hall's totara (*Podocarpus hallii*), and matai (*Prumnopitys taxifolia*), and a main canopy of *Quintinia serrata* and kamahi (*Weinmannia racemosa*) or, at higher altitudes, pepperwood (*Pseudowintera colorata*) or *Quintinia serrata*.

Red deer colonised the area from the south or south-east c. 40–50 years ago, and cattle were present from the turn of the century (McKelvey 1963) until the 1970s (Jane 1979, unpubl. NZFS report). Possums also colonised the area from the south. Peak possum numbers and the associated depletion of the vegetation had occurred in our study area by the time of Jane's survey in 1978. The area east of, and including, the southeastern most margin of our study was aerially poisoned in 1984 to reduce the incidence of bovine tuberculosis in possums (Broome & Krzystyniak 1985, unpubl. NZFS report), and the entire area was poisoned again in winter 1994 on completion of this study (Fraser *et al*. 1995, unpubl. Landcare Research report). Pigs have also been long present, but goats remain absent.

4.2 ANIMAL ABUNDANCE AND FAECAL OUTPUT

Animal distribution and relative abundance were assessed from faecal-pellet counts and, for possums, the trap-catch method also. Likely long-term trends in animal numbers were assessed from hunter reports and previous surveys.

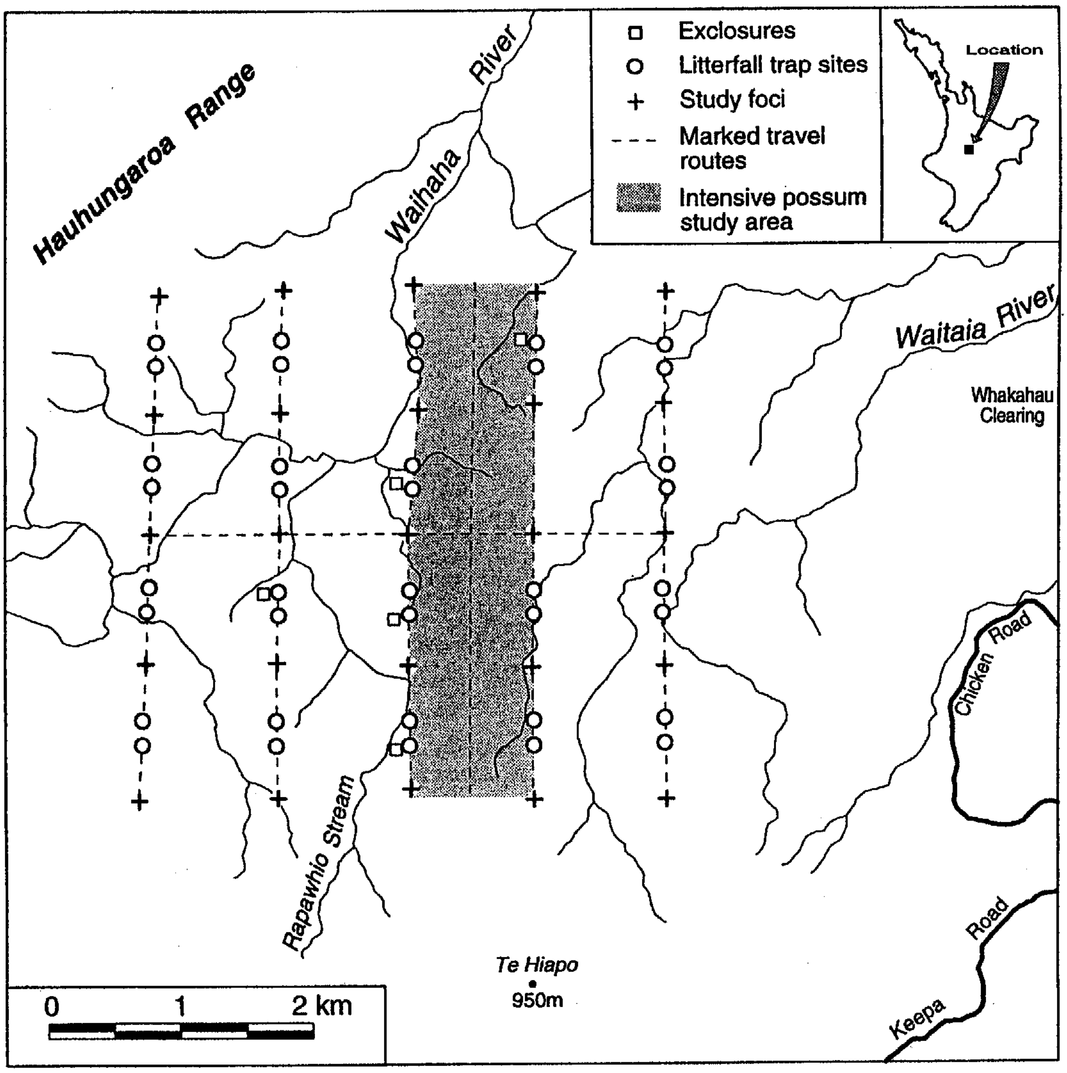


FIGURE. 1. THE STUDY AREA SHOWING LOCATIONS OF THE MARKED TRANSECTS, THE 25 PELLET COUNT AND VEGETATION ASSESSMENT FOCI, THE LITTERFALL TRAPS AND EXCLOSURES, AND THE CENTRAL POSSUM STUDY AREA.

4.2.1 Deer

We counted and marked all intact deer pellet groups (Baddeley 1985) found on 40 permanently marked 2.5 m radius plots established at each of the 25 foci on the 4 km^2 grid (1000 plots in total). The plots were spaced at 20 m intervals along four 200 m transects radiating along the major compass axes from each focus, and were searched quarterly from May/June 1990 to December 1992 and in December 1993. From these surveys we derived estimates of the faecal pellet group standing crop (the total number of groups present at any one time) and recruitment rate (the number of pellet groups deposited per hectare per day). Because deer avoid marked plots (see section 6.1) an additional 500 unmarked plots were searched each December (1990-1993). Overall deer density in the study area was estimated by correcting the annual recruitment rate recorded on the permanently marked plots for the difference between marked and unmarked plots and dividing by an assumed defecation rate for red deer of 20 groups per day in winter and 25 in summer (i.e., an annual average of 22.5 groups/deer/day; Mitchell & McCowan 1983, cited by Ratcliffe 1987). This is

This is considerably higher than the 12.5 groups/deer/day based on studies of North American wapiti (*Cervus elaphus nelsoni*) that has been assumed in previous New Zealand studies (e.g., Nugent *et al*. 1987), but that lower figure was used because it was the only data available for *Cervus elaphus* at that time.

To estimate absolute faecal output, the corrected density of pellet groups deposited each season was multiplied by the mean dry weight of pellet groups for that season, which was determined by collecting, drying (70ºC for 24 h), and weighing freshly deposited pellet groups from throughout the study area. These pellet groups were collected semi-randomly during the course of other work.

To investigate the relationship between deer density and seedling height on the permanently marked plots, we used the actual (uncorrected) pellet group recruitment rate for those plots as an index of relative deer abundance and use.

4.2.2 Possums

The presence or absence of possum faecal pellets was also recorded quarterly on 1.14 m radius plots (Baddeley 1985) with the same plot centres as those used to estimate deer abundance. There were no differences in pellet frequency (the percentage of plots with pellets present) between marked and unmarked plots.

In September 1993 and March 1994, the faecal-pellet recruitment rate for possums was measured directly on 10 transects located along the north-south grid lines between foci. On each transect, 29 plots (1.14 m radius) were located at 20 m intervals, and all pellets initially present were counted and removed. After 1 and 2 weeks, any fresh pellets were counted and collected, then dried (70º for 24 h), and weighed to determine the recruitment rate and total weight of pellets deposited per hectare per day. After the second resurvey, possum leg-hold traps were set at the 22 or 23 most central plot sites on each transect for 3 (September 1993) or 4 (March 1994) successive nights. Catch rate was recorded and used to estimate the absolute numbers of possums in the study area.

4.3 FOREST COMPOSITION AND FORAGE AVAILABILITY

4.3.1 Overstorey stem density and basal area

The composition of the forest overstorey was assessed by measuring stem diameter at 1.35 m above ground level for all trees and tree ferns >2 m tall on 355 circular 5 m radius plots centred on the permanently marked pellet plots. Methodology generally followed Allen & McLennan (1983). On all plots cover class scores (percentage of the canopy above the plot) were subjectively estimated for each species to determine relative species abundance between sites. The presence of epiphytes was also recorded.

4.3.2 Litterfall production

Overstorey litterfall production was assessed from 40 litterfall traps (0.28 m^2). Two traps were positioned along the north-south grid lines between each focus so that each was 400 m from the nearest focus (see Fig. 1). The forest overstorey was assessed at each trap, and traps were cleared quarterly from their establishment in September 1990 until March 1993. The material from each trap was sorted by species, dried, and weighed. Some traps were damaged by windthrown trees or branches or deliberately destroyed by hunters, but these were replaced as soon as possible.

4.3.3 Browse tier biomass and edible litterfall

In both March 1991 and March 1992, the botanical composition and biomass of forage (the foliage present) within the browse tier were determined by harvesting all potentially edible foliage within 2 m of ground level on 500 plots of 1 m^2 (20 plots per focus in each year), following the procedures in Nugent (1990). The harvested material was divided into three classes (edible litterfall, growing foliage within 45 cm of ground level, and growing foliage 45–200 cm above ground level), and then sorted by species, dried, and weighed. In addition, the heights of all woody seedlings were recorded. For three common species (pepperwood, *N. pedunculata* and *Coprosma "taylorae"*) the percentage of plot volume occupied was estimated visually. These percentages were later converted to estimates of dry foliar biomass using conversion factors derived from calibration trials.

Seasonal changes in the availability of edible litterfall were assessed by collecting edible litterfall from 250 plots (10/focus) in September and December 1991 and in March and June 1992.

4.3.4 Exclosures

Five deer exclosures were established near litterfall traps (see Fig. 1). Within each exclosure 32 plots (1 m^2) were established. A different eight of these were harvested at time of establishment, 1 year later, and 2 years later, using the same procedures as above. One of these exclosures was broken into by deer. Two "natural exclosures" were found, one large (>0.1 ha) and one small (c.20 m^2). Semi-quantitative "recce" descriptions (Allen & McLennan 1983) were made of the vegetation in the large exclosure and a similar site nearby to which deer had access. The vegetation of the small exclosure was described less formally.

4.4 DIET AND FORAGE CONSUMPTION

4.4.1 Deer

Samples of deer rumen contents were obtained from 104 deer shot by helicopter-based commercial hunters or research staff in the upper Waihaha catchment. Samples were washed over a 5.6 mm sieve and the retained fraction was sorted by species (or groups of related species), dried and weighed (Nugent & Challies 1988). Mean percentage dry weight composition was compared between four 3-month seasons (summer = December–February, autumn = March–May, and so on) and between helicopter- and ground-shot animals.

4.4.2 Possums

Possums were collected (using cyanide poison) initially from throughout the study area, but from September 1990 to December 1992 we systematically collected possums from a central 4 km^2 strip (see Fig. 1), aiming to take eight animals from each of the four 1 km^2 blocks within that strip in each of eight 1.5-month periods through the year.

Because microhistological analysis of faeces or stomach contents is seriously flawed as a technique for estimating diets (Barker 1986), we initially used a sieving approach similar to that used for deer but adapted for possums by using a smaller sieve (2 mm). Retained material was floated in a shallow tray of water and 100 fragments were randomly selected, identified, dried, and weighed. Although initially promising, it gradually became clear that species passed through the sieve differentially, and a new "layer-separation" technique was developed (Sweetapple & Nugent, in prep.). For possums poisoned with cyanide, the foods present in the stomach can be separated into layers, and the uniform material within each layer can be identified, then dried and weighed. The existence of such clearly identifiable layers indicates that little mixing (and therefore presumably little digestion) of foods occurs within the possum stomach. The layer-separation technique was used to analyse material from c. 10 possums for each 3 month season from mid 1991 to the end of 1992. A further c. 20 stomachs had already been analysed by sieving for the same period, and for all samples collected before that. For this report, data from both techniques are pooled, with no attempt to correct for any biases associated with sieving.

For both possums and deer, total forage consumption was estimated from total annual faecal output and digestibility data from the literature (Fitzgerald 1977, Domingue *et al*. 1991). For foliage only, total forage consumption was then partitioned by species according to their relative proportions in the annual diet.

4.5 FOLIAGE PREFERENCE AND UTILISATION INDICES

Preference indices (PIs) were derived to compare relative use (% in diet) with availability (% of forage available). These indices were calculated separately for deer and possums using Ivlev's index of electivity (see Nugent 1990) and range from &1 (present on vegetation plots but not in the rumens or stomachs sampled) to +1 (the converse), with a PI of 0 for species used in direct proportion to their availability. Diet and availability estimates were calculated for foliage only, and for deer, availability was that measured for the browse tier only. For possums, the forage available in the browse tier was added to an estimate of the overstorey forage available (litterfall production × foliage retention time (FRT)). The FRT for most species was provided by G. Hall (unpubl. data), while the remainder were "best-guess" assumptions.

Utilisation indices (UIs) were used to express actual foliage consumption by deer and possums as a percentage of the estimated foliage production for each plant species. For possums, foliage production was taken to be the sum of foliar litterfall, the estimated browse tier production, and the amounts used by possums and deer. For deer, three different indices were calculated (see Appendix 10.8).

5. Results

5.1 ANIMAL ABUNDANCE AND FAECAL OUTPUT

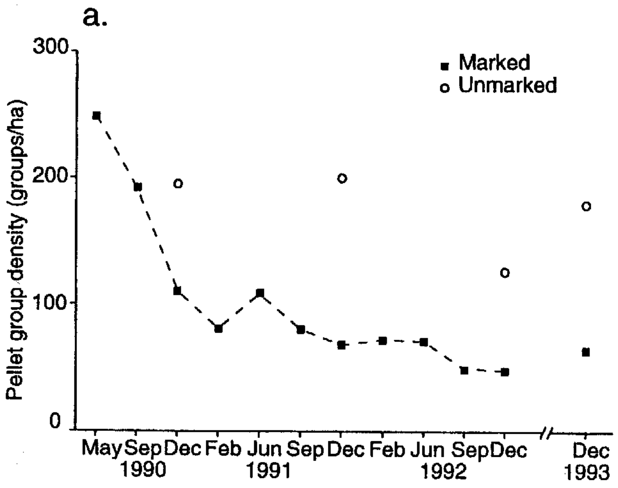
5.1.1 Deer

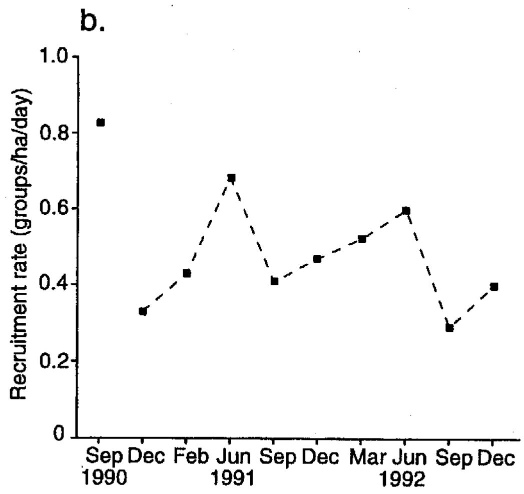
Anecdotal reports from recreational and commercial hunters suggest a substantial decline in deer density occurred during the late 1970s and early 1980s, coincident with the advent of commercial (ground and aerial) hunting. Helicopter harvests for all of Pureora Forest Park declined during the mid 1980s as hunters focused on live capture of deer, but from 1988 increased again as the focus reverted to carcass recovery. These reports are consistent with the estimates of faecal pellet density recorded during our study being about half those recorded in 1982/83 for the whole of the eastern flank of the Hauhungaroa Range (Broome & Krzystyniak 1985).

Pellet group density on the permanently marked plots declined sharply in the seasons after plot establishment in June 1990 and then stabilised (Fig. 2a). This decline reflected avoidance of the marked plots by deer rather than a decrease in deer density in the study area. The density of pellet groups on unmarked plots remained reasonably stable except in December 1992 (see Fig. 2a). The lower pellet group density in December 1992 partly reflected faster-than-usual disappearance of pellets in that year as the number of pellet groups recruited on marked plots was only slightly lower than in 1991 (182 and 166 groups/ha/yr, respectively, Fig. 2b). However, 26 deer were shot within the study area by research staff in 1992 compared with four or fewer in each of the other 3 years, so deer densities were probably also somewhat lower than average in 1992.

Pellet group densities on unmarked plots were 2.95, 2.65 and 2.80 (0 = 2.80) times higher than on marked plots in December 1991, 1992, and 1993 respectively. Correcting for plot avoidance and assuming a defecation rate of 22.5 groups/deer/day per day (Mitchell & McCowan 1983, cited by Ratcliffe 1987) suggests a density of c. 5.9 deer/km^2. This is similar to a deer density estimate derived by extrapolation from our estimate of forage consumption. The average live weight of deer shot in or near our study area was c. 72 kg (n=45) and deer of this size would consume c. 1.3 kg of dry matter per day (Domingue *et al.* 1991). Total actual forage consumption in the study area of 8.2 kg/km^2/day (see next paragraph) therefore suggests a density of c. 6.2 deer/km^2.

The mean dry weight of pellet groups varied between seasons (26.0, 24.4, 33.7 and 29.7 g for summer, autumn, winter and spring respectively). Multiplying these figures by the mean number of pellet groups recruited per season in 1991 and 1992 (Fig. 2b), and correcting for plot avoidance, indicates that the average annual faecal output was c. 13.6 kg/ha. Assuming that deer digest c. 55% of the forage ingested (Domingue *et al.* 1991), this faecal output estimate suggests an average annual forage consumption of 30 kg/ha/yr.





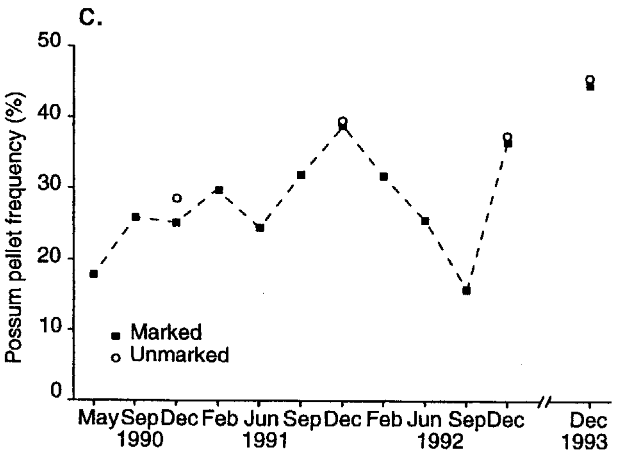


FIGURE. 2. CHANGES IN FAECAL PELLET DENSITY FOR DEER AND POSSUMS 1990-1993: (a) UNCORRECTED DEER PELLET GROUP DENSITIES PRESENT ON 1000 MARKED AND 500 UNMARKED PLOTS, (b) DEER PELLET GROUP RECRUITMENT RATE (ON 1000 MARKED PLOTS ONLY) FOR THE PRECEDING 3 MONTH SEASON (THE HIGH VALUE FOR SEPTEMBER 1990 REFLECTS THE LOCATION OF GROUPS NOT FOUND WHEN PLOTS WERE FIRST ESTABLISHED IN MAY 1990), (c) POSSUM PELLET FREQUENCY ON MARKED AND UNMARKED PLOTS.

5.1.2 Possums

Pellet frequencies did not differ between marked and unmarked plots in each of the four December surveys (Fig. 2c). However, pellet frequencies varied markedly between seasons within years, presumably reflecting the impact of seasonal differences in rainfall on pellet disappearance rates and seasonal variation in the total faecal output (see below). This seasonal variability in pellet frequency precludes accurate assessment of possum population trends during the study, but results from the four December surveys suggest that the possum population was increasing (pellet frequencies increased from 28% in 1990 to 45% in 1993). This is consistent with the study area being trapped by commercial hunters until 1988 (P. Avery, pers. comm.) and the area immediately east of the study area being aerially poisoned in 1984, with a subsequent recovery in possum numbers.

Direct assessment of possum pellet recruitment rate indicated a near-significant 40% increase in the number of pellets/ha/day between September 1993 and March 1994, which was supported by a 32% increase in trapping success (Table 1). In contrast, faecal output by weight declined (non-significantly) by 11%, which reflected a significant 35% decline in the mean dry weight of individual possum pellets (Table 1). Although the trap-catch rate and the number of pellets/ha/day suggest an increase, possum numbers probably declined between these two seasons (in agreement with the observed decline in faecal output by weight), because in any one breeding year possum numbers will be lowest in March just before the main birth pulse (although some spring

TABLE 1. COMPARISONS OF MEAN POSSUM DENSITY AND FAECAL OUTPUT ESTIMATES (±95% CONFIDENCE LIMITS) IN SEPTEMBER 1993 AND MARCH 1994.

	SEPTEMBER 1993		MARCH 1994		
	0	95% CL	0	95% CL	PROBABILITY
Trapping success (%)	18.6	±0.24	24.7	±0.26	<0.01
No. of pellets/ha/day	227	±34	318	±50	0.06
Pellet weight (g)	0.425	±0.015	0.279	±0.009	<0.001
Faecal output (kg/ha/yr)	34.9	±5.5	31.2	±4.9	0.3

breeding does occur in the study area). The greater trapping success in March 1994 probably reflects better weather, but possibly also the greater independence of juveniles (many of which were backriders in September 1993). The significant change in mean pellet weight is consistent with previous observations of considerable variation in the mean number of pellets deposited per plot over periods of only a few weeks (D. Morgan, unpubl. data).

Averaged across both assessments, possum faecal output for the whole study area was estimated at 33.0 ± 7.0 kg/ha/yr, ranging between 4.1 and 104.7 kg/ha/yr for individual transects. Possum densities were higher than average in the central 4 km^2 possum diet study area (faecal output = 44.4 ± 12.4 kg/ha/yr). These values under-estimate actual values slightly because some pellets never reach the ground and others are missed during plot searches.

Based on experience in previous possum-removal studies, the overall trap-catch rate (September 1993 and March 1994 combined) equates to a population density of c. 3.0 possums/ha (C. Frampton, pers. comm.). The average number of pellets/day (273/ha) therefore suggests possums were depositing 91 pellets/day (similar to the 105 pellets/day reported by Fitzgerald 1977).

5.2 FOREST COMPOSITION AND FORAGE AVAILABILITY

5.2.1 Overstorey composition

Sixty-three species >2 m tall were identified within the study area, but 38 of these were present on fewer than 5% of plots (Appendix 10.1). Pepperwood was most widespread (present on 87% of plots), followed by *Neomyrtus pedunculata* 73%, bush lawyer (*Rubus cissoides*) 69%, Hall's totara 63%, marbleleaf (*Carpodetus serratus*) 56%, *Quintinia serrata* 52%, kamahi 52%, toro (*Myrsine salicina*) 41%, black maire (*Nestegis cunninghamii*) 31%, pokaka (*Elaeocarpus hookerianus*) 27%, and broadleaf (*Griselinia littoralis*) 26%.

Overstorey stem density averaged 5316 ± 137 stems/ha, of which pepperwood comprised 31%, *N. pedunculata* 12%, bush lawyer 9%, *Q. serrata* 7%, wineberry (*Aristotelia serrata*) 7%, kamahi 6%, toro 4%, Hall's totara 4%, marbleleaf 4%, and *Coprosma* "*taylorae*" 3%. More than half the species (34) had stem densities of <10/ha.

Total basal area was estimated at 73 ± 18 m^2/ha, with podocarps much more dominant than their stem densities would indicate. Hall's totara comprised 19% of basal area, miro 14%, *Q. serrata* 11%, matai 11%, broadleaf 10%, rimu 8%, kamahi 5%, marbleleaf 5%, pepperwood 4%, and toro 3%.

Cover class scores indicated a similar order of abundance as stem density, except species with small average stem diameters ranked lower for mean cover class.

5.2.2 Epiphytes

More than 40 species were recorded as epiphytes (Appendix 10.2), with the various *Hymenophyllum* species (filmy ferns) occurring on most plots (78%). *Asplenium flaccidum* 69%, *Phymatosorus diversifolius* 57%, *Ctenopteris heterophylla* 22%, and *Asplenium polyodon* 7% were the other predominant fern species that occurred as epiphytes. Although the biomass of epiphytes was not quantified, *Collospermum microspermum* which occurred on only 35% of plots appeared to have the greatest overall biomass. Nineteen tree species were observed as epiphytes, but only four of these occurred on more than 2% of plots (broadleaf 17%, *Coprosma tenuifolia* 7%, *C. grandifolia* 4%, and fivefinger (*Pseudopanax arboreus*) 3%.

5.2.3 Litterfall

Total litterfall production averaged 4.28 tonnes/ha in 1991 and 3.98 tonnes/ha in 1992; 23% of this consisted of wood, and 7% of fine difficult-to-sort material including humus, tiny leaves and leaf scales, and bark fragments (Appendix 10.3). Fruit and flowers comprised 3% and 4% of total litterfall, respectively. On average about 2.5 tonnes/ha of foliar litterfall were produced annually in the study area. This is at the lower end of the range of values reported for podocarp-hardwood forest: e.g., 3.2 tonnes/ha from forest with a similar basal area (66 m^2/ha) in the Orongorongo Valley (Daniel 1975), 2.3 and 3.1 tonnes/ha for other Orongorongo Valley areas (Cowan *et al*. 1985), and 3.6 tonnes/ha from a Westland forest (Levett *et al*. 1985). The low value in our study area may reflect the higher altitude or the predominance of podocarps (nearly half the basal area, cf. 5% in the Orongorongo Valley).

Foliar litterfall was dominated by *Quintinia serrata* 31.7%, miro 9.6%, Hall's totara 6.9%, marbleleaf 6.9%, kamahi 6.7%, pepperwood 4.2%, toro 3.9%, bush lawyer 3.5%, black maire 3.4%, and pokaka 3.0% (Fig. 3; Appendix 10.3). Foliar litterfall was highest in summer and autumn, and lowest in winter and spring, largely reflecting the seasonal pattern for *Q. serrata* and miro (the most common components).

5.2.4 Edible litterfall

The quantity of potentially edible litterfall (green or yellowed leaves) present at any one time was small compared to total litterfall production, averaging just 28.9 kg/ha in the 4 seasons measured (Appendix 10.4). This material was dominated by bush lawyer, broadleaf, black maire, pepperwood, and marbleleaf.

Overall, edible litterfall was most abundant in June and September and scarcest in March. The availability of broadleaf litterfall peaked in December, but it was also high in June. For the seven species comprising >1% of the annual deer diet (section 6.3), 9.0 kg/ha were recorded in September, 11.0 kg/ha in December,

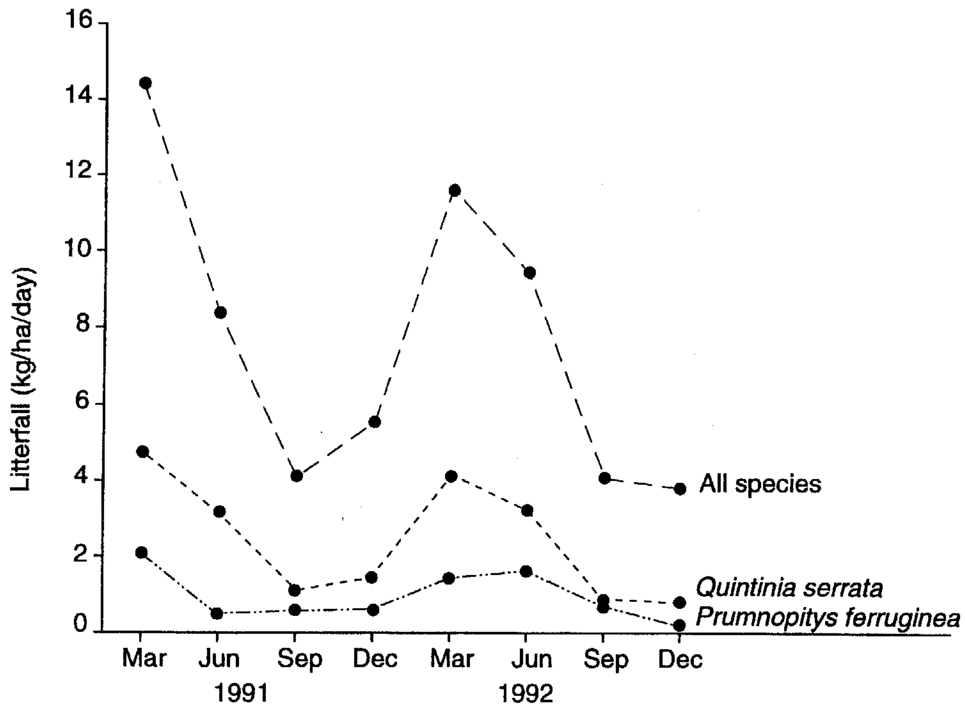
FIGURE. 3. SEASONAL VARIATION IN FOLIAR LITTERFALL PATTERNS FOR ALL SPECIES AND THE TWO MAIN COMPONENTS, *Quintinia serrata* AND *Prumnopitys ferruginea*.

7.9 kg/ha in March, and 11.8 kg/ha in June. These results indicate that the winter peak in availability of deer-preferred edible litterfall is not as marked as previously thought (Nugent 1990).

5.2.5 Browse tier biomass

A total of 134 plant species were identified within the browse tier. Total forage availability in this tier averaged 288 kg/ha, with 10% consisting of edible litterfall, 61% of foliage growing within 45 cm of ground level, and 29% of foliage in the 45–200 cm tier. Woody plants (45%) and ferns (44%) predominated (Appendix 10.5), with pepperwood (48.0 kg/ha), *Cyathea smithii* (27.8), waterfern (*Histiopteris incisa;* 23.4), *Blechnum fluviatile* (20.9), Hall's totara (17.2), *Leptopteris superba* (13.5), and *Dicksonia squarrosa* (11.0) being, in order of decreasing abundance, the most common individual species. For all other species, forage availability was <9 kg/ha.

Total forage availability was less than that recorded in beech or shrub-hardwood forest in the Blue Mountains (550 and 467 kg/ha, respectively; Nugent 1990). However, the difference mainly reflects the differing quantities of ferns and grasses that are of low palatability to deer (*Blechnum discolor, B. capense,* and *Uncinia* spp.), with similar quantities of woody-plant foliage (between 110 and 190 kg/ha) available in all three forest types (beech, shrub-hardwood, and podocarp-hardwood). For the seven most important deer foods, only 9.1 kg/ha of growing foliage was available. Kamahi comprised 50% of this, mostly as overstorey foliage that hung down into the browse tier.



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A total of 134 plant species were identified within the browse tier. Total forage availability in this tier averaged 288 kg/ha, with 10% consisting of edible litterfall, 61% of foliage growing within 45 cm of ground level, and 29% of foliage in the 45-200 cm tier. Woody plants (45%) and ferns (44%) predominated (Appendix 10.5), with pepperwood (48.0 kg/ha), *Cyathea smithii* (27.8), waterfern *(Histiopteris incisa;* 23.4), *Blechnum fluviatile (20.9),* Hall's totara (17.2), *Leptopteris superba (13.5),* and *Dicksonia squarrosa (11.0)* being, in order of decreasing abundance, the most common individual species. For all other species, forage availability was <9 kg/ha.

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5.3 DIET AND FORAGE CONSUMPTION

5.3.1 Deer

A total of 101 plant species or species groups were identified in the 104 rumens analysed, but only 50 comprised >0.1% of the total diet. Woody plants comprised c. 70% of the annual diet, with seven broadleaved tree species being the most important of this group (broadleaf 22%, lancewood *(Pseudopanax crassifolius)* 14%, pokaka 6%, kamahi 6%, mahoe *(Melicytus ramiflorus)* 3%, marbleleaf 1%, and *Coprosma grandifolia* 1%; Fig. 4; Appendix 10.6). Fern foliage (17%) was also important, with *Blechnum fluviatile* (8%) and *Dicksonia squarrosa* (4%) being the most commonly used individual species. Overall, grasses were moderately important (10%) and consisted mainly of introduced grasses and bush rice grass *(Ehrharta diplax)*.

Deer made greater use of woody species in autumn and winter. Although the use of broadleaf did not differ seasonally, lancewood and kamahi use was higher in autumn and winter and lower in spring and summer (see Fig. 4b). The most notable seasonal difference was a threefold increase in fern use between winter and summer, which was largely due to increased use of *D. squarrosa* and B. *fluviatile* (see Fig. 4a,c).

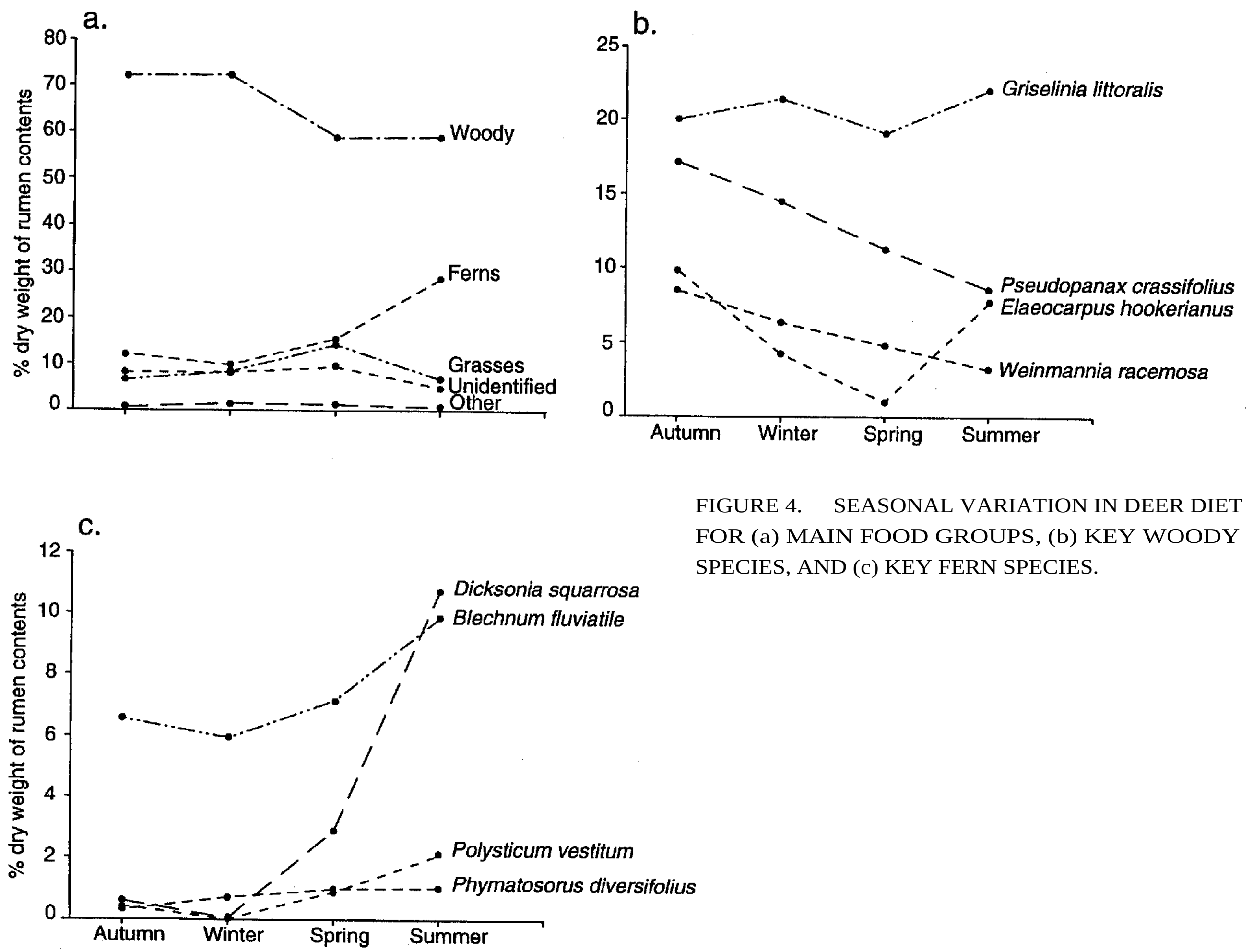

FIGURE 4. SEASONAL VARIATION IN DEER DIET FOR (a) MAIN FOOD GROUPS, (b) KEY WOODY SPECIES, AND (c) KEY FERN SPECIES.

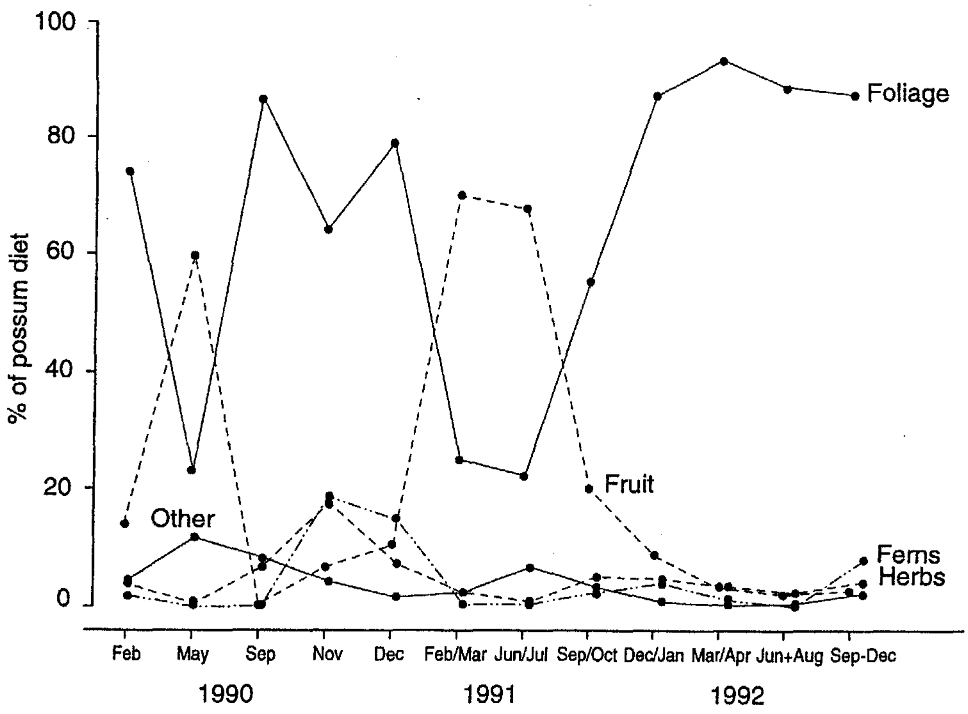

FIGURE 5. SEASONAL VARIATION IN POSSUM DIET FOR THE MAIN FOOD GROUPS.

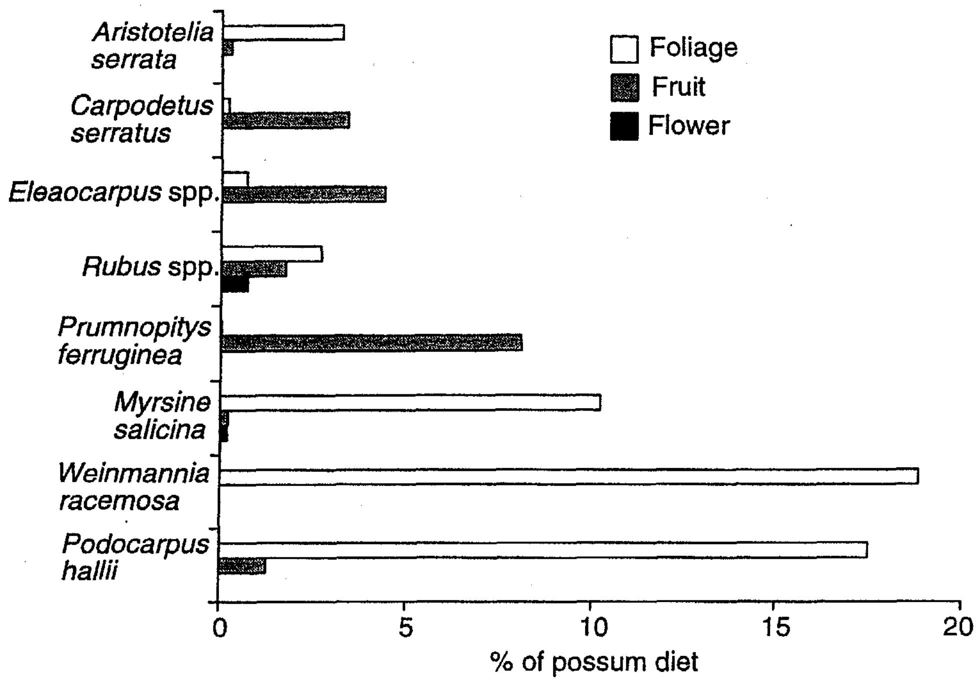

FIGURE 6. RELATIVE IMPORTANCE OF FOLIAGE, FRUIT, AND FLOWERS IN THE ANNUAL DIET OF POSSUMS.

Most of the material consumed by deer was classed either as adult foliage (either green "fresh" leaves (56% of annual diet) or older yellowed senescent leaves (24%)) or as stems (12%). Deer obtained most woody-plant foliage as litterfall (see also Nugent & Challies 1988, Nugent 1990, Fraser 1991, Nugent 1993). For broadleaf, the main food, 70% consisted of yellowed leaves (93% in summer and 55% in winter). For lancewood, 53% of the leaves eaten in summer were yellowed (cf. <1% of those eaten in winter). For lancewood and pokaka, the green leaves consumed were obviously from above the browse tier because they were almost always of adult rather than juvenile form. Partly digested and unidentifiable fibre (7%) was probably also of leaf or stem origin (we suspect mostly from lancewood leaves or grasses because these foods were typically present in samples with larger amounts of unidentifiable fibre). Small woody seedlings, fruit, and other material (such as fungi) each comprised <1% of annual diet.

5.3.2 Possums

A similar number of foods (102 species or species groups) were identified for possums as for deer. However, fewer foods (42) comprised >0.1% of the mean annual diets (Appendix 10.7). Woody plants also predominated in the possum diet (c. 80% of annual diet), with ferns of lesser importance (c. 4%). In contrast to the deer diet, herbs were moderately important (5%) and grasses were not (<1%). Invertebrates formed about 2% of the diet over the 3 years, although this is probably an overestimate (sieving bias). Although some differences between years are apparent and these are partly complicated by the different analytical approaches used, the overall patterns are relatively consistent.

The plant parts eaten by possums were more varied than those eaten by deer. Most notably, possums used fruit extensively in 1990 and 1991, but fruit was relatively unimportant in 1992 (Fig. 5), presumably reflecting its non-availability that year. The use of fruit was strongly seasonal, comprising a high proportion of the diet in autumn 1990 and in autumn and winter 1991. The main fruits eaten were miro, pokaka and hinau (*Elaeocarpus dentatus*) (which were not easily distinguished), and marbleleaf. For Hall's totara, toro, and wineberry, some fruit was eaten, but foliage was more important. Flowers were also occasionally eaten by possums (Fig. 6), and in spring 1991 bush lawyer flowers comprised 7% of seasonal diet (a probable under-estimate). Flowers of toro and *Clematis* spp. comprised >1% of seasonal diet on two occasions. Insects and insect larvae also comprised >1% of diet in some seasons, usually either winter or spring. A single feather was observed in one stomach in spring 1991, but birds did not form a significant part of possum diet in the study area — we are confident that, with the layer separation methods at least, any egg material would have been detected, especially if the embryo had begun to develop.

Use of foliage varied inversely in relation to the use of fruit (Fig. 5). Of the foliage consumed, Hall's totara was used year-round but with a strong peak in summer, while use of kamahi and toro, the second and third most important species, was lowest in that season (0–6%). In 1991 and 1992, kamahi consistently comprised c. 30% of the foliage consumed in all seasons except summer. Toro was more seasonally variable, comprising c. 15% of foliage consumed in autumn, c. 30% in winter, and c. 25% in spring. The switch from kamahi and toro to Hall's totara in summer indicates that Hall's totara foliage is most preferred by possums at the height of the growing season.

Miro, pokaka, and hinau fruit were important foods during late autumn 1990 and 1991 and winter 1991 but of minimal importance in any season in 1992. Marbleleaf fruit was also identified as an important component of the diet in 1991 but not in other years. There was an apparent fruiting failure in 1992 which coincided with a wet cold winter. Many dead or dying possums were seen in September that year (cf. few or none seen in 1990, 1991, or 1993).

Some marbleleaf foliage was consumed when possums were feeding on marbleleaf fruit in 1991, but apparently not at all in 1992 when fruit were absent. Cowan (1990a) describes similar year-to-year variation in the use of marbleleaf fruit. This suggests that possums eat foliage of some fruit-bearing plants when fruit is present, but would not bother otherwise. Bush lawyer foliage was a moderately important diet component (3-16%) in summer and autumn (when bush lawyer fruit was available), compared with <1% in most other seasons, yet foliage was sometimes eaten in summer and autumn when fruit was not. Wineberry use was also strongly seasonally, comprising 3-6% of spring and autumn diet but <1% in other seasons.

About 10-20% of annual possum diet was likely to have been obtained at ground level (principally ferns, herbs, and invertebrates). For ferns and herbs, use tended to be highest in spring or summer, whereas invertebrates (mainly *Diptera* larvae) were most heavily used in autumn/winter in 1990 and 1991.

5.3.3 Deer vs possums

Although deer and possums consumed a similar range of species, there was little dietary overlap in their main foods (Fig. 7). Even for the few apparently "shared" food species, the overlap was minimal - for pokaka, marbleleaf, and wineberry, possums ate mainly fruit whereas deer ate foliage. Only kamahi foliage was common to both, but it is likely that possums browsed canopy leaves whereas deer consumed litterfall. Unlike deer, possums seldom ate senescent leaves. Similar dietary separation between possums and ungulates (thar and chamois) has been observed in the Southern Alps (Parkes & Thomson 1993, unpubl. Landcare Research contract report).

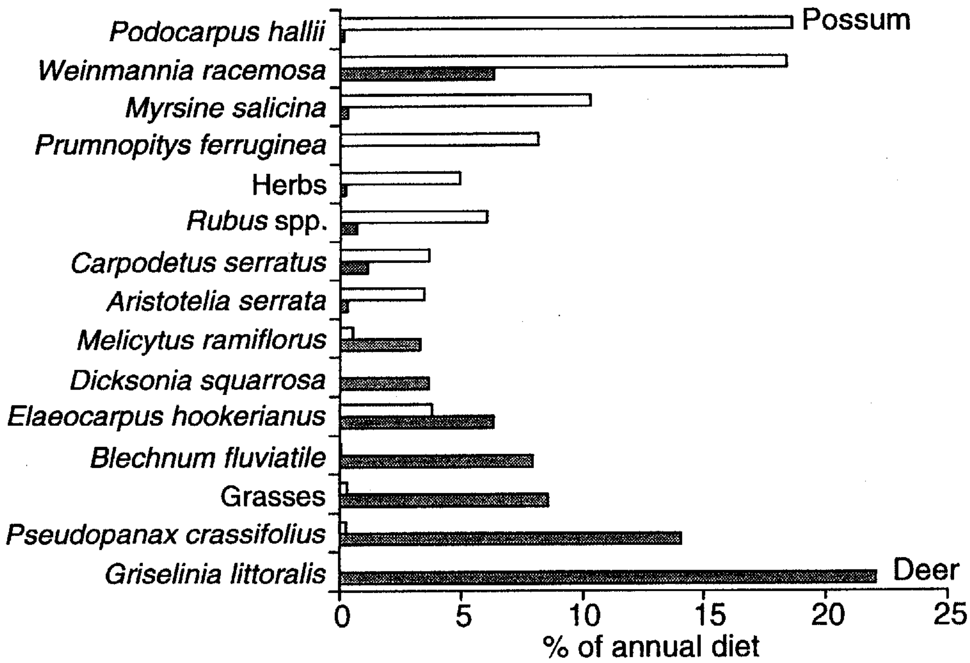

FIGURE 7. DIETARY OVERLAP BETWEEN POSSUMS AND DEER FOR THEIR MAIN FOOD ITEMS (POSSUM DATA INCLUDE FRUIT AND FLOWERS).

Although possum diet appeared more variable seasonally and between years than deer diet, the foliage component of the possum diet was more restricted, particularly for woody species. Of the 42 woody species identified in the deer rumen samples, 11 comprised >1% and 33 comprised >0.1% of the foliar material. Of the 39 woody species in possum stomachs, only six comprised >1% of the foliage consumed and only 18 comprised >0.1%.

An average of 5.9 foods (species or species groups) were identified in each possum stomach, 5.4 of these comprising ≥1% of the material sorted. In contrast, of the average of 16.9 foods identified in each deer rumen, only 9.4 comprised >1%. This difference is partly because most possum stomachs did not contain food from a full night's feeding, and partly because of greater mean retention times of foods in deer rumens than in possum stomachs. However, it may also indicate a greater tendency for possums to focus on a few foods each day.

5.4 FOLIAGE PREFERENCE AND UTILISATION INDICES

For the species or species groups comprising >0.1% of possum or deer diet, or with total annual foliage production (AFP) of >0.1 kg/ha/yr, the number preferred by possums and deer was similar (28 and 32, respectively). However, deer preferred more of the woody species than possums, whereas possums preferred more of the rare small-leafed herbaceous species (Table 2; Appendices 10.8, 10.9).

Possums consumed only 3.3% of the annual foliage production, and deer only 1.1% (Fig. 8; Appendices 10.8, 10.9). Of the 40 most productive species (by total AFP), possums consumed detectable amounts of only 16 species. This included an estimated 44% of AFP for mahoe, 20–30% for large- and small-leaved *Coprosma* species, c. 10% for Hall's totara, toro, and kamahi (their three main foods), and only small amounts for the 10 other species or species groups (Fig. 8). Possums consumed c. 9% of AFP for *Polysticum vestitum* but only small

TABLE 2. NUMBERS OF PREFERRED SPECIES OR SPECIES GROUPS, BY PLANT CATEGORY, FOR POSSUMS AND DEER. ONLY SPECIES OR SPECIES GROUPS COMPRISING >0.1% OF ANNUAL DIET OR WITH TOTAL ANNUAL FOLIAGE PRODUCTION >0.1 kg/ha/yr ARE INCLUDED. PI = PREFERENCE INDEX (PI>0 = PREFERRED, PI<0 = LESS OR NOT PREFERRED).

	POSSUMS		DEER	
	PI>0	PI<0	PI>0	PI<0
Woody	11	31	17	27
Ferns	3	16	5	16
Grasses	0	6	2	5
Herbs	8	2	2	10
Other	0	2	2	1
Total	22	57	28	59

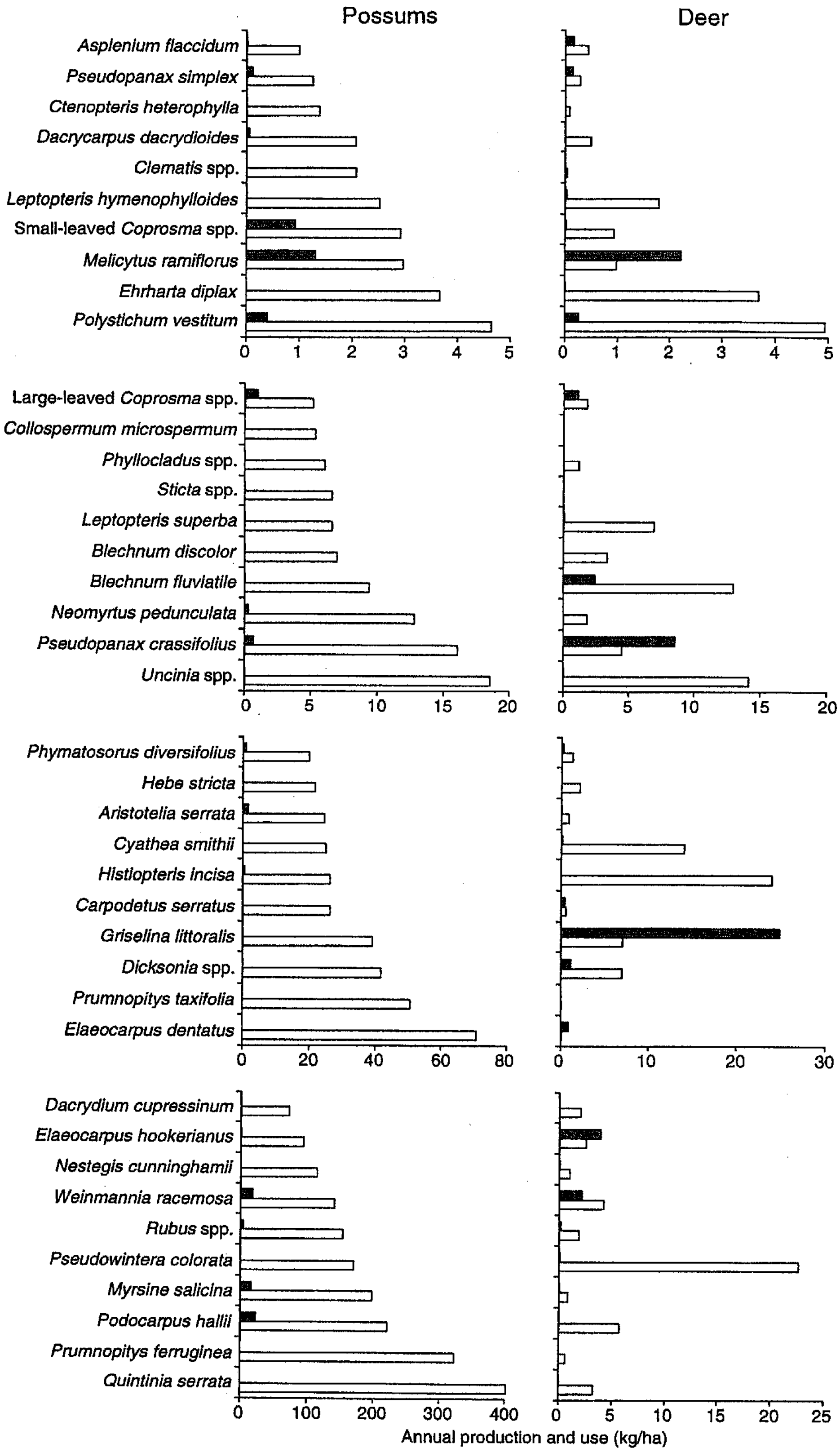

FIGURE 8. COMPARISONS BETWEEN ESTIMATED ANNUAL FOLIAGE PRODUCTION (OPEN BARS) AND ESTIMATED USE (SOLID BARS) FOR POSSUMS AND DEER. ONLY THE 40 MOST COMMON (i.e., HIGHEST ANNUAL FOLIAGE PRODUCTION) SPECIES ARE SHOWN AND FOR DEER THE X-AXIS IS ANNUAL BROWSE TIER PRODUCTION RATHER THAN TOTAL PRODUCTION.

percentages (<5%) of any of the other common ferns, grasses, or non-vascular plants with AFP of >1 kg/ha/yr. However, possums did consume significant proportions of many herbaceous species (see Appendix 10.9), all of which were rare (AFP<1 kg/ha/yr).

Although deer consumed only about one-third the quantity of foliage eaten by possums, the quantity actually available to them was far less. Only 191 kg of foliage was produced annually within the browse tier, about 8% of total AFP (Appendix 10.8). Therefore, deer use a much higher proportion of the growing foliage available to them (Fig. 8). Because deer use not only foliage produced within the browse tier, but also litterfall from the canopy, the quantities actually used occasionally exceeded the estimated annual browse tier production (ABTP) for preferred species (see Fig. 8). Utilisation Index 1 (Appendix 10.8) was therefore calculated by assuming that deer did not prefer growing foliage to edible litterfall. Even though this is likely to give conservative estimates of utilisation (because growing foliage intuitively appears likely to be preferable to senescent, frequently yellowed foliage), the resulting index suggests that deer remove most (if not all) of the ABTP for most of their main foods (broadleaf, lancewood, pokaka, large-leaved *Coprosma* species, and mahoe). An exception is kamahi (39% of ABTP for Utilisation Index 1).

5.5 IMPACTS ON REGENERATION

5.5.1 Inhibition of height growth in woody plants

Overall, there were nearly 200 000 short (<51 cm) seedlings, 15 000 tall seedlings (51–200 cm), and 5000 "adult" (>200 cm) saplings and trees per hectare. With one exception (pokaka), all of the deer-preferred species (PI>0) had fewer tall seedlings than "adults", whereas species not preferred by deer (PI<0) typically had more than twice as many tall seedlings as "adults" (Table 3, Fig. 9). Therefore, deer appear to be impeding regeneration of most of the preferred woody species. The exception, pokaka, appears better able to cope with deer browsing because of its juvenile divaricating small-leaved habit. This habit probably also explains the greater than average (for prefered species) value for marbleleaf. Four species (*Quintinia serrata*, toro, wineberry and *Myrsine divaricata*) with low deer PIs also had low tall-seedling-to-"adult" stem ratios (Fig. 9), but of these *Q. serrata* may have been more heavily affected in the past (see section 6.6), and both wineberry and toro are preferred by possums. In addition, the low apparent use of toro is probably a statistical anomaly because we frequently observed heavy browsing of epicormic shoots within the browse tier but not above it, a clear indication of high deer (rather than possum) use. Although many of the species heavily used by possums were also those with low tall-seedling-to-"adult" stem ratios, there were more exceptions than for deer, most notably Hall's totara, their main food (Fig. 9).

Inhibition of regeneration was also apparent in the height distributions for short woody seedlings. Non-divaricating woody species preferred by deer tended to have few or no seedlings >10 cm tall, consistent with the high utilisation indices for these species. The occasional seedlings >10 cm tall were invariably

TABLE 3. NUMBER OF STEMS/ha, BY TIER, AND THE RATIO OF TALL SEEDLINGS (51–200 cm) TO "ADULT" STEMS (>200 cm). SPECIES WITH FEWER THAN 5 STEMS/ha IN THE >200 cm CLASS ARE EXCLUDED.

	TIER(cm)			RATIO
	0–50	51–200	>200	
All species	198 950	15 150	5316	2.8
More tall seedlings than "adults":				
Pseudowintera colorata	37 940	7690	1658	4.6
Neomyrtus pedunculata	11 860	3780	620	6.1
Podocarpus hallii	4410	610	215	2.8
Coprosma "taylorae"	4450	690	135	5.1
Hebe stricta	1250	250	128	2.0
Nestegis cunninghamii	9160	210	85	2.5
Elaeocarpus hookerianus	9340	350	64	5.5
Prumnopitys ferruginea	3210	150	37	4.1
Melicope simplex	1040	130	20	6.5
Dacrydium cupressinum	340	130	19	6.8
Leucopogon fasciculatus	420	40	15	2.7
Prumnopitys taxifolia	940	20	11	1.8
Pseudopanax anomalus	1470	190	10	19.0
Phyllocladus trichomanoides	370	80	7	11.4
Fewer tall seedlings than "adults":				
Aristotelia serrata	560	180	364	0.5
Quintinia serrata	4660	190	356	0.5
Weinmannia racemosa	7410	20	317	0.1
Myrsine salicina	28 910	30	217	0.1
Carpodetus serratus	1390	150	190	0.8
Griselinia littoralis	30 050	10	58	0.2
Pseudopanax crassifolius	21 670	10	29	0.3
Coprosma tenuifolia	2700	30	30	1.0
Coprosma foetidissima	140	20	20	1.0
Pseudopanax simplex	3950	0	13	0.0
Myrsine divaricata	170	10	12	0.8
Coprosma grandifolia	1760	0	10	0.0
Melicytus ramiflorus	350	0	5	0.0

"hidden" in less accessible areas such as bush lawyer thickets or steep banks. In contrast, species seldom eaten by deer frequently had >50% of seedlings in the >10 cm classes. Between these extremes, some species not often eaten by deer or possums had moderate numbers of seedlings >10 cm, as did palatable but browse-resistant species such as pokaka, marbleleaf, and kaikomako (*Pennantia corymbosa*).

Diameter class distributions indicate the extent of regeneration inhibition more clearly. Species apparently little affected by browsing had many more small-diameter (<1 cm) tall seedlings and saplings than large-diameter stems (e.g., Fig. 10a–f). These included *Pseudowintera colorata, Neomyrtus pedunculata*, pokaka, and all the podocarp species. Pokaka was the only deer-preferred species in this group.

For a second group of species, small-diameter seedlings were reasonably common, but there were fewer saplings than stems of larger diameter (Fig. 10g–i). This group includes *Quintinia serrata*, black maire, and marbleleaf. We

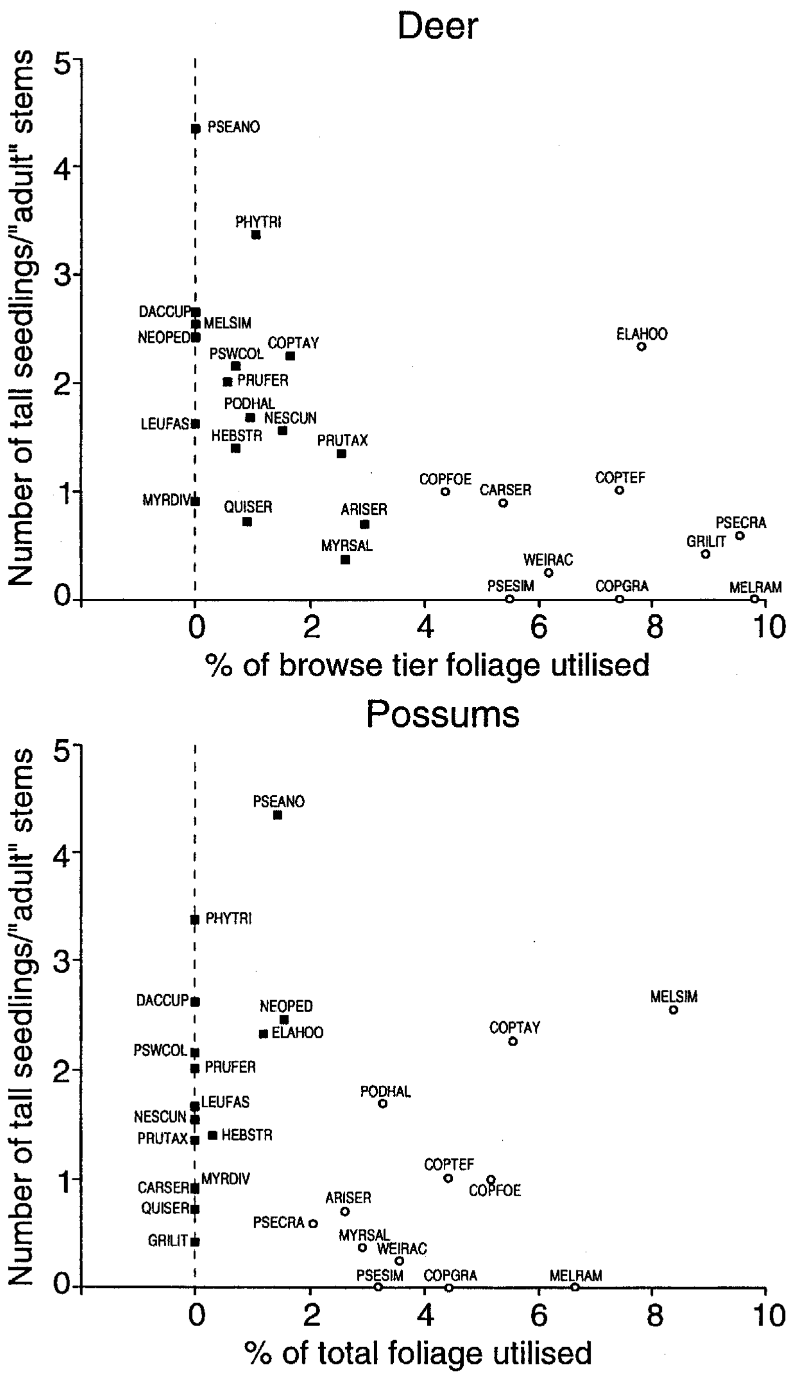

FIGURE 9. RELATIONSHIP BETWEEN "REGENERATION SUPPRESSION" (THE RATIO OF TALL SEEDLINGS (50-200 cm) TO "ADULT" STEMS (>200 cm)) AND UTILISATION FOR DEER AND POSSUMS. THE LABELS FOR EACH POINT REPRESENT THE FIRST THREE LETTERS FROM EACH OF THE GENUS AND SPECIES NAMES; • DENOTES PI<0, O DENOTES PI>0. A KEY DIFFERENCE BETWEEN POSSUMS AND DEER IS THAT POSSUMS CAN ALSO AFFECT THE ABUNDANCE OF "ADULT" STEMS. BOTH AXES ARE TRANSFORMED (SQUARE ROOT) FOR VISUAL CLARITY.

suggest that for most of these species, regeneration has been impeded by higher deer densities in the past, but they are now at least partly recovering (i.e., these are species that have benefited from the deer control provided by recreational and commercial hunters). Although most of the species in this

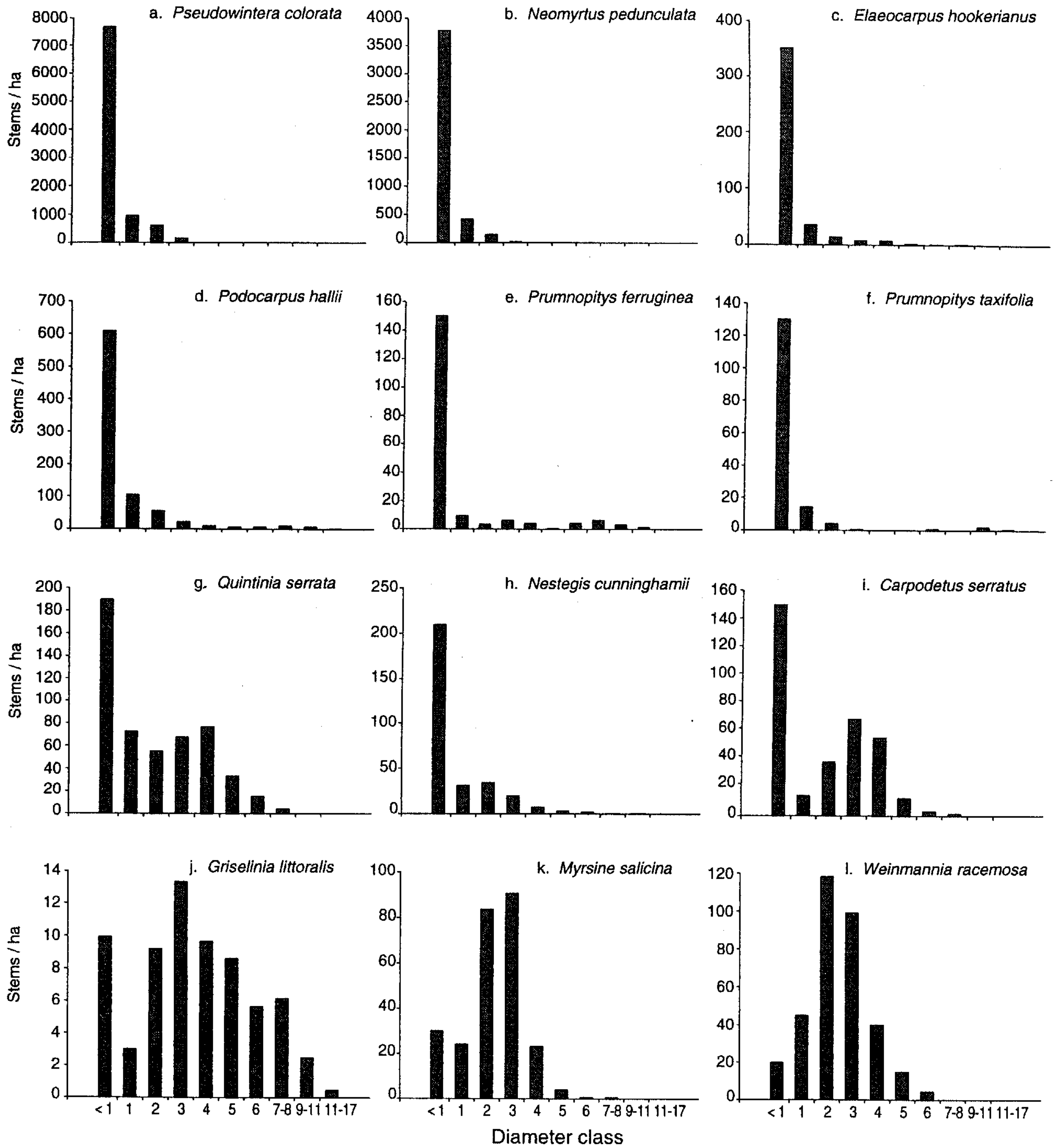

FIGURE 10. DIAMETER-CLASS DISTRIBUTIONS FOR REPRESENTATIVE PLANT SPECIES IN WHICH REGENERATION IS APPARENTLY LITTLE AFFECTED (A-F), SPECIES THAT MAY HAVE BEEN AFFECTED IN THE PAST BUT ARE LESS SO NOW (G-I), AND SPECIES THAT ARE HEAVILY AFFECTED (J-L). TREE DIAMETERS WERE TRANS-FORMED (SQUARE ROOT) TO REDUCE SPREAD.

group were not preferred by deer, they all occurred in the diet in small quantities. Marbleleaf, the only deer-preferred species in this group, has a divaricating juvenile habit.

For the remaining species, small-diameter seedlings and saplings are relatively scarce, indicating an ongoing and severe inhibition of regeneration (Fig.10j-l).

Except for toro, this group is composed entirely of deer-preferred species, and includes broadleaf, kamahi, and lancewood. As noted above, we believe that the exception, toro, is also actually a deer-preferred food (despite the low sample PI calculated from our data).

5.5.2 Exclosures

The two annual remeasurements of the four experimental exclosures indicated that woody plants responded only slowly to the removal of deer browsing pressure. All four undamaged exclosures were in closed-canopy forest, with lower than average browse tier biomass. For the three most common heavily suppressed species (broadleaf, toro, and lancewood), the number of seedlings in the 3–15 cm tier has more than doubled, whereas the number of non-deer-preferred species has changed little (Table 4). However, the mean height of seedlings increased only slightly, and maximum seedling height after 2 years was only 5–10 cm for deer-preferred species. The increase in woody plant biomass was therefore minimal, consistent with the low annual production of woody forage species in the browse tier estimated from the standing crop of biomass and assumed foliage retenetion times.

Excluding thallose lichens (seldom eaten by possums or deer), the harvest of non-woody biomass (ferns, herbs, and grasses) increased from 32 kg/ha to 70 kg/ha, mainly reflecting a fourfold increase in deer-preferred species (principally *Blechnum fluviatile* and *Dicksonia squarrosa*). For most species, sample sizes were too low to demonstrate significant differences, but *B. fluviatile* was present on most plots and doubled in biomass each year. *B. fluviatile* also appeared to be increasing in abundance outside exclosures

TABLE 4. NUMBERS OF WOODY SEEDLINGS 3–15 cm TALL IN FOUR EXCLOSURES. EIGHT DIFFERENT 1 m^2 PLOTS WERE ASSESSED WITHIN EACH EXCLOSURE 0, 1, AND 2 YEARS AFTER THE EXCLOSURE WAS ESTABLISHED. ONLY SPECIES FOR WHICH A TOTAL OF >10 SEEDLINGS WERE RECORDED ARE SHOWN.

	YEARS SINCE ESTABLISHMENT		
	0	1	2
Preferred by deer (PI>0):			
Coprosma tenuifolia	9	3	7
Griselinia littoralis	16	35	53
Myrsine salicina	11	18	37
Pseudopanax crassifolius	14	15	23
Pennantia corymbosa	6	11	2
Total	56	82	122
Avoided by deer (PI<0):			
Coprosma "taylorae"	13	3	19
Nestegis cunninghamii	11	10	6
Podocarpus hallii	3	4	5
Pseudopanax anomalus	5	7	4
Pseudowintera colorata	12	21	28
Quintinia serrata	11	0	2
Total	55	45	64

despite moderately heavy use by deer (19% of ABTP utilised annually), as the biomass of this species was greater in 1992 than in 1991.

Examination of the two "natural exclosures" inaccessible to deer but accessible to possums confirmed the effects of deer on woody seedling abundance and height inferred from the data above. Although broadleaf, large-leaved *Coprosma* species and fivefinger were more common as epiphytic seedlings above the reach of deer than at ground level (Appendix 10.2), these species (and others) were also common as tall seedlings on bluffs and in the two natural exclosures.

In the larger of these (flat terrace forest dominated by *Quintinia serrata*), tall seedlings (0.3–2.0 m) of broadleaf, kamahi, *C. grandifolia, P. simplex, C. lucida*, and fivefinger were present (>1%, and usually >5% of ground cover), but were absent or rare (<1%) in an adjacent area of similar forest accessible to deer. Tree fuchsia (*Fuchsia excorticata*) saplings were also present on the steep sides of this area, but not on the flat top. The understorey was not particularly dense, but preferred ferns were more abundant in the natural exclosure.

In contrast, the fern cover in the smaller natural exclosure at a damp site was near complete. This area was previously accessible to deer as a disused game trail lead down into it. *Blechnum procerum* and *Astelia solandri* were present at ground level. Tall seedlings and saplings were observed for broadleaf, toro, black maire, tree fuchsia, pokaka, *Coprosma grandifolia, C. lucida, Pseudopanax. simplex, C. tenuifolia,* fivefinger, *Alseuosmia pusilla, A. turneri,* and *Quintinia serrata*. On the adjacent accessible bluff top a few metres away, only pepperwood and tiny seedlings of *Q. serrata* were present, with some browse apparent on the latter.

5.5.3 Relationship between animal density and seedling height

Deer and possum density differed significantly between foci. The differences were consistent between 1991 and 1992 (R^2>0.6 for both species), indicating that the distribution pattern of animals (and presumably therefore use of foliage) was stable.

There were few significant relationships between the mean height of short seedlings (<50 cm) at each focus and possum or deer density. For most deer-preferred species (and also for toro), mean seedling heights at all foci were low (usually <5 cm) and independent of deer density (Fig. 11). Therefore, even at the lowest deer densities within our study area (approximately 2 deer/km^2) there was no evidence of any recovery in regeneration for these species. The key exceptions were marbleleaf, pokaka, and kamahi, the first two being "protected" by their divaricating habit. For kamahi, mean seedling height did increase significantly with decreasing deer density (i.e., the tallest seedlings were found in areas with fewest deer). Significantly more deer-preferred species (10/12) had negative regression coefficients than species not preferred by deer (8/20, $p<0.05$). This suggests that seedling height is inversely related to deer density for most deer-preferred species, but the decrease in height with any increase in deer density is small. For marbleleaf, pokaka, and the non-deer-preferred species, mean seedling heights were usually >5 cm, and statistically appeared to be independent of deer density.

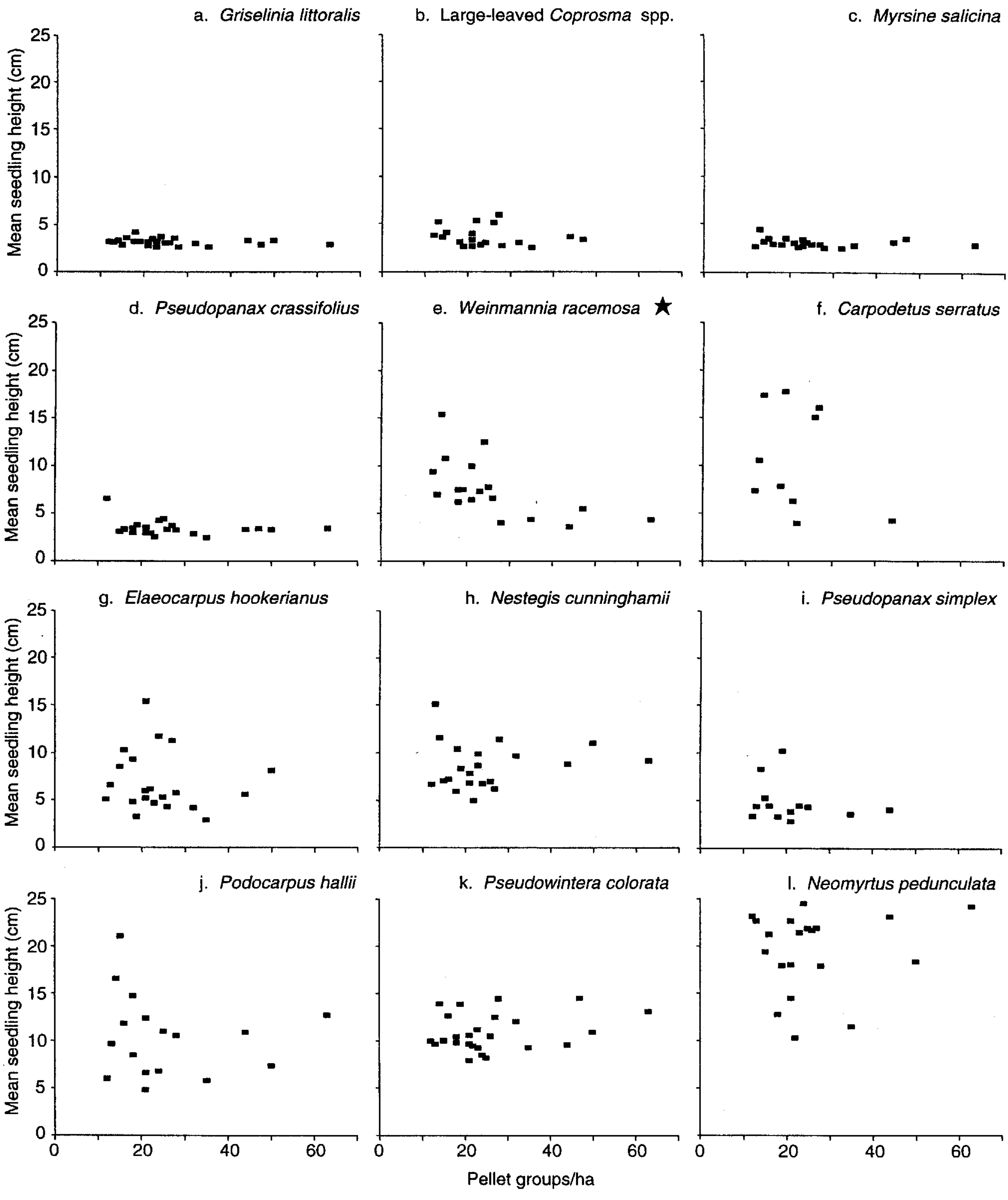

FIGURE 11. RELATIONSHIP BETWEEN RELATIVE DEER DENSITY AND MEAN SEEDLING HEIGHT IN THE 3-45 CM TIER AT EACH OF THE 25 FOCI. FOCI WITH <10 SEEDLINGS ARE EXCLUDED, AS WERE SEEDLINGS <3 cm TALL (MOST SEEDLINGS REACH THIS HEIGHT SOON AFTER GERMINATING, REGARDLESS OF DEER DENSITY). THE INDEX OF RELATIVE DEER DENSITY IS THE TOTAL NUMBER OF GROUPS DEPOSITED ON THE 40 PERMANENT PLOTS AT EACH FOCUS IN 1991 AND 1992; DENOTES A SIGNIFICANT INVERSE RELATIONSHIP BETWEEN DEER DENSITY AND SEEDLING HEIGHT.

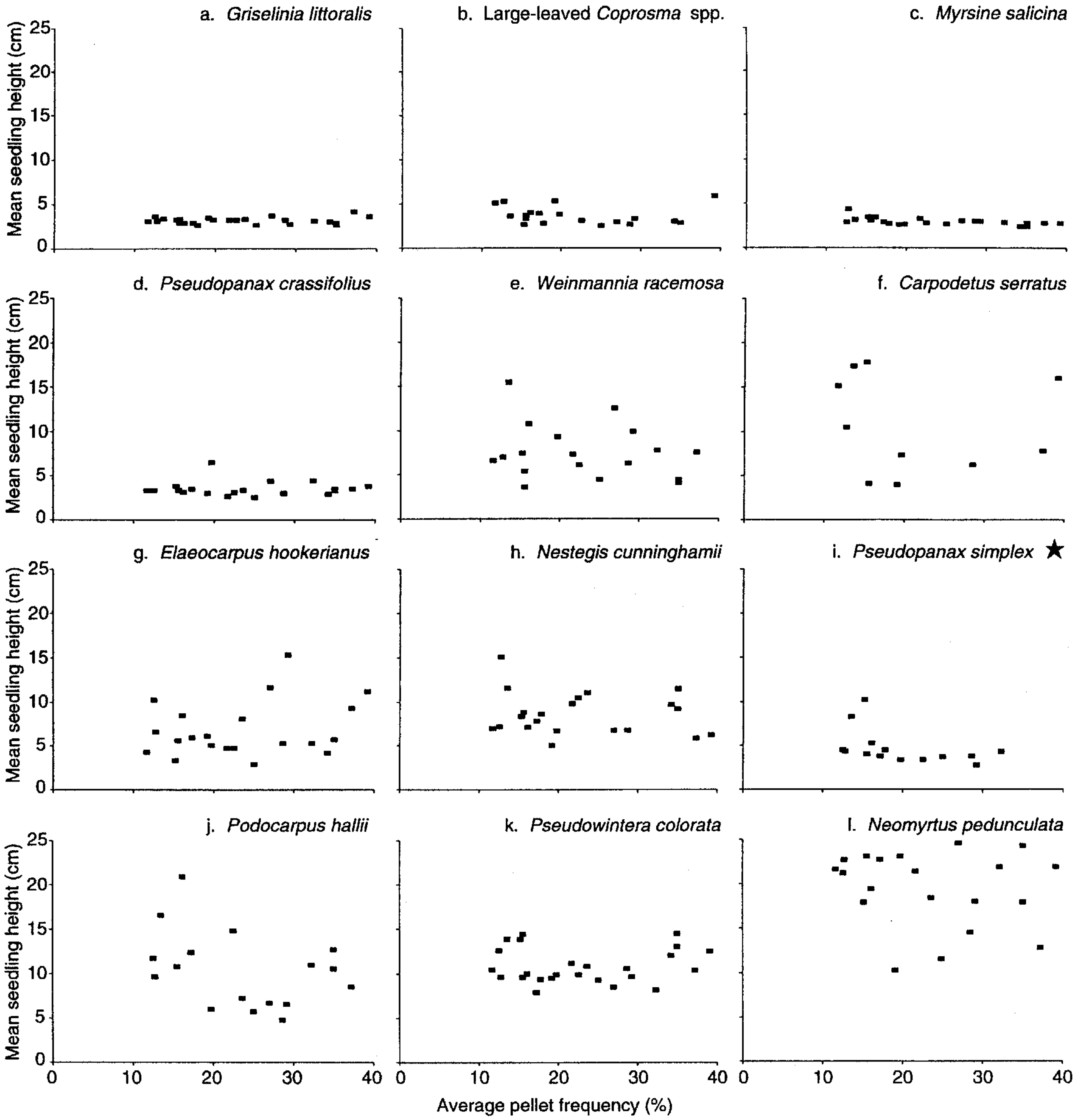

FIGURE 12. RELATIONSHIP BETWEEN RELATIVE POSSUM DENSITY AND MEAN SEEDLING HEIGHT IN THE 3-45 cm TIER AT EACH OF THE 25 FOCI. FOCI WITH <10 SEEDLINGS ARE EXCLUDED, AS WERE SEEDLINGS <3 cm TALL. THE INDEX OF RELATIVE POSSUM DENSITY IS THE AVERAGE PELLET FREQUENCY ON THE 40 PERMANENT PLOTS AT EACH FOCUS IN 1991 AND 1992; * DENOTES A SIGNIFICANT INVERSE RELATIONSHIP BETWEEN POSSUM DENSITY AND SEEDLING HEIGHT.

preferred species with negative regression coefficients did not differ significantly. Further, the overall mean height for Hall's totara and kamahi seedlings were >5 cm, indicating little impact of possums on seedling growth. These results indicate that possum density has little impact on seedling heights within the range of densities observed within our study area.

5.6 SUMMARIES FOR KEY WOODY SPECIES

Quintinia serrata

This was the most common canopy tree species and accounted for c. 30% of overstorey foliage production. *Q. serrata* was not eaten by possums and only rarely by deer. On at least some deer-preferred sites, browsing by deer appeared to remove small seedlings, but there was seldom any evidence of browse once seedlings exceeded 50 cm. Higher deer densities in the past may have partially impeded regeneration (see Fig. 10g), but this species is not presently threatened by possums or deer.

Miro

Although stem densities were low (37/ha), this species ranked second in basal area and foliage production. For possums, miro fruit was an important food source in some years, but they did not eat the foliage. Deer occasionally browsed miro seedlings growing in the open. This and the low number of small-diameter saplings (see Fig. 10f) suggest that deer may have previously slowed regeneration of this species. The numbers of tall seedlings recorded also suggests that, although possums (and rats and pigs) appeared to consume much of the seed produced, sufficient seed survives to retain the species.

Hall's totara

This species was the second most common woody species for browse-tier foliage production. Most foliage production came from large trees >1 m in diameter, but tall seedlings and saplings were common also. Hall's totara was not eaten by deer but was the main food of possums, which removed about 10% of annual foliage production (mostly the outermost sun-grown leaves). Many large Hall's totara in the study area appeared to be dying or already dead, particularly those on ridge sites. Possums did not appear to affect seedling growth or young trees growing in the shade.

Marbleleaf

Fruit from this species comprised c. 10% of possum diet in 1992, but little in other years. Possums ate minimal marbleleaf foliage. However, the foliage comprised c. 1% of deer diet, mostly as green adult foliage probably obtained from broken branches or fallen trees, rather than individual fallen leaves, which were mostly yellowed. The small-leaved divaricate juvenile form in shady areas was seldom eaten by deer, but was usually heavily browsed in canopy gaps. Although palatable to deer, marbleleaf appears to be sufficiently browse-resistant to remain at or near present densities.

Kamahi

This is the only woody species whose foliage was important to both possums and deer, although it is likely that possums fed on canopy foliage and deer fed on litterfall and foliage hanging down into the browse tier. Kamahi was the most abundant of the deer-preferred woody species within the browse tier (3.7 kg/ha), and deer removed about half the ABTP. Ground-level regeneration was severely impeded, but this species should respond to a significant reduction in deer density. Kamahi regeneration was often abundant on raised surfaces out of the reach of deer (e.g., fallen logs, tree fern trunks; Smale 1994). The impact of possums is unclear, but the amount of foliage removed annually (c. 13%) appears to be insufficient to cause widespread dieback.

Pepperwood

This was the most abundant woody species and was not eaten by possum or deer. It is probably that pepperwood has benefited from reduced competition with other species in the browse tier.

Toro

This species was an important possum food but a minor deer food. Although the 8% of AFP removed by possums did not appear to be causing widespread dieback of toro, there were few tall seedlings present. As already noted, epicormic shoots within 2 m of ground level were heavily browsed, whereas those above 2 m were not, indicating that deer were responsible. We suspect that our data underestimated the importance of toro in the deer diet simply by chance. An alternative possibility is that toro foliage may distintegrate more readily than other species and as a consequence could have mostly passed through the sieve used in the diet analyses. Toro is likely to respond only to major reductions in deer density.

Bush lawyer

Flowers and fruit from bush lawyer were important spring and summer foods for possums in some years. Both possums and deer removed small amounts of foliage, but with little apparent impact on abundance or regeneration.

Black maire

This species was a minor deer food and was occasionally eaten by possums. Although there appeared to be little present impact on black maire, it may have been affected in the past.

Pokaka

This species was an important source of fruit for possums and of fallen leaves for deer. Small seedlings (<5 cm) were extremely abundant in some places, and although most die or are removed by deer, sufficient seedlings appeared to survive to maintain species abundance.

Phyllocladus species

Neither deer nor possums eat *Phyllocladus* spp., but saplings up to a few centimetres in diameter can be damaged or killed by antler-thrash.

Wineberry

This species was a moderately important spring and autumn food for possums, and was also eaten by deer. Nevertheless, wineberry was common and does not appear to be threatened at present animal densities.

Broadleaf

This was the main deer food and ground-level regeneration of this species was virtually non-existent. However, broadleaf was not eaten by possums and it regenerates freely on bluffs and as epiphytes, particularly on old conspecifics (Smale 1994). Many of the larger epiphytes produce flowers and fruit. It therefore appears unlikely that broadleaf would disappear completely, but very low deer densities would be required for the species to be able to regenerate at ground level.

Large-leaved *Coprosma* species

Because *C. tenuifolia* and *C. grandifolia* are similar, it was difficult to reliably distinguish between them in stomach and rumen material. Therefore, preference and utilisation indices were calculated for these two species combined. A greater relative abundance of tall seedlings of *C. tenuifolia* suggests it is less palatable than *C. grandifolia*. *C. lucida* was confined to bluffs.

Rimu

This species was not eaten by possums or deer. Rimu seedlings and saplings up to 5 m tall were common in places, whereas subcanopy saplings and young trees more than 5 m tall were rare, suggesting rimu had benefited from the reduced competition for light and space. The apparent increase in abundance of rimu will not be altered by future changes in animal numbers.

Matai

Although this species was represented in the canopy by only a few large-diameter trees, it also appeared to have benefited from reduced competition. However, it was sometimes browsed by deer and as a result had a low ratio of tall seedlings to larger stems. It is likely that high deer numbers would affect this species.

Lancewood, *P. simplex*, and fivefinger

Regeneration of these species was severely inhibited by deer and, at least for *P. simplex*, by possums as well. Possums can also affect established trees, principally by browsing the petioles in late winter. Although they seldom eat the leaf itself, possums almost completely stripped many lancewood trees in winter 1992. However, these trees subsequently recovered. The leaves dropped by possums were an important food source for deer in winter. These species are likely to respond to significant decreases in deer densities.

Mahoe

Although this species was browsed heavily by possums, it persisted in some localised areas, including where possum densities were highest. Mahoe was also a relatively important deer food, and low deer densities are probably needed for this species to regenerate.

Tree fuchsia

Although adult trees of this species were rare in the study area, they were reasonably common to the east (Waitaia catchment). Tree fuchsia in that area was heavily browsed in late spring/early summer (December), but seldom browsed later in the summer, when it was in full leaf. Elsewhere, the former presence of tree fuchsia was evident from the fallen or standing trunks of dead trees around the numerous small herb and turf clearings. These areas are being recolonised gradually by pepperwood and other browse-resistant species. Although seedlings of tree fuchsia were relatively common throughout the study area, they were rare or absent in open areas (where they were probably removed by deer and possums). Possum browse on tree fuchsia seedlings was evident over a small area within 20 m of our hut near the centre of the study area (an area that deer avoided completely). Elsewhere, occasional seedlings reached a height of several metres in areas of dense undergrowth that were inaccessible to deer. Control of both possums and deer would be required for tree fuchsia to regenerate abundantly. It is unclear whether the apparently browse-tolerant tree fuchsia to the east would recolonise the study area in the absence of deer.

6. Conclusions

6.1 ANIMAL ABUNDANCE AND FAECAL OUTPUT

Possum densities appeared to increase slightly during the study period but were still relatively low (≤3/ha) compared with densities in most other areas of podocarp-hardwood forest (7–24/ha; Cowan 1990b). However, similar low densities have also been observed recently for an uncontrolled possum population in podocarp-hardwood forest in the Hunua Range (Sweetapple & Fitzgerald 1994, unpubl. Landcare Research contract report). The possums were in good physical condition, with some spring breeding, which suggests that they were below carrying capacity. We hypothesize that the possum population in the study area is regulated by occasional harsh winters (as in 1992 when mortality was significant) and the unpredictable availability of fruits in autumn and winter.

Considerable spring and autumn variation in the number of possum faecal pellets recorded (even though the number of possums appeared likely to have been stable) indicates that the presence/absence and standing crop techniques are relatively imprecise measures of possum abundance. The weight of faecal material deposited may be a better index.

Current deer densities in the study area (c. 6/km^2) are moderate and reflect the impact of recreational and commercial hunting (and perhaps disease). Most deer are in average physical condition. The coincidence of the deer density estimate derived using a defecation rate of 22.5 groups/deer/day (Mitchell & McCowan 1983, cited by Ratcliffe 1987) with one based on an estimate of daily forage consumption and published forage intake rates suggests that the 22.5 groups/deer/day rate may be more appropriate for red deer in New Zealand forests than the 12.5 groups/deer/day used previously to estimate deer numbers (e.g., Nugent *et al.* 1987).

Absolute deer abundance cannot be directly assessed from permanently marked faecal pellet plots unless there is some calibration between marked and unmarked plots. However, direct measurement of pellet group recruitment on permanent plots can provide indices of population size for assessing population changes (e.g., before and after control).

6.2 DIET AND FORAGE CONSUMPTION

Deer diet was generally similar to that of white-tailed deer (*Odocoileus virginianus*) in podocarp-hardwood forest on Stewart Island (Nugent & Challies 1988) and fallow deer (*Dama dama*) in hardwood forest in the Blue Mountains (Nugent 1990). The differences appear to reflect plant species availability, although in our study area broadleaf appeared to be less favoured than in other areas despite its availability.

Hall's totara was the most important possum food in our study area. Coleman *et al.* (1985) also identified it as a preferred but minor species in central Westland (0.8% of possum diet, cf. 0.2% of basal area). This species has also been recently identified as a key possum food on Bank's Peninsula (I. Payton, pers. comm.), southern Stewart Island (G. Nugent, unpubl. data), and in the Ruahine Range (G. Rogers, pers. comm.). Its importance in the diet provides an explanation for its virtual elimination from the canopy in some areas of Westland (Pekelharing & Batcheler 1990).

Herbivores removed little of the total annual foliage production (3.3% for possums and 1.1% for deer). The limited dietary overlap between possums and deer in the study area means there is little competition for food. Possum diet included more plant parts (fruit and flowers as well as leaves) and so is likely to be more variable between years than that of deer as a consequence of wide variation in fruit abundance. However, possums focused on a narrower range of woody plants than deer. Deer removed c. 10% of all foliage produced in the browse tier. Consequently, deer have a greater impact on regeneration within the browse tier than possums. In addition, because deer obtained much of their food as litterfall, consumption for many preferred species exceeded the amount of material actually produced within the browse tier. Although the consumption of litterfall does not directly affect regeneration, it does increase the amount of food available to deer, effectively increasing the potential carrying capacity. This results in increased browsing pressure on species whose seedlings (i.e., regeneration) are preferred over litterfall.

6.3 IMPACTS ON REGENERATION

Although deer affect a wider range of plant species than possums, their impact is seldom absolute — many species survive as epiphytes or in inaccessible places (Stewart & Burrows 1989). Possum impacts are also seldom absolute. Although tree fuchsia has disappeared from many areas, it continued to survive just east of our study area. Neither possums nor deer are likely to cause major deforestation in the Waihaha catchment, or even cause major shifts in the abundance of most of the common species. Consequently, the overall diversity of the vegetation is unlikely to change greatly in the longer term. Some of the changes that have already happened or are ongoing (such as the apparent flush of rimu regeneration, and the predominance of pepperwood seedlings within the browse tier) are now largely irreversible. For unpalatable species such as these, the regenerative cohort now established will persist for a full life cycle (perhaps a millenium for rimu) regardless of whether deer and possums are present.

Hall's totara appeared to be the main species threatened by possums. Many adult trees were in poor condition, and although possums might not be the only cause (New Zealand Forest Service 1982), improvements in foliage cover since possum numbers were reduced in winter 1994 (unpubl. data) indicates that possum control will help trees recover. Somewhat paradoxically, possum control does not appear to be required to protect regenerating totara while it is at the sub-canopy stage.

Although possums consumed fruit of many species, small seedlings were plentiful for all species (relative to adult abundance), suggesting that seed abundance was not limiting regeneration. The potential impacts of fruit consumption by possums are probably more important in terms of competition with native birds (Leathwick *et al*. 1983; Cowan 1990a).

The abundance of broadleaf and the large-leaved *Coprosma* species as epiphytes indicates that these species will remain common and widespread, even though deer prevented virtually all ground-level regeneration. Lancewood, fivefinger, *Pseudopanax simplex*, patee (*Schefflera digitata*), and tree fuchsia were already relatively rare, and because they seldom occurred as epiphytes, as a group, will probably become increrasingly confined to the occasional sites protected from deer (bluffs and steep banks).

In summary, our results support the conceptual model of deer impacts proposed by Nugent (1990, 1992). This model is developed further in Fig. 13a, in line with our key results:

- The least preferred and most browse-resistant tree species benefit from reduced competition, although some species are affected at very high deer densities.
- The most preferred tree species show little indication of recovery, even at the lowest deer density within our study area, unless they are "protected" by a divaricating habit (pokaka, marbleleaf, kaikomako).
- Kamahi appears to be the only tree species likely to respond to moderate reductions in deer density.

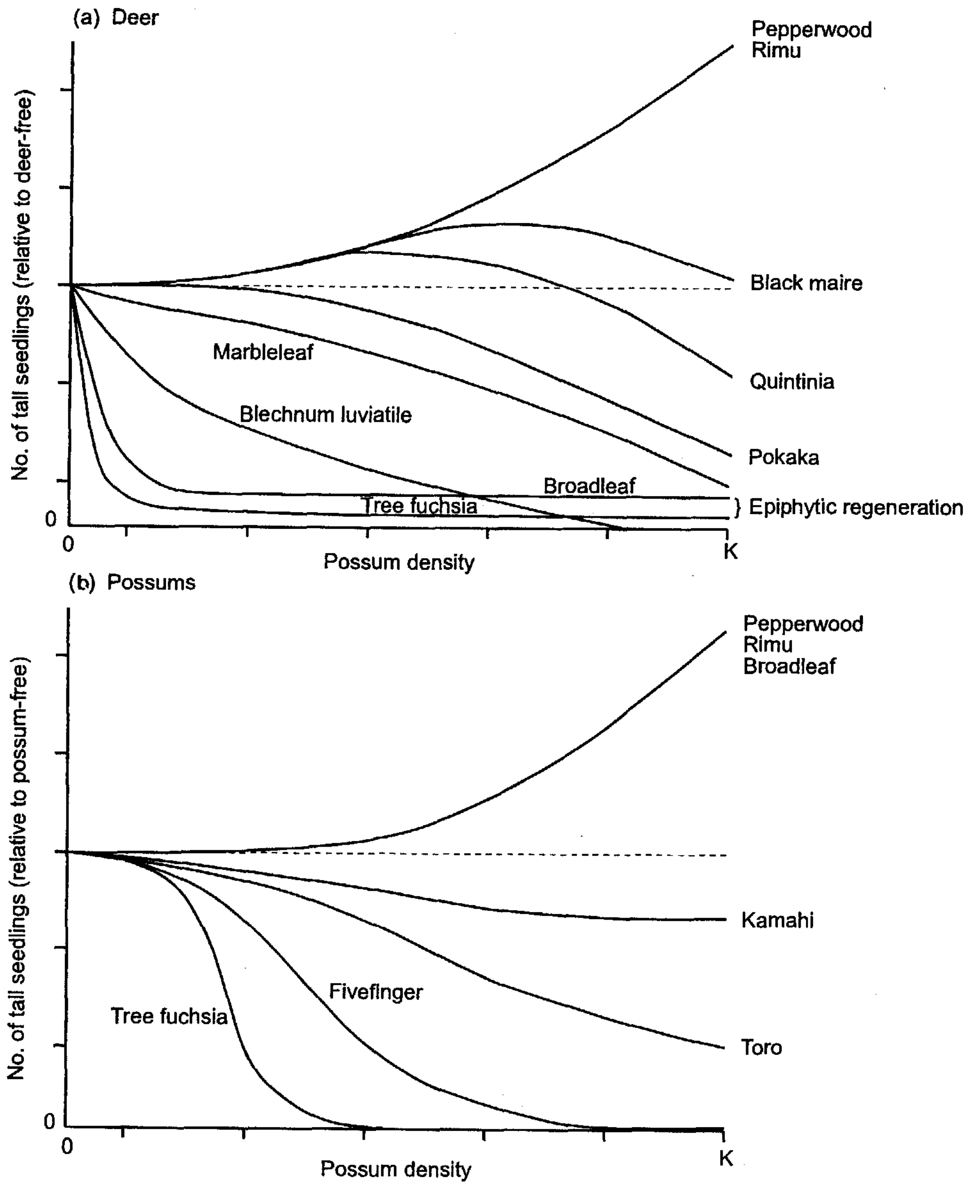

FIGURE 13. CONCEPTUAL MODELS OF DEER AND POSSUM IMPACTS. FOR DEER (a), THE MODEL IS CONSISTENT WITH OUR DATA OVER THE RANGES OF DENSITIES IN THE WAIHAHA CATCHMENT (i.e., <10 DEER/km^2), BUT HYPOTHHTICAL ABOVE THAT. FOR POSSUMS (b), THE MODEL IS LARGELY HYPOTHETICAL.

- Although highly-preferred species appear likely to regenerate at ground level only at low deer densities (<2 deer/km^2), many of these species (broadleaf, large-leaved Coprosma spp., and kamahi) can regenerate epiphytically (and, we presume, self-sustainably) at any deer densities (Stewart & Burrows 1989; Smale 1994).

A similar model of possum impacts is proposed (Fig. 13b):

- For highly-preferred species, such as tree fuchsia, possum impact increases steadily with animal density until utilisation exceeds production, when most trees die. Because possums browse individuals within a species sequentially, a few individuals may survive if they are somewhat protected (perhaps by chemical or other defences, or by occurring in areas of low possum use).

- For less-preferred species, the threshold is either reached at higher densities, or not at all.
- Unpreferred species such as pepperwood are able to take advantage of the space created by canopy deaths.

7. Recommendations

- Present priorities in possum and ungulate (deer and goat) control for vegetation protection should be reassessed, giving greater consideration to the dominant influence of ungulates on patterns of ground-level regeneration. The focus should be on protecting species from both pests as required. There is little point in protecting existing canopies from possums if deer and goats prevent their regeneration in the longer term.
- For areas with long-established populations of possums and ungulates, long-term possum-only control to protect conservation values should be justified only where possums threaten the native fauna (either by competition or direct predation) or where the aim is to protect one or more of the relatively few species whose normal regeneration is not also threatened by ungulates (e.g., Hall's totara, mistletoe). For protection of vegetation biodiversity within such forests, ungulate control alone appears likely to be more beneficial than possum control alone.
- The level of browsing that can be sustained by the key plant species threatened by possums needs to be determined. In particular, the long-term influences of possums on totara needs to be investigated to determine whether uncontrolled possum populations prevent most totara from reaching maturity and producing seed. The effects of possum control on established "over-mature" totara that have been severely damaged by possums also needs to be monitored.
- Methods for the assessment of possum impacts need to be developed to include changes in regeneration patterns and on ground-level vegetation generally, as well as impacts on the canopy.
- Faecal pellet counts for monitoring long-term possum density trends should always be conducted at the same time of year and, ideally, the weights of pellets should also be recorded. For monitoring percentage kill over short periods, a non-treatment block is essential for assessing the effect of natural changes in faecal output and disappearance rates of pellets on pellet count estimates.

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10. Appendix

10.1 OVERSTOREY STEM FREQUENCIES (ON 5 m RADIUS PLOTS, N=355), STEM DENSITIES, AND BASAL AREAS IN THE UPPER WAIHAHA CATCHMENT (IN ORDER OF DECREASING BASAL AREA).

Species with basal areas <0.1 m^2/ha are listed separately with their frequencies of occurrence only.

	FREQUENCY (%)	STEM DENSITY (no./ha)		BASAL AREA (m^2/ha)	
		MEAN	S.D.	MEAN	S.D.
Podocarpus hallii	62.6	215	260	13.46	42.00
Prumnopitys ferruginea	20.0	37	81	10.42	70.00
Quintinia serrata	52.4	356	580	8.19	14.70
Prumnopitys taxifolia	8.4	11	36	7.81	54.10
Griselinia littoralis	25.6	58	118	6.99	26.80
Dacrydium cupressinum	11.3	19	60	5.56	58.30
Weinmannia racemosa	51.8	317	614	4.00	7.50
Carpodetus serratus	55.8	190	261	3.38	6.10
Pseudowintera colorata	86.8	1658	1701	3.13	4.80
Myrsine salicina	40.6	217	437	2.13	5.30
Nestegis cunninghamii	31.0	85	181	1.11	5.60
Elaeocarpus hookerianus	27.3	64	144	1.02	4.50
Dacrycarpus dacrydioides	1.1	2	21	0.64	12.10
Aristotelia serrata	18.3	364	1256	0.62	2.60
Dicksonia fibrosa	6.2	10	45	0.61	2.90
Neomyrtus pedunculata	73.3	620	921	0.59	1.00
Phyllocladus alpinus	7.9	60	350	0.44	3.00
Pseudopanax crassifolius	13.8	29	92	0.36	1.30
Phyllocladus glaucus	3.9	16	124	0.30	2.20
Rubus cissoides	68.7	479	833	0.28	0.40
Coprosma "taylorae"	22.3	135	445	0.24	1.00
Melicytus ramiflorus	1.7	5	41	0.19	1.80
Nestegis lanceolata	2.3	4	34	0.18	2.80
Cyathea smithii	4.8	6	31	0.17	0.80
Pseudopanax simplex	7.6	13	54	0.15	1.00
Elaeocarpus dentatus	2.5	3	23	0.13	1.00
Phyllocladus trichomanoides	3.4	7	54	0.11	1.00
Dicksonia squarrosa	2.5	4	32	0.10	0.80
Olearia ilicifolia	0.6	1	15	0.09	1.30
Hebe stricta	8.7	128	726	0.08	0.50
Beilschmiedia tawa	1.7	7	74	0.08	1.00
Coprosma tenuifolia	14.9	29	89	0.07	0.30
Coprosma spathulata	0.8	10	115	0.06	0.70
Coprosma foetidissima	7.0	20	108	0.04	0.20
Pennantia corymbosa	0.8	1	16	0.03	0.40
Coprosma grandifolia	2.5	5	39	0.02	0.20
Schefflera digitata	1.4	2	19	0.02	0.20
Myrsine australis	1.1	1	13	0.02	0.20
Melicope simplex	12.1	20	61	0.01	<0.1
Pseudopanax anomalus	3.1	10	81	0.01	<0.1
All species	100.0	5316	2580	72.85	114.30

Species <0.1 m^2/ha

Clematis spp. 0.8 (% frequency of occurrence); *Coprosma lucida* 0.8; *C. rhamnoides* 0.3; small-leaved *Coprosma* spp. 0.3; unidentified *Coprosma* spp. 0.6; *Dracophyllum subulatum* 0.6; *Halocarpus bidwillii* 0.3; *Hoheria sexstylosa* 0.3; *Kunzea ericoides* 1.7; *Leucopogon fasciculatus* 3.1; *Leptospermum scoparium* 0.8; *Muehlenbeckia australis* 3.7; *Myrsine divaricata* 2.8; *Olearia rani* 0.3; *Parsonsia capsularis* 4.5; *Parsonsia* spp. 2.8; *Pseudopanax arboreus* 0.3; *Rubus schmidelioides* 3.7; unidentified *Rubus* spp. 0.3.

10.2 EPIPHYTE FREQUENCIES (% OF 355 5 m RADIUS "OVERSTOREY" PLOTS ON WHICH THE SPECIES WAS OBSERVED).

	FREQUENCY (%)
Hymenophyllum spp.	80.56
Asplenium flaccidum	70.56
Phymatosorus diversifolius	57.50
Collospermum microspermum	34.72
Ctenopteris heterophylla	21.94
Griselinia littoralis	17.22
Asplenium polyodon	7.22
Coprosma tenuifolia	7.22
Earina autumnalis	5.56
Coprosma grandifolia	4.44
Earina mucronata	3.33
Pseudopanax arboreus	2.50
Trichomanes reniforme	2.50
Weinmannia racemosa	2.22
Grammitis billardieri	1.94
Coprosma foetidissima	1.67
Astelia spp.	1.11
Quintinia serrata	1.11

Species occurring on fewer than 1% of plots

Alseuosmia turneri; Carpodetus serratus; Coprosma lucida; C. "taylorae"; Cordyline australis; Dacrydium cupressinum; Dendrobium cunninghamii; Dicksonia squarrosa; Hebe stricta; Melicytus lanceolatus; Muehlenbeckia australis; Neomyrtus pedunculata; Nestegis lanceolata; Podocarpus hallii; Polysticum vestitum; Pseudopanax crassifolius; P. edgerleyi; P. simplex; Pyrrosia eleagnifolia; Tmesipteris elongata; Trichomanes reniforme; Uncinia spp.

10.3 TOTAL ANNUAL LITTERFALL BIOMASS (kg/ha) FOR 1991 AND 1992 FOR THE 30 LITTERFALL TRAPS FROM WHICH SAMPLES WERE OBTAINED IN EVERY SEASON OVER THOSE TWO YEARS.

The average amount of fruit, flower, and foliage making up the total litterfall in these two years is also shown. The amount of foliage produced by each species is expressed as a percentage of the total foliar production (i.e., excluding fine unsorted material, woody material, fruit, flowers, and faeces). *Asplenium* spp., *Astelia solandri, Blechnum* spp., *Collospermum microspermum, Coprosma foetidissima, Lindsaea trichomanoides, Metrosideros* spp., and *Pyrrosia eleagnifolia* were identified in trace amounts (<0.1% foliage).

	BIOMASS (kg/ha)						
				AVERAGES FOR 1991/92			
	1991	1992	TOTAL	FRUIT	FLOWER	FOLIAGE	% FOLIAGE
Total	4276.4	3997.0	4136.7	111.0	177.9	2498.9	100.00
Quintinia serrata	950.0	826.4	888.2	43.9	60.9	792.3	31.71
Prumnopitys ferruginea	333.3	356.8	345.1	42.4	53.4	240.3	9.62
Podocarpus hallii	216.0	139.2	177.6	3.8	1.9	171.9	6.88
Carpodetus serratus	187.2	167.9	177.5	1.3	1.8	171.8	6.88
Weinmannia racemosa	184.4	121.5	152.9	7.2	28.9	116.9	4.68
Pseudowintera colorata	103.6	109.0	106.3	0.3		106.0	4.24
Myrsine salicina	110.9	91.6	101.2	3.3		97.9	3.92
Rubus cissoides	95.6	82.0	88.8		0.1	88.7	3.55
Nestegis cunninghamii	82.4	89.9	86.1	0.2		85.9	3.44
Elaeocarpus hookerianus	79.1	78.7	78.9	3.2		75.7	3.03
Phyllocladus trichomanoides	27.4	120.9	74.2		1.5	72.6	2.91
Phyllocladus glaucus	70.5	76.0	73.2		9.6	63.6	2.55
Aristotelia serrata	77.3	50.6	63.9	1.8	0.3	61.9	2.48
Griselinia littoralis	49.2	49.4	49.3	0.7		48.6	1.95
Dacrydium cupressinum	60.0	37.0	48.5		0.3	48.2	1.93
Prumnopitys taxifolia	63.2	27.6	45.4	1.1	11.1	33.2	1.33
Elaeocarpus dentatus	51.2	29.6	40.4			40.4	1.62
Phyllocladus alpinus	66.5	8.2	37.4		7.2	30.2	1.21
Hebe stricta	25.1	30.2	27.7		0.1	27.5	1.10
Rubus schmidelioides	20.1	18.4	19.3			19.3	0.77
Phymatosorus diversifolius	22.3	14.9	18.6			18.6	0.74
Phyllocladus spp.	6.9	26.9	16.9		0.5	16.4	0.65
Histiopteris incisa	8.6	24.0	16.3			16.3	0.65
Dracophyllum subulatum	18.7	12.5	15.6		0.3	15.3	0.61
Pseudopanax crassifolius	14.0	6.6	10.3	1.2		9.1	0.36
Coprosma "taylorae"	8.2	8.8	8.5	0.8		7.7	0.31
Neomyrtus pedunculata	5.7	8.8	7.2			7.2	0.29
Pseudopanax simplex	2.0	2.9	2.4			2.4	0.10
Dicksonia squarrosa	1.3	3.0	2.2			2.2	0.09
Clematis spp.	0.9	3.2	2.0			2.0	0.08
Myrsine australis	2.6	0.0	1.3			1.3	0.05
Coprosma grandifolia	1.0	1.0	1.0			1.0	0.04
Coprosma tenuifolia	0.6	1.3	1.0			1.0	0.04
Ctenopteris heterophylla	0.2	1.1	0.7			0.7	0.03
Dacrycarpus dacrydioides	0.0	1.3	0.6			0.6	0.03

BIOMASS (kg/ha)

	1991	1992	TOTAL	AVERAGES FOR 1991/92 FRUIT	FLOWER	FOLIAGE	% FOLIAGE
Asplenium polyodon	0.4	0.4	0.4			0.4	0.02
Coprosma spp.	1.0	0.0	0.5			0.5	0.02
Cyathea smithii	0.5	0.3	0.4			0.4	0.02
Melicytus ramiflorus	0.3	0.8	0.5			0.5	0.02
Nestegis lanceolata	1.2	0.0	0.6			0.6	0.02
Asplenium flaccidum	0.2	0.4	0.3			0.3	0.01
Earina mucronata	0.0	0.3	0.2			0.2	0.01
Myrsine divaricata	0.3	0.0	0.1			0.1	0.01
Pennantia corymbosa	0.4	0.2	0.3			0.3	0.01
Fine unsorted material	372.7	221.0	296.9				
Hymenophyllum spp.	0.1	0.4	0.3				
Lichen	15.6	25.0	20.3				
Moss	55.9	78.0	67.0				
Possum faeces	21.5	28.3	24.9				
Rat faeces			0.8				
Wood	859.9	1018.9	939.4				

10.4 BIOMASS (kg/ha) OF POTENTIALLY EDIBLE LITTERFALL (PREDOMINANTLY FOLIAGE) PRESENT ON 250 1 m^2 PLOTS AT 3 MONTH INTERVALS BETWEEN SEPTEMBER 1991 AND JUNE 1992.

Seasonal data are shown for the 25 most common species and the remaining less common species or species groups are listed in order of decreasing abundance.

	BIOMASS (kg/ha)				
	SEP 91	DEC 91	MAR 92	JUN 92	MEAN
All species	31.9	26.4	22.5	34.6	28.9
Rubus cissoides	4.3	2.5	2.2	4.4	3.3
Griselinia littoralis	1.7	5.1	2.7	3.3	3.2
Nestegis cunninghamii	3.7	4.9	1.9	2.0	3.1
Pseudowintera colorata	3.0	1.0	2.5	3.8	2.6
Carpodetus serratus	3.0	2.6	0.9	3.2	2.4
Sticta spp.	0.9	0.8	2.2	3.3	1.8
Weinmannia racemosa	2.0	1.1	1.0	2.8	1.7
Elaecarpus hookerianus	1.4	1.1	2.3	1.1	1.5
Myrsine salicina	2.1	1.8	1.0	1.0	1.5
Quintinia serrata	1.6	0.5	1.5	2.6	1.5
Prumnopitys ferruginea	1.1	0.3	0.8	1.0	0.8
Pseudopanax crassifolius	0.5	0.8	0.9	1.1	0.8
Dacrydium cupressinum	1.6	0.5	0.2	0.5	0.7
Prumnopitys taxifolia	0.5	0.2	0.5	0.9	0.5
Hebe stricta	0.2	0.3	0.4	0.5	0.4
Podocarpus hallii	0.8	0.3	0.2	0.3	0.4
Pseudopanax simplex	0.4	0.6	0.2	0.3	0.4
Aristotelia serrata	0.3	0.3	0.2	0.3	0.3
Coprosma tenuifolia	0.2	0.1	0.1	0.2	0.2
Phymatosorus diversifolius	0.2	0.1	0.2	0.2	0.2
Rubus schmidelioides	0.2	0.5	0.0	0.1	0.2
Usnea spp.	0.3	0.2	0.1	0.4	0.2
Asplenium flaccidum	0.2	0.1	0.1	0.1	0.1
Coprosma grandifolia	0.2	0.2	0.0	0.1	0.1
Lichen	0.4	0.0	0.0	0.0	0.1

Species or species groups averaging <0.1 kg/ha in these four seasons

Alseuosmia pusilla, A. turneri, Asplenium polyodon, Astelia solandri, Beilschmiedia tawa, Blechnum capense, B. colensoi, B. fluviatile, B. procerum, Chiloglottis cornuta, Clematis spp., *Collospermum microspermum, Coprosma foetidissima, C. lucida, Ctenopteris heterophylla, Cyathea smithii, Dacrycarpus dacrydioides, Dicksonia squarrosa, Dicksonia* spp., *Earina autumnalis, E. mucronata, Elaeocarpus dentatus, Fuchsia excorticata, Grammitis billardieri, Histiopteris incisa, Hymenophyllum* spp., *Leptopteris hymenophylloides, Melicope simplex, Melicytus lanceolatus, M. ramiflorus, Muehlenbeckia australis, Myrsine australis, Nertera* spp., *Nestegis lanceolata, Olearia ilicifolia, Parsonsia* spp., *Pennantia corymbosa, Phyllocladus alpinus, P. glaucus, P. trichomanoides, Polysticum vestitum, Pyrrosia eleagnifolia, Schefflera digitata, Trichomanes reniforme, Uncinia* spp., unidentified fungi, unidentified grasses, unidentified seeds.

10.5 BROWSE TIER FOLIAR BIOMASS (kg/ha) BY SPECIES FROM 500 1 m^2 PLOTS SAMPLED IN MARCH (DATA FOR 1991 AND 1992 POOLED).

For major categories and for species with >1.0 kg/ha of edible litterfall biomass, the "short" (0–45 cm above ground level), "tall" (46–200 cm), total foliar biomass, and percentage of the all-species biomass are shown. For species with <1 kg/ha biomass, the species are listed in order of decreasing abundance within categories for the 0.1–1.0 kg/ha range (uncommon), and in alphabetical order for the <0.1 kg/ha range (scarce).

	BIOMASS (kg/ha)				
	EDIBLE LITTERFALL	SHORT	TALL	TOTAL BIOMASS	% OF TOTAL
All woody	**19.54**	**27.25**	**84.11**	**130.90**	**45.4**
Pseudowintera colorata	2.94	11.99	33.09	48.02	16.7
Podocarpus hallii	0.22	1.25	15.77	17.24	6.0
Quintinia serrata	1.18	0.72	5.77	7.67	2.7
Dacrydium cupressinum	0.36	0.45	5.67	6.48	2.2
Weinmannia racemosa	1.55	0.97	3.61	6.14	2.1
Rubus cissoides	2.30	0.80	2.56	5.65	2.0
Hebe stricta	0.37	0.33	3.97	4.67	1.6
Nestegis cunninghamii	2.09	1.40	0.51	4.00	1.4
Griselinia littoralis	2.49	0.64	0.10	3.23	1.1
Neomyrtus pedunculata	0.00	2.50	0.60	3.10	1.1
Elaeocarpus hookerianus	1.60	0.50	0.53	2.62	0.9
Myrsine salicina	1.05	1.19	0.37	2.60	0.9
Phyllocladus alpinus	0.01	0.01	2.33	2.36	0.8
Prumnopitys ferruginea	0.50	0.90	1.02	2.42	0.8
Carpodetus serratus	1.00	0.13	0.42	1.56	0.5
Coprosma tenuifolia	0.08	0.10	1.38	1.56	0.5
Aristotelia serrata	0.18	0.04	0.96	1.17	0.4
Phyllocladus trichomanoides	0.10	0.15	0.81	1.05	0.4
Pseudopanax crassifolius	0.66	0.60	0.00	1.26	0.4
All ferns	**4.53**	**122.31**	**0.00**	**126.84**	**44.0**
Cyathea smithii	0.00	27.79	0.00	27.79	9.6
Histiopteris incisa	0.05	23.32	0.00	23.37	8.1
Blechnum fluviatile	0.00	20.93	0.00	20.94	7.3
Leptopteris superba	0.00	13.53	0.00	13.53	4.7
Dicksonia squarrosa	0.00	10.97	0.00	10.97	3.8
Polysticum vestitum	0.01	8.52	0.00	8.54	3.0
Blechnum discolor	0.00	6.75	0.00	6.75	2.3
Trichomanes reniforme	3.84	0.27	0.00	4.12	1.4
Leptopteris hymenophylloides	0.00	3.47	0.00	3.47	1.2
Blechnum colensoi	0.00	1.91	0.00	1.91	0.7
All grasses	**1.33**	**18.80**	**0.00**	**20.13**	**3.2**
Uncinia spp.	0.00	8.05	0.00	8.05	2.8
Uncinia divaricata	0.00	6.01	0.00	6.01	2.1
Ehrharta diplax	0.00	3.67	0.00	3.67	1.3
Collospermum microspermum	1.24	0.00	0.00	1.24	0.4
All herbs	**0.02**	**2.96**	**0.04**	**3.02**	**0.5**
All other	**2.66**	**4.56**	**0.00**	**7.22**	**2.5**
Sticta spp.	2.40	4.54	0.00	6.94	2.4
	28.07	**175.89**	**84.15**	**288.12**	**100.0**

Biomass 0.1–1.0 kg/ha

Woody	*Dacrydium dacrydioides* 0.99; *Phyllocladus glaucus* 0.98; *Coprosma "taylorae"* 0.76; *Leucopogon fasciculatus* 0.76; *Beilschmiedia tawa* 0.66; *Pseudopanax anomalus* 0.63; *Melicope simplex* 0.59; *Pseudopanax simplex* 0.41; *Alseuosmia pusilla* 0.39; *Prumnopitys taxifolia* 0.34; *Metrosideros diffusa* 0.21; *Muehlenbeckia australis* 0.17; *Parsonsia* spp. 0.16; *Elaeocarpus dentatus* 0.14; *Coprosma foetidissima* 0.13; *Rubus schmidelioides* 0.13; *Coprosma grandifolia* 0.11; *Alseuosmia turneri* 0.10.
Ferns	*Dicksonia fibrosa* 0.77; *Asplenium flaccidum* 0.74; *Blechnum procerum* 0.63; *Phymatosorus* spp. 0.62; *Blechnum chambersii* 0.51; *Asplenium bulbiferum* 0.46; *Blechnum capense* 0.43; *Grammitis billardieri* 0.23; *Ctenopteris heterophylla* 0.22; *Cyathea dealbata* 0.10.
Grasses	*Juncus* spp. 0.70; *Empodisma minus* 0.67; *Carex* spp. 0.32; *Astelia solandri* 0.11.
Herbs	*Hydrocotyle moschata* 0.81; *Pratia angulata* 0.37; *Viola filicaulis* 0.26; *Acaena anserinifolia* 0.24; *Cardamine debilis* 0.12; *Urtica incisa* 0.12; *Ranunculus reflexus* 0.11.
Other	*Dawsonia superba* 0.58; *Usnea* spp. 0.27.

Biomass <0.1 kg/ha

Woody	*Clematis* spp.; *Coprosma ciliata; C. lucida; C. rhamnoides; C. rotundifolia;* unidentified *Coprosma* spp.; *Cyathodes juniperina; Fuchsia excorticata; Geniostoma rupestre* var. *ligustrifolium; Hedycarya arborea; Hoheria sexstylosa; Melicytus lanceolatus; M. ramiflorus; Myrsine australis; M. divaricata; Nestegis lanceolata; Olearia ilicifolia; O. rani; Pennantia corymbosa; Pseudopanax arboreus; Rhabdothamnus solandri; Ripogonum scandens; Rubus australis; Schefflera digitata;* unidentified podocarp seedlings
Ferns	*Asplenium hookerianum; A. polyodon; Blechnum penna-marina; B. vulcanicum; Grammitis rigida; Hypolepis rufobarbata; Lindsaea trichomanoides; Paesia scaberula; Pteris* spp.; *Pyrrosia eleagnifolia*
Grasses	*Agrostis* spp.; unidentified grasses
Herbs	*Cardamine hirsuta; Chiloglottis cornuta; Cirsium* spp.; *Corybas* spp.; *Earina autumnalis; E. mucronata; Epilobium* spp.; *Gnaphalium* spp.; *Gunnera monoica; Hydrocotyle novae-zealandiae;* unidentified *Hydrocotyle* spp.; *Jovellana repens; Luzula* spp.; *Mycelis muralis; Nertera* spp.; *Ophioglossum coriaceum; Oxalis* spp.; *Potamogeton suboblongus; Ranunculus glabrifolius; Scirpus* spp.; unidentified aquatic spp.; unidentified herbs; *Urtica australis*
Other	*Cladonia* spp.; fungi; lichen

10.6 DEER DIET (MEAN % DRY WEIGHT OF RUMEN SAMPLES) BY SEASON.

Annual mean values were calculated by weighing % composition for each season by the estimated annual faecal output in that season. Unidentified material (fibre and stem) was excluded from the calculations. Species comprising <0.1% of the weighted mean annual diet are listed separately (with the weighted annual mean) in decreasing order of importance within the main food categories.

	AUTUMN	WINTER	SPRING	SUMMER
No. of rumens sampled	14	28	45	17
% of annual faecal output	29.4	22.0	24.3	23.3

	MEAN % DRY WEIGHT					
	AUTUMN	WINTER	SPRING	SUMMER	UNWEIGHTED MEAN	WEIGHTED MEAN
All woody	**72.08**	**72.20**	**58.96**	**58.90**	**65.54**	**70.53**
Griselinia littoralis	19.99	21.39	19.09	22.04	20.63	22.04
Pseudopanax crassifolius	17.11	14.46	11.28	8.54	12.85	14.02
Unidentified stems	8.22	10.38	6.13	7.73	8.12	8.65
Elaeocarpus hookerianus	9.76	4.24	0.95	7.75	5.68	6.32
Weinmannia racemosa	8.47	6.35	4.79	3.20	5.70	6.28
Melicytus ramiflorus	1.03	3.32	4.31	4.17	3.21	3.30
Carpodetus serratus	0.37	1.37	1.98	0.59	1.08	1.11
Coprosma grandifolia	0.61	1.89	1.00	0.76	1.07	1.10
Large-leaved *Coprosma* spp.	1.17	0.99	0.70	0.47	0.83	0.91
Coprosma tenuifolia	0.68	0.93	1.25	0.48	0.84	0.89
Rubus cissoides	0.29	0.96	0.58	0.62	0.61	0.63
Coprosma lucida	0.24	1.04	0.14	1.01	0.61	0.62
Pittosporum spp.	0.69	0.01	1.47	0.04	0.55	0.62
Elaeocarpus dentatus	0.03	1.12	0.82		0.49	0.49
Pseudopanax simplex	0.20	0.81	0.40	0.20	0.40	0.41
Pseudowintera colorata	0.85	0.25	0.27	0.04	0.35	0.41
Aristotelia serrata	0.07	0.93	0.32	0.07	0.35	0.35
Myrsine salicina	0.45	0.40	0.20	0.09	0.29	0.31
Melicytus lanceolatus	0.74	0.13	0.01	0.06	0.24	0.28
Podocarpus hallii	0.27	0.11	0.02	0.16	0.14	0.16
Pseudopanax arboreus	0.07		0.43	0.11	0.15	0.16
Schefflera digitata	0.03	0.39	0.21	0.02	0.16	0.16
Nestegis cunninghamii	0.16	0.07	0.24	0.08	0.14	0.15
Hedycarya arborea	0.05	0.28	0.22		0.18	0.14
Pennantia corymbosa		0.04	0.20	0.22	0.15	0.12
Quintinia serrata	0.18	0.00	0.17		0.12	0.10
All ferns	**12.09**	**9.75**	**15.44**	**28.56**	**16.46**	**17.43**
Blechnum fluviatile	6.58	5.93	7.16	9.89	7.39	7.89
Dicksonia squarrosa	0.59	0.02	2.90	10.71	3.56	3.65
Unidentified ferns	3.40	1.00	0.35	0.48	1.31	1.54
Polysticum vestitum	0.34	0.01	0.89	2.11	0.84	0.88
Phymatosorus diversifolius	0.32	0.69	0.97	1.02	0.75	0.78
Cyathea spp.	0.00	0.53	0.03	1.73	0.57	0.57

	MEAN % DRY WEIGHT					
	AUTUMN	WINTER	SPRING	SUMMER	UNWEIGHTED MEAN	WEIGHTED MEAN
Asplenium flaccidum	0.21	1.18	0.39	0.31	0.52	0.53
Unidentified *Blechnum* spp.	0.08	0.09	1.92	0.24	0.47	0.47
Hymenophyllum spp.	0.07	0.11	0.15	0.82	0.29	0.29
Leptopteris superba			0.15	0.73	0.22	0.22
Histiopteris incisa	0.08	0.11	0.17	0.06	0.11	0.11
Leptopteris hymenophylloides				0.42	0.11	0.11
All grasses	**6.72**	**8.40**	**14.28**	**6.77**	**9.04**	**9.61**
Unidentified grasses	5.38	7.58	12.78	6.59	8.08	8.54
Cordyline spp.	1.07				0.27	0.34
Uncinia spp.	0.27	0.15	0.41	0.01	0.21	0.23
Astelia spp.		0.28	0.36	0.03	0.17	0.17
Phormium tenax			0.64		0.16	0.17
All herbs	**0.10**	**0.05**	**0.61**	**0.15**	**0.23**	**0.24**
Ranunculus reflexus			0.35	0.06	0.10	0.11
All other	**0.79**	**1.40**	**1.23**	**0.67**	**1.02**	**1.08**
Lichen (*Usnea*-like)	0.28	0.87	0.87	0.06	0.50	0.55
Moss	0.14	0.27	0.31	0.48	0.30	0.31
Fungi	0.23	0.26	0.02	0.13	0.16	0.17
Unidentified	**8.21**	**8.20**	**9.50**	**4.94**	**7.71**	**8.32**
Fibre	8.01	7.93	9.24	4.16	7.34	7.92
Leaves	0.20	0.27	0.26	0.78	0.38	0.39

Weighed mean % of annual diet <0.1

Woody *Clematis* spp. 0.09; small-leaved *Coprosma* spp. 0.09; Pseudopanax arboreus 0.08; *Ripogonum scandens* 0.08; *Olearia rani* 0.07; unidentified *Coprosma* spp. 0.06; *Coprosma foetidissima* 0.05; *Beilschmiedia tawa* 0.04; *Hebe stricta* 0.04; *Phyllocladus trichomanoides* 0.04; unidentified *Rubus* spp. 0.04; *Geniostoma rupestre* var. *ligustrifolium* 0.02; *Prumnopitys taxifolia* 0.02; *Fuchsia excorticata* 0.01; *Myrsine australis* 0.01; *Prumnopitys ferruginea* 0.01; *Rubus schmidelioides* 0.01; *Gaultheria* spp. <0.01; *Leucopogon fasciculatus* <0.01; *Neomyrtus pedunculata* <0.00; *Parsonsia* spp. <0.01; *Rubus australis* <0.01; *Sophora tetraptera* <0.01.

Ferns *Leptopteris* spp. 0.09; *Asplenium bulbiferum* 0.06; *A. oblongifolium* 0.04; unidentified *Asplenium* spp. 0.04; *Blechnum chambersii* 0.03; *B. capense* 0.01; *Grammitis* spp. 0.01; *Ctenopteris heterophylla* <0.01; *Blechnum nigrum* <0.01; B. *penna-marina* <0.01.

Grasses *Ehrharta diplax* 0.06; *Freycinetia baueriana* 0.05; *Carex* spp. 0.04; *Juncus* spp. <0.00

Herbs Unidentified herbs 0.05; *Lotus* spp. 0.02; *Acaena* spp. 0.01; *Hydrocotyle* spp. 0.01; *Lagenifera* spp. 0.01; *Mycelis muralis* 0.01; *Pratia angulata* 0.01; *Cardamine debilis* <0.01; *Euphrasia cuneata* <0.01; *Ranunculus* spp. <0.01; *Trifolium* spp. <0.01; *Viola* spp. <0.01

Other	*Pseudocyphellaria* spp. 0.04; invertebrates 0.01

10.7 ANNUAL POSSUM DIET (MEAN % DRY WEIGHT OF STOMACH CONTENTS).

For 1990 and the first two seasons of 1991 stomach contents were sieved then sorted, while for later seasons a combination of the sieving and layer-separation techniques was used (see methods). The annual means shown are the averages of the four seasons within each year. Data are shown for main food types, for individual species (with species comprising ≤0.1% of the 3-year mean annual diet listed separately), and for individual species by main food type.

	1990	1991	1992	1990–92
Approx. seasonal sample sizes	c.26	c.51	c.29	c.35

	MEAN % DRY WEIGHT			
	1990	1991	1992	1990–92
Annual diet by main food type:				
Flowers	0.32	3.43	0.26	1.34
Fruit	20.03	42.05	4.08	22.06
Leaves (green)	58.50	37.96	87.52	61.33
Leaves (old)	0.80	0.51	0.00	0.44
Leaves (seedling)	2.62	6.82	1.44	3.63
Other foods	7.14	3.60	1.09	3.95
Stems	10.58	5.61	5.58	7.26
Annual diet by species:				
All woody plants	**73.76**	**79.33**	**85.32**	**79.47**
Podocarpus halli	11.04	15.60	29.13	18.59
Weinmannia racemosa	25.11	8.73	21.25	18.36
Myrsine salicina	4.96	8.11	17.80	10.29
Prumnopitys ferruginea	11.42	12.54	0.39	8.12
Rubus spp.	7.75	3.25	0.53	3.84
Elaeocarpus hookerianus	0.40	10.09	0.88	3.79
Carpodetus serratus	0.00	10.86	0.00	3.62
Aristotelia serrata	7.15	1.41	1.77	3.44
Rubus cissoides	0.00	1.82	4.62	2.15
Elaeocarpus dentatus	3.60	0.14	0.00	1.25
Coprosma "taylorae"	0.12	1.13	0.98	0.74
Prumnopitys taxifolia	0.00	0.69	0.98	0.55
Melicytus ramiflorus	0.12	0.03	1.42	0.52
Neomyrtus pedunculata	0.48	0.77	0.31	0.52
Clematis spp.	0.00	1.02	0.00	0.34
Coprosma tenuifolia	0.01	0.04	0.85	0.30
Large-leaved *Coprosma* spp.	0.06	0.61	0.22	0.30
Pseudopanax crassifolius	0.02	0.11	0.78	0.30
Dacrydium cupressinum	0.48	0.28	0.00	0.25
Melicope simplex	0.00	0.22	0.51	0.24
Rubus schmidelioides	0.00	0.00	0.54	0.18
Hedycarya arborea	0.00	0.50	0.00	0.17
Muehlenbeckia australis	0.00	0.04	0.27	0.10

	MEAN % DRY WEIGHT			
	1990	1991	1992	1990–92
All ferns	**5.46**	**4.92**	**4.10**	**4.82**
Polysticum vestitum	2.20	2.02	1.02	1.75
Histiopteris incisa	0.08	1.53	0.77	0.79
Unidentified ferns	1.33	0.56	0.43	0.77
Phymatosorus diversifolius	0.59	0.55	1.02	0.72
Asplenium bulbiferum	0.04	0.12	0.59	0.25
Blechnum spp.	0.32	0.06	0.14	0.17
Leptopteris spp.	0.41	0.01	0.05	0.16
Leptopteris superba	0.30	0.03	0.00	0.11
Blechnum fluviatile	0.19	0.04	0.08	0.10
All grasses	**0.64**	**0.30**	**0.07**	**0.33**
Unidentified grasses	0.62	0.29	0.07	0.32
All herbs	**7.18**	**3.88**	**3.67**	**4.91**
Unidentified herbs	5.33	2.54	1.74	3.20
Pratia angulata	0.98	0.08	0.26	0.44
Hydrocotyle spp.	0.18	0.57	0.28	0.34
Viola spp.	0.19	0.13	0.50	0.27
Veronica serpyllifolia	0.36	0.00	0.00	0.12
Potamogeton spp.	0.13	0.00	0.20	0.11
Mycelis muralis	0.00	0.18	0.13	0.10
All other	**7.15**	**3.52**	**0.97**	**3.88**
Invertebrate larvae	2.83	0.76	0.12	1.23
Invertebrates	2.43	0.68	0.10	1.07
Fungi	0.62	1.19	0.11	0.64
Moss	0.97	0.54	0.40	0.63
Lichen	0.31	0.24	0.00	0.18
Unidentified	**6.13**	**8.51**	**6.68**	**7.10**
Fibre	0.66	3.73	2.98	2.46
Stems	4.00	0.61	2.46	2.36
Fruit	0.68	3.43	0.49	1.53
Leaves	0.79	0.59	0.62	0.67

Foods comprising ≤0.1% of mean annual diet

Woody *Coprosma* (large-leaved) spp. 0.10; *Myrsine divaricata* 0.09; unidentified bark 0.09; *Fuchsia excorticata* 0.09; *Pseudowintera colorata* 0.08; *Quintinia serrata* 0.07; *Pseudopanax simplex* 0.05; *Nestegis cunninghamii* 0.04; *Coprosma grandifolia* 0.03; *Parsonsia* spp. 0.03; *Coprosma rotundifolia* 0.02; *Libocedrus pulmosa* 0.02; *Pseudopanax arboreus* 0.02; *Coprosma foetidissima* 0.01; *C. rhamnoides* 0.01; *Hebe* spp. 0.01; *Myrsine australis* 0.01; *Olearia* spp. 0.01; *Pseudopanax anomalus* 0.01; *Griselinia littoralis* <0.01; *Melicytus lanceolatus* <0.01; *Metrosideros* spp. <0.01; *Pennantia corymbosa* <0.01; *Phyllocladus alpinus* <0.01; *Rubus australis* <0.01; unidentified podocarp seedlings <0.01; *Urtica ferox* <0.01.

Ferns *Hymenophyllum* spp. 0.10; *Blechnum penna-marina* 0.05; *Asplenium flaccidum* 0.01; *A. hookerianum* 0.01; unidentified *Asplenium* spp. 0.01; *Dicksonia* spp. 0.01; *Leptopteris* *hymenophylloides* 0.01; *Pyrrosia eleagnifolia* 0.01; *Blechnum capense* <0.01; *Hypolepis rufobarbata* <0.01.

Grasses *Carex* spp. 0.01; *Collospermum* spp. <0.01; *Uncinia* spp. <0.01.

Herbs *Cardamine debilis* 0.10; *Acaena* spp. 0.09; *Epilobium* spp. 0.04; *Cerastium* spp. 0.03; *Nertera* spp. 0.02; *Ranunculus* spp. 0.02; *Trifolium repens* 0.01; *Hydrocotyle moschata* 0.01; *Oxalis* spp. 0.01; *Hydrocotyle microphylla* 0.01; *Senecio jacobaea* <0.01; *Myosotis* spp. <0.01.

Other litter 0.04; *Marcantia* spp. 0.04; litter/soil 0.03; soil 0.01; feathers <0.01.

unidentified material 0.07; fruit 0.01; flowers 0.01.

10.8 DEER PREFERENCE AND UTILISATION INDICES.

For each potential food plant, annual consumption was calculated by multiplying the estimated total foliage use by deer (30/kg/ha/yr) for the entire study area by the percentage of the annual deer diet (foliage only) for that species. Browse tier production was calculated by dividing the measured browse tier biomass by an assumed foliage retention time (FRT, based on data provided by G. Hall) and adding the estimated amounts consumed by deer and possums. For deer, total consumption of forage grown within the browse tier was estimated by multiplying the total consumption by the ratio of growing forage to total forage (i.e., including litterfall), and for possums no tree material was included. Three utilisation indices are presented: 1 = utilisation of forage grown within the browse tier as a % of browse-tier production (cannot exceed 100%); 2 = total foliage use (including litterfall) as a % of browse tier production; 3 = total foliage use (including litterfall) of browse tier and overstorey production combined. The least-preferred species (PIs<-0.5) and rare species (browse tier production <1 kg/ha/yr) are listed separately at the end of the table with estimates of browse-tier production.

	DEER FORAGE USE kg/ha/yr	FRT YEARS	BROWSE TIER PRODUCTION kg/ha/yr	UTILISATION INDICES 1	2	3	PREFERENCE INDEX
All woody	**18.86**	**2.0**	**73.2**	**21.9**	**25.7**	**0.7**	**0.2**
Melicytus ramiflorus	0.97	1.2	0.4	96.5	224.6	64.3	1.0
Melicytus lanceolatus	0.09	1.2	0.1	91.0	93.0	91.2	1.0
Hedycarya arborea	0.04	2.0	0.0	99.5	99.5	99.5	1.0
Cordyline spp.	0.12	2.0	0.0	0.0	100.0	100.0	1.0
Pittosporum spp.	0.19	2.0	0.0	0.0	100.0	100.0	1.0
Pseudopanax arboreus	0.07	1.5	0.0	0.0	100.0	100.0	1.0
Ripogonum scandens	0.02	1.5	0.0	98.6	98.6	98.6	1.0
Griselinia littoralis	6.68	2.0	1.9	80.5	352.4	12.0	0.9
Pseudopanax crassifolius	4.27	3.0	2.2	91.0	191.0	31.5	0.9
Elaeocarpus hookerianus	2.02	2.0	1.3	60.7	155.3	2.6	0.8
Elaeocarpus dentatus	0.13	2.0	0.0	65.7	643.0	0.3	0.8
Schefflera digitata	0.04	1.2	0.1	48.8	48.8	48.8	0.8
Olearia spp.	0.02	2.0	0.0	68.8	68.8	68.8	0.8
Large-leaved *Coprosma* spp.	1.05	2.0	1.7	55.5	61.6	24.9	0.7
Pennantia corymbosa	0.04	2.0	0.1	47.9	49.5	9.9	0.6
Weinmannia racemosa	1.92	2.0	3.7	38.5	51.5	1.6	0.5
Pseudopanax simplex	0.12	1.5	0.2	29.6	48.9	4.3	0.5
Carpodetus serratus	0.32	2.0	0.4	29.0	82.0	0.2	0.3
Myrsine australis	0.00	2.0	0.0	28.8	29.3	0.3	0.3
Coprosma foetidissima	0.01	2.0	0.1	18.6	23.9	18.7	0.0
Fuchsia excorticata	0.00	1.0	0.0	9.6	10.9	10.8	0.0
Aristotelia serrata	0.09	1.2	0.9	8.7	10.2	0.1	-0.1
Clematis spp.	0.00	2.0	0.0	9.6	11.1	0.2	-0.3
Rubus spp.	0.20	2.0	1.8	6.4	10.8	0.2	−0.5
Myrsine salicina	0.10	2.0	0.8	6.8	11.4	0.1	-0.5
Nestegis cunninghamii	0.05	2.0	1.0	2.3	4.7	0.1	-0.8
Pseudowintera colorata	0.13	2.0	22.7	0.5	0.6	0.1	−0.9

	DEER FORAGE USE kg/ha/yr	FRT YEARS	BROWSE TIER PRODUCTION kg/ha/yr	UTILISATION INDICES 1	2	3	PREFERENCE INDEX
Podocarpus hallii	0.05	3.0	5.7	0.9	0.9	0.0	−0.9
Quintinia serrata	0.03	2.0	3.3	0.8	1.0	0.0	−0.9
Phyllocladus spp.	0.01	3.5	1.2	1.1	1.1	0.0	−0.9
Hebe spp.	0.01	2.0	2.2	0.5	0.5	0.0	−1.0
Dacrydium cupressinum	0.00	3.0	2.0	0.0	0.0	0.0	−1.0
Melicope simplex	0.00	1.2	1.0	0.0	0.0	0.0	−1.0
Neomyrtus pedunculata	0.00	2.0	1.9	0.0	0.0	0.0	−1.0
All ferns	**4.51**	**2.0**	**63.2**	**6.9**	**7.1**	**5.2**	**−0.5**
Phymatosorus diversifolius	0.23	2.0	1.2	8.1	19.4	1.2	0.6
Blechnum penna-marina	0.00	2.0	0.1	1.0	1.0	1.0	0.5
Asplenium polyodon	0.01	2.0	0.0	32.1	62.1	2.7	0.4
Asplenium flaccidum	0.15	2.0	0.4	28.9	37.3	20.8	0.3
Blechnum procerum	0.13	2.0	0.4	29.7	29.8	29.8	0.3
Blechnum fluviatile	2.41	2.0	13.0	18.6	18.6	18.6	0.1
Dicksonia spp.	1.16	2.0	7.0	16.4	16.4	12.5	0.0
Asplenium bulbiferum	0.02	2.0	0.3	8.4	8.4	8.4	−0.4
Polysticum vestitum	0.28	2.0	4.9	5.6	5.6	5.6	−0.5
Leptopteris hymenophylloides	0.03	2.0	1.8	1.9	1.9	1.9	−0.8
Cyathea smithii	0.18	2.0	14.1	1.2	1.2	1.2	−0.9
Leptopteris superba	0.10	2.0	6.9	1.5	1.5	1.5	−0.9
Histiopteris incisa	0.03	1.0	24.0	0.1	0.1	0.1	−1.0
Blechnum colensoi	0.00	2.0	1.0	0.1	0.1	0.1	−1.0
Blechnum discolor	0.00	2.0	3.4	0.0	0.0	0.0	−1.0
All grasses	**2.73**	**1.0**	**22.6**	**16.1**	**12.1**	**12.5**	**0.3**
Phormium tenax	0.05	1.0	0.0	100.0	100.0	100.0	1.0
Astelia solandri	0.06	1.0	0.0	36.0	207.5	41.6	0.7
Carex spp.	0.01	1.0	0.3	3.4	3.4	3.4	−0.5
Uncinia spp.	0.07	1.0	14.2	0.9	0.5	0.5	−0.8
Ehrharta diplax	0.02	1.0	3.7	0.4	0.4	0.4	−0.9
All herbs	**0.07**	**0.5**	**9.3**	**0.7**	**0.7**	**0.7**	**−0.6**
Lotus spp.	0.01	0.5	0.0	100.0	100.0	100.0	1.0
Lagenifera spp.	0.00	1.0	0.0	100.0	100.0	100.0	1.0
Ranunculus spp.	0.03	0.5	0.3	10.8	10.8	10.8	0.4
Hydrocotyle spp.	0.00	0.5	1.8	0.3	0.3	0.3	−0.9
Empodisma minus	0.00	0.5	1.3	0.0	0.0	0.0	−1.0
All other	**0.22**	**1.0**	**4.7**	**3.0**	**4.7**	**4.6**	**−0.5**
Basidiomycetes	0.05	0.1	0.1	61.2	85.6	68.8	1.0
Pseudocyphellaria spp.	0.02	0.5	0.0	100.0	100.0	100.0	1.0
Usnea spp.	0.03	2.0	0.0	18.6	269.8	76.8	0.0
Sticta spp.	0.07	2.0	2.3	2.1	3.2	3.2	−0.8
All species	**30.00**	**2.0**	**191.2**	**10.4**	**15.7**	**1.1**	**0.0**

Species with preference indices <-0.5 and browse tier production <1 kg/ha/yr

Woody small-leaved *Coprosma* spp. 0.9; *Prumnopitys ferruginea* 0.6; *Dacrycarpus dacrydioides* 0.5; *Leucopogon fasciculatus* 0.4; *Beilschmiedia tawa* 0.3; *Pseudopanax anomalus* 0.3; *Alseuosmia pusilla* 0.2; *Muehlenbeckia australis* 0.2; *Metrosideros diffusa* 0.1; *Parsonsia* sp. 0.1; *Alseuosmia turneri* <0.1; *Cyathodes juniperina* <0.1; *Geniostoma rupestre* var. *ligustrifolium* <0.1; *Myrsine* *divaricata* <0.1; *Nestegis lanceolata* <0.1; Olearia ilicifolia <0.1; *Prumnopitys taxifolia* <0.1; *Rhabdothamnus solandri* <0.1.

Ferns *Blechnum chambersii* 0.3; *B. capense* 0.2; *Trichomanes reniforme* 0.1; *Grammitis billardieri* 0.1; *Ctenopteris heterophylla* 0.1; *Cyathea dealbata* 0.1; *Asplenium hookerianum* <0.1; *Blechnum vulcanicum* <0.1; *Grammitis rigida* <0.1; *Hypolepis rufobarbata* <0.1; *Lindsaea trichomanoides* <0.1; *Ophioglossum coriaceum* <0.1; *Paesia scaberula* <0.1; *Pterostylis* spp. <0.1; *Pyrrosia eleagnifolia* <0.1.

Grasses *Juncus* spp. 0.7; *Collospermum microspermum* <0.1; *Luzula* spp. <0.1; *Scirpus* spp. <0.1.

Herbs *Pratia angulata* 0.9; *Viola* spp. 0.9; *Acaena* spp. 0.6; *Cardamine debilis* 0.5; *Mycelis muralis* 0.3; *Potamogeton* spp. 0.2; *Epilobium* spp. 0.1; *Gunnera monoica* 0.1; *Nertera* spp. 0.1; unidentified waterplant 0.1; *Urtica incisa* 0.1; *Agrostis* spp. <0.1; *Cardamine hirsuta* <0.1; *Carex coriacea* <0.1; *Chiloglottis cornuta* <0.1; *Cirsium* spp. <0.1; *Corybas* spp. <0.1; *Earina* spp. <0.1; *Gnaphalium* spp. <0.1; *Jovellana repens* <0.1; *Oxalis* spp. <0.1.

Other *Dawsonia superba* 0.3; *Cladonia* spp. <0.1.

10.9 POSSUM PREFERENCE AND UTILISATION INDICES.

For each potential food plant, annual foliage consumption was calculated by multiplying the estimated total foliage use (79 kg/ha/yr) for the 4 km^2 possum study area as per Appendix 10.8. Total foliage production was estimated by multiplying foliar litterfall measurements, estimated browse tier production (calculated from the measurements of biomass divided by the appropriate FRT), and estimated annual deer and possum forage consumption. Species that were seldom or never eaten by possums (PIs<-0.5) and that were rare (total production <1 kg/ha/yr) are listed at the end of the table with estimates of total production.

	POSSUM FORAGE USE kg/ha/yr	FRT YEARS	TOTAL PRODUCTION kg/ha/yr	UTILISATION INDEX	PREFERENCE INDEX
All woody	**70.9**	**2.0**	**2184.9**	**3.2**	**0.0**
Melicytus ramiflorus	1.3	1.2	3.0	44.1	1.0
Melicope simplex	0.5	1.2	0.7	69.4	1.0
Muehlenbeckia australis	0.3	1.0	0.4	67.7	1.0
Large-leaved *Coprosma* spp.	1.0	2.0	5.1	19.5	0.8
small-leaved *Coprosma* spp.	0.9	3.0	2.9	31.7	0.8
Coprosma foetidissima	0.0	2.0	0.1	26.5	0.8
Parsonsia spp.	0.1	2.0	0.3	17.8	0.7
Weinmannia racemosa	17.9	2.0	140.9	12.7	0.6
Aristotelia serrata	1.7	1.2	24.5	6.8	0.6
Pseudopanax simplex	0.1	1.5	1.2	10.1	0.6
Olearia spp.	0.0	2.0	0.3	10.0	0.5
Podocarpus halli	23.6	3.0	221.1	10.7	0.4
Myrsine salicina	16.6	2.0	198.0	8.4	0.4
Pseudopanax crassifolius	0.7	3.0	16.1	4.2	0.1
Rubus spp.	4.3	2.0	153.4	2.8	−0.1
Dacrycarpus dacrydioides	0.1	2.0	2.1	2.7	−0.1
Neomyrtus pedunculata	0.3	2.0	12.8	2.4	−0.2
Pseudopanax anomalus	0.0	2.0	0.6	2.1	−0.2
Myrsine australis	0.0	2.0	0.8	1.7	−0.3
Elaeocarpus hookerianus	1.3	2.0	94.0	1.4	−0.4
Quintinia serrata	0.0	2.0	401.6	0.0	−1.0
Prumnopitys ferruginea	0.0	3.0	323.3	0.0	−1.0
Pseudowintera colorata	0.0	2.0	170.0	0.0	−1.0
Nestegis cunninghamii	0.0	2.0	114.6	0.0	−1.0
Dacrydium cupressinum	0.0	3.0	72.8	0.0	−1.0
Elaeocarpus dentatus	0.0	2.0	70.9	0.0	−1.0
Prumnopitys taxifolia	0.0	3.0	50.6	0.0	−1.0
Griselinia littoralis	0.0	2.0	39.2	0.0	−1.0
Carpodetus serratus	0.0	2.0	26.4	0.0	−1.0
Hebe spp.	0.0	2.0	21.9	0.1	−1.0
Phyllocladus spp.	0.0	3.5	6.0	0.0	−1.0
Clematis spp.	0.0	2.0	2.1	0.0	−1.0
All ferns	**2.0**	**2.0**	**130.4**	**1.5**	**−0.4**
Blechnum penna-marina	0.1	2.0	0.1	99.0	1.0
Blechnum spp.	0.1	2.0	0.2	74.6	1.0
Pyrrosia eleagnifolia	0.0	2.0	0.1	26.0	0.8

	POSSUM FORAGE USE kg/ha/yr	FRT YEARS	TOTAL PRODUCTION kg/ha/yr	UTILISATION INDEX	PREFERENCE INDEX
Polysticum vestitum	0.4	2.0	4.6	8.6	0.5
Phymatosorus diversifolius	1.0	2.0	19.9	4.9	0.2
Histiopteris incisa	0.7	1.0	26.4	2.5	0.2
Blechnum capanese	0.0	2.0	0.3	3.0	−0.1
Asplenium flaccidum	0.0	2.0	1.0	2.2	−0.2
Blechnum fluviatile	0.1	2.0	9.4	0.8	−0.5
Leptopteris superba	0.0	2.0	6.6	0.6	−0.7
Leptopteris hymenophylloides	0.0	2.0	2.5	0.6	−0.7
Dicksonia spp.	0.0	2.0	41.8	0.0	−1.0
Cyathea smithii	0.0	2.0	25.1	0.0	−1.0
Blechnum discolor	0.0	2.0	6.9	0.0	−1.0
All grasses	**0.1**	**1.0**	**38.5**	**0.4**	**−0.5**
Uncinia spp.	0.0	1.0	18.6	0.0	−1.0
Scirpus spp.	0.0	0.5	6.5	0.0	−1.0
Collospermum microspermum	0.0	1.0	5.3	0.0	−1.0
Ehrharta diplax	0.0	1.0	3.7	0.0	−1.0
All herbs	**3.5**	**0.5**	**5.8**	**28.6**	**0.9**
Viola spp.	0.4	0.5	0.9	46.3	1.0
Mycelis muralis	0.3	0.5	0.3	96.8	1.0
Cardamine debilis	0.2	0.5	0.4	49.7	1.0
Hydrocotyle spp.	0.2	0.5	0.4	43.2	1.0
Pratia angulata	0.2	0.5	0.3	71.8	1.0
Potamogeton spp.	0.2	0.5	0.2	98.6	1.0
Epilobium spp.	0.1	0.5	0.1	97.3	1.0
Nertera spp.	0.1	0.5	0.1	95.7	1.0
Trifolium spp.	0.0	0.5	0.0	100.0	1.0
Oxalis spp.	0.0	0.5	0.0	100.0	1.0
Senecio jacobaea	0.0	0.5	0.0	100.0	1.0
Acaena spp.	0.1	0.5	0.9	15.6	0.9
All other	**0.0**	**1.0**	**19.6**	**0.0**	**−1.0**
Lichen	0.0	2.0	19.4	0.0	−1.0
All species	**79.2**	**2.0**	**2371.1**	**3.3**	**0.0**

Species with preference indices <-0.5 and with total foliar production <1 kg/ha/yr

Woody *Nestegis lanceolata* 0.7; *Pennantia corymbosa* 0.3; *Alseuosmia pusilla* 0.2; *Beilschmiedia tawa* 0.2; *Metrosideros diffusa* 0.2; *Olearia ilicifolia* 0.2; *Leucopogon fasciculatus* 0.1; *Pseudopanax arboreus* 0.1; *Schefflera digitata* 0.1; *Alseuosmia turneri* <0.1; *Dracophyllum subulatum* <0.1; *Fuchsia excorticata* <0.1; *Geniostoma rupestre* var. *ligustrifolium* <0.1; *Hedycarya arborea* <0.1; *Kunzea ericoides* <0.1; *Myrsine divaricata* <0.1; *Ripogonum scandens* <0.1.

Ferns *Ctenopteris heterophylla* 1.4; *Asplenium polyodon* 0.8; *Blechnum procerum* 0.4; *Asplenium bulbiferum* 0.2; *Blechnum colensoi* 0.1; *Grammitis billardieri* 0.1; *Lindsaea trichomanoides* 0.1; *Asplenium hookerianum* <0.1; *Blechnum chambersii* <0.1;

	Grammitis rigida <0.1; *Hypolepis rufobarbata* <0.1; *Paesia scaberula* <0.1; *Trichomanes reniforme* <0.1.
Grasses	*Carex* spp. 0.8; *Juncus* spp. 0.7; *Astelia solandri* 0.1; *Agrostis* spp. <0.1; *Carex coriacea* <0.1; *Luzula* spp. <0.1.
Herbs	*Earina* spp. 0.3; *Ranunculus* spp. 0.2; *Urtica incisa* 0.1; *Urtica australis* <0.1; *Corybas* spp. <0.1; *Cirsium* spp. <0.1; *Chiloglottis cornuta* <0.1; *Cardamine hirsuta* <0.1; *Pterostylis* spp. <0.1.
Other	fungus 0.1; *Usnea* spp. <0.1; *Cladonia* spp. <0.1.