

## Sex ratio

### *Trend over time*

Overall, the sex ratio of the sika deer harvest over the period 1987-1995 has been biased in favour of stags ( $\chi^2=16.17$ ,  $p<0.001$ ). Hunters killed similar numbers of stags and hinds up to and including 1991 ( $\chi^2=1.77$ , n.s.), although the small samples for some years may have masked any significant trends. However, there was a significant difference in the harvest sex ratio between the 1987-1991 and 1992-1995 periods ( $z=-1.81$ ,  $p_{1\text{-tailed}}<0.05$ ), with the proportion of stags in the annual harvest increasing (Table 3). This is consistent with the stag-biased harvests also reported from other areas in recent years (e.g., Blue Mountains RHA: Nugent 1990a, unpubl. FRI contract report; Pureora Conservation Park: Fraser 1996a). This could reflect the effect of a concentration of hunting effort in the roar (trophy hunting) and the greater vulnerability of stags at particular times of the year. Alternatively, it could suggest that some recreational hunters are now practising their own form of herd management by refraining from shooting hinds.

TABLE 3: NUMBERS OF MALE AND FEMALE SIKA DEER SHOT BY RECREATIONAL HUNTERS IN THE KAIMANAWA RHA (1987-1995) AND THE SEX RATIO (% MALES) FOR EACH YEAR'S HARVEST.

Year	No. of males	No. of females	% males	$\chi^2$	p
1987 <sup>a</sup>	21	17	55.3	0.42	n.s.
1988 <sup>a</sup>	61	53	53.5	0.56	n.s.
1989 <sup>a</sup>	38	40	48.7	0.05	n.s.
1990	194	176	52.4	0.88	n.s.
1991	206	192	51.8	0.49	n.s.
1992	184	134	57.9	7.86	<0.01
1993	178	130	57.8	7.48	<0.01
1994	127	96	56.4	3.74	<0.10
1995 <sup>b</sup>	48	42	53.3	0.40	n.s.
Total	1057	880	54.6	16.17	<0.001

<sup>a</sup> the figures for these years differ from the totals for sika deer in Table 2 because prior to 1990 the sex of any kills was not routinely reported on hunting permit returns

<sup>b</sup> part-year only

### *Geographic and seasonal variation*

The sex ratio of the harvest within each hunting block and within each month were compared with the overall harvest sex ratio (54.6% stags, 45.4% hinds). The overall bias in the harvest was reflected in most hunting blocks, with the exception of the Cascade ( $\chi^2=4.10$ ,  $p<0.05$ ) and Upper Kaipo ( $\chi^2=5.64$ ,  $p<0.05$ ) blocks, where significantly more hinds were shot. Similarly, the sex ratio of the harvest was relatively constant throughout the year with the exception of April, when significantly more stags were shot ( $\chi^2=12.19$ ,  $p<0.001$ ), and November, when significantly more hinds were shot ( $\chi^2=7.17$ ,  $p<0.01$ ).

### Sex-specific growth curves

Sex-specific growth curves derived using the Weibull equation showed that age explained 80% of the variation in jawbone hinge length for both stags and hinds (Fig. 7). The few outliers that deviate substantially from the curves could result from errors in ageing, out-of-season births, and misclassification of sex (Nugent 1989). The growth curve equations use age in months and are as follows:

$$\text{Males:} \quad \text{expected hinge length (mm)} = 222.563 * (1 - e^{-0.593 * \text{AGE}^{0.425}})$$

$$\text{Females:} \quad \text{expected hinge length (mm)} = 209.481 * (1 - e^{-0.651 * \text{AGE}^{0.420}})$$

These equations were used to calculate sex-specific population averages for hinge length at any given age (see Appendix 11.4).

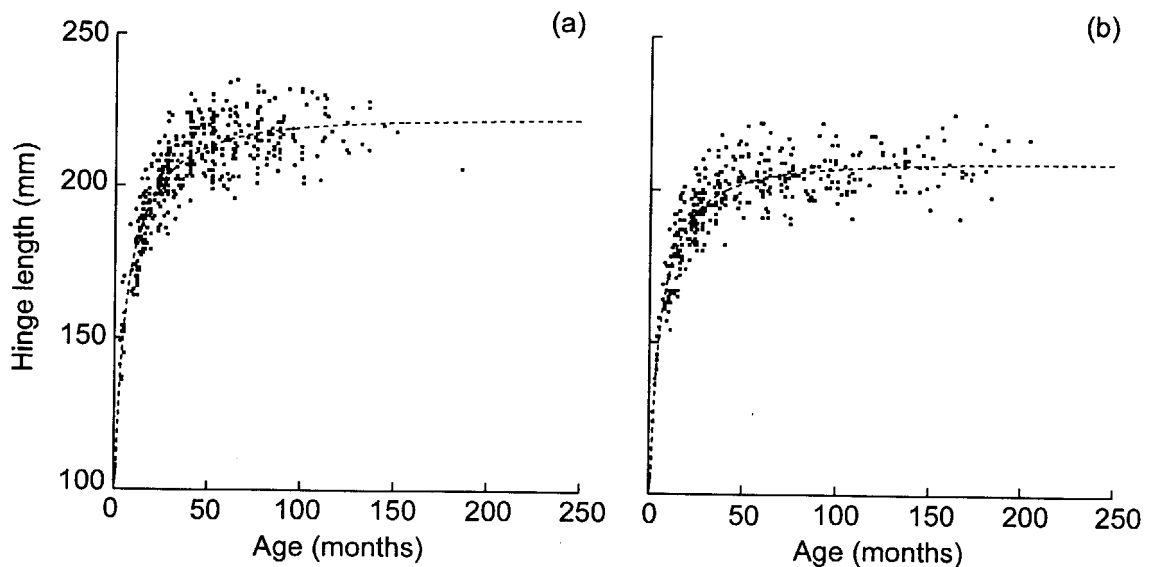


FIGURE 7: WEIBULL GROWTH CURVES AND RAW DATA FOR JAWBONE HINGE LENGTH FOR (a) MALE (N=448) AND (b) FEMALE (N=375) SIKA DEER, KAIMANAWA RHA (1987-1995).

### Condition indices

The condition indices estimated from actual and expected jawbone parameters were independent of both age and sex (see Appendix 11.5 for ANOVA results). Therefore, all the data for each index can be pooled to test for differences in condition according to location, cohort, and year shot. Two-way interactions between these factors were not tested.

### Trends over time

The age- and sex-standardised indices of jawbone size did not differ between cohorts (1967-1993), or the year in which the animals were shot (1987-1995; see Appendix 11.6 for ANOVA results). This indicates that overall growth rates and asymptotic sizes (i.e., maximum attained) have not changed much since the late 1960s, and suggests that there has been little change in the quantity or quality of forage available to deer over that period. This is consistent with the relatively small changes in deer kill rates since the mid 1980s, and therefore suggests that the deer population in the RHA is stable.

## Geographic variation

Condition indices varied significantly between hunting blocks (see Appendix 11.6). Mean jawbone size of sika deer from the northern part of the RHA (the Clements Road, Merrylees, and Hinemaiaia blocks) tended to be larger than average (Fig. 8), and average or below average for the other hunting blocks, particularly for the Cascade, Jap Creek, and Upper Oamaru blocks.

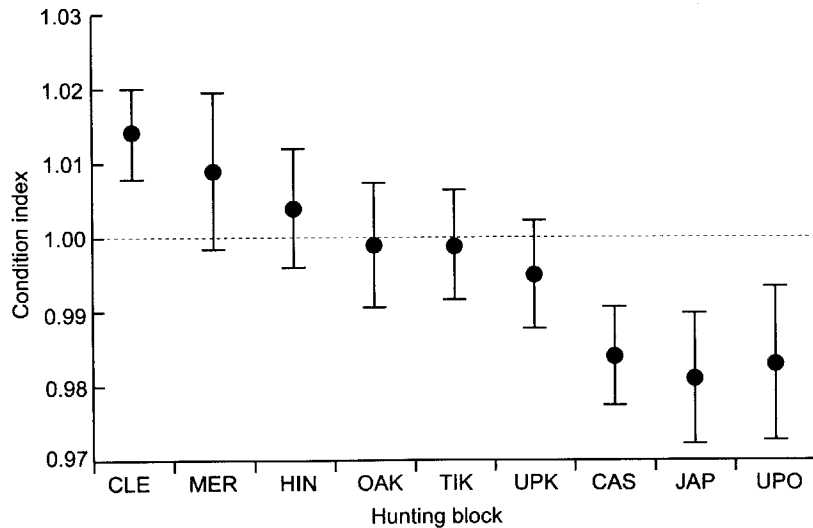


FIGURE 8: AGE- AND SEX-STANDARDISED INDICES OF CONDITION (195% CONFIDENCE LIMITS) FOR SIKA DEER FROM THE KAIMANAWA RHA (N=818), FOR EACH HUNTING BLOCK (CLE = CLEMENTS ROAD, MER = MERRYLEES, HIN = HINEMAIAIA, OAK = OAMARU-KAIPO, TIK = TIKITIKI, UPK = UPPER KAIPO, CAS = CASCADE, JAP = JAP CREEK, UPO = UPPER OAMARU).

The decrease in mean condition indices (i.e., skeletal size) from north to south is associated with a subtle decrease in forest diversity in terms of species richness (Elder 1962), a general increase in altitude, and an increase in deer density (or at least in hunting success rates; see Section 5.1). The Clements Road (relatively diverse forest) and Upper Oamaru (relatively simple forest) hunting blocks represent the extremes of this habitat diversity. In addition, the density of palatable species is greater in the Clements Road and Hinemaiaia hunting blocks in the north (there were no vegetation or browse plots in the Merrylees hunting block), than in the Jap Creek and Upper Oamaru hunting blocks in the south (Brabyn 1988).

## Age structure

The age structure of the Kaimanawa RHA sika deer harvest (Fig. 9) is indicative of a heavily harvested population (c. 75% of the deer harvested are <5 years old) and is similar to the red deer harvest in nearby Pureora Conservation Park (Fraser 1996a). The average age of deer shot was 4.4 years, compared with 3.6 years in Pureora Conservation Park and <3 years in the Blue Mountains RHA. This may be related to the more elusive nature of sika deer, enabling them, on average, to survive to greater ages, or it could suggest that recreational hunters exert a lower degree of population control in the Kaimanawa RHA. Although

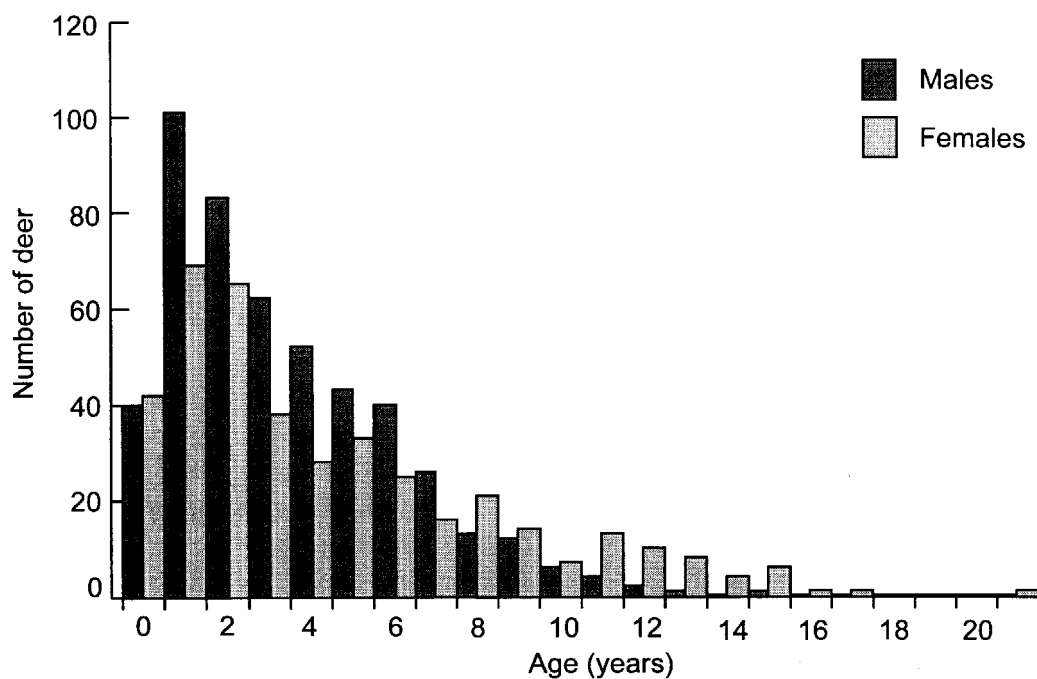


FIGURE 9: AGE STRUCTURE OF SIKA DEER HARVESTED BY RECREATIONAL HUNTERS IN THE KAIMANAWA RHA IN THE PERIOD 1987-1993 (N=888).

there was a tendency for the mean age to be lowest in blocks with the greatest hunting pressure, this was not statistically significant.

Some relatively old deer are still shot by hunters (52 deer (6%) were >10 years old), most of which were hinds (c. 85%). The male-biased harvest, particularly for the younger age classes (1-4 years), is probably the main factor responsible for few stags surviving to >10 years old. Male deer are more vulnerable to hunters not only during the roar but also because they are displaced from maternal groups at an earlier age than females. The low number of fawns shot relative to yearlings suggests that they are less vulnerable to hunters, either benefiting from their close association with their mothers or because hunters refrain from shooting fawns. In contrast, recently independent and inexperienced yearlings are widely viewed by hunters as the easiest quarry.

The mean age of sika stags (c. 3.9 years) was significantly less than for hinds (c. 4.9 years; see Appendix 11.7 for ANOVA results). Examination of mean ages by sex for each hunting block showed that the greatest difference in mean age between the sexes occurred in the Merrylees, Hinemaiaia, Jap Creek, and Upper Oamaru hunting blocks. However, these differences were significant only for the Merrylees and Hinemaiaia blocks.

### 5.3 1987-88 VEGETATION SURVEY

The mean basal area of forests in the Kaimanawa RHA (c. 69 m<sup>2</sup>/ha) is similar to that reported by Wardle (1984) for other red and silver beech associations in New Zealand. The resurvey of 40 permanent vegetation plots in the Kaimanawa RHA in 1987-88 indicated that the basal areas of the main canopy species (red and silver beech) had not changed since 1978-79 (Brabyn 1988). However,

there had been a significant increase in overall densities of stems >2 cm dbh (diameter at breast height), mainly due to increases in the browse tier in the density of species of low deer palatability such as *Neomyrtus pedunculata* and *Pseudowintera colorata*. Between 1978–79 and 1987–88, densities of seedlings <135 cm tall generally increased in all vegetation associations and for both palatable and unpalatable species.

Brabyn (1988) was unable to identify particular vegetation associations that were more susceptible to the impacts of browsing animals, and concluded that deer numbers in the RHA at that time appeared to pose little threat to soil and water values because basal areas, stem densities, and seedling densities were stable or increasing. However, it is likely that selective browsing by deer (and also possums) had already removed most highly palatable species prior to the establishment of the permanent plots in 1978/79, as species which cannot withstand browsing pressure are rapidly removed and the vacant spaces are gradually replaced by less preferred or more browse-resistant plant species (Wardle 1984). The increased abundance of the least palatable species between the 1978/79 and 1987/88 surveys indicates that this replacement process was still occurring.

Since 1988, deer numbers have either declined slightly or remained stable, so present deer numbers probably do not present a threat to overall forest cover, canopy condition, and regeneration of the dominant canopy species. Deer are, however, likely to still be contributing to changes in species composition and to an overall decline in the species richness (biodiversity) of the forest understorey, as well as preventing the re-establishment of palatable species that have all but disappeared.

#### 5.4 CURRENT DEER IMPACTS ON THE VEGETATION

A total of 75 woody and fern species were identified within the browse tier (<2 m) in the five blocks surveyed in 1995. Browse damage was recorded on 49 (65%) of these species (Appendix 11.8). The number of species and the proportion of those browsed were similar in each of the 5 blocks (Table 4). Only 26 woody and fern species were recorded in all the hunting blocks sampled, with a further 10 species recorded from 4 of the 5 blocks. These 36 species included the dominant species in all vegetation tiers, and the vegetation types were broadly similar in all the areas sampled. The species which contributed most to variation in species composition between blocks were generally less common woody subcanopy species or ferns in the ground-level vegetation tiers. One important exception to this was the relative abundance of mountain beech (*Nothofagus solandri* var. *cliffortioides*) in the Jap Creek and Upper Oamaru hunting blocks.

##### **Browse indices**

We have used a range of browse indices (Table 5) to determine the nature of any variation in deer impacts within the Kaimanawa RHA, particularly differences between the northern and southern parts of the RHA, because these represent

TABLE 4: NUMBERS OF WOODY AND FERN SPECIES RECORDED WITHIN THE BROWSE TIER (<2 M) IN THE FIVE HUNTING BLOCKS SURVEYED (1995), AND THE NUMBERS AND PROPORTIONS OF THESE WITH BROWSE DAMAGE.

Hunting block	No. of species recorded	No. of species with browse damage	% of species browsed
Clements Road	50	29	58.0
Hinemaiaia	46	29	63.0
Cascade	45	24	53.3
Jap Creek	51	25	49.0
Upper Oamaru	49	30	61.2
All blocks	75	49	65.3

TABLE 5: BROWSE INDEX AND SUSCEPTIBILITY RATING RESULTS FOR SELECTED VEGETATION SPECIES IN THE KAIMANAWA RHA, 1995. NORTH = CLEMENTS ROAD AND HINEMAIAIA, CENTRAL = CASCADE, AND SOUTH = JAP CREEK AND UPPER OAMARU HUNTING BLOCKS. REFER TO APPENDIX 11.1 FOR DEFINITIONS AND METHODS OF CALCULATION FOR THE BROWSE INDICES AND SUSCEPTIBILITY RATING. BLANKS DENOTE SPECIES ABSENCES ON THE BROWSE PLOTS.

Species	Browse index			% Total browse			Browse pressure index			Susceptibility rating
	North	Central	South	North	Central	South	North	Central	South	
<b>High palatability:</b>										
<i>Asplenium bulbiferum</i>	10		0	1.5			1.0			5.5
<i>Carpodetus serratus</i>	27	28	13	3.9	4.7	1.0	0.7	2.3	1.2	4.4
<i>Coprosma robusta</i>	15	2	4	2.2	0.3	0.3	0.2	0.2	0.3	21.5
<i>Fuchsia excorticata</i>	7	0	6	1.0		0.5	0.4		0.7	7.3
<i>Griselinia littoralis</i>	10	0	48	1.5		3.8	0.1		0.4	11.4
<i>Notbofagus solandri</i> var. <i>cliffortioides</i>		2	81		0.3	6.5		2.0	1.2	5.2
<i>Pseudopanax simplex</i>	16	0	8	2.3		0.6	0.4		0.2	7.4
<i>Weinmannia racemosa</i>	10	5	19	1.5	0.8	1.5	1.7	2.5	3.2	2.6
<b>Moderate palatability:</b>										
<i>Aristotelia serrata</i>	17	0	0	2.5			0.6			3.3
<i>Blechnum fluviatile</i>	31	0	6	4.5		0.5	0.5		0.2	
<i>Coprosma foetidissima</i>	7	15	85	1.0	2.5	6.8	1.2	1.9	2.3	1.5
<i>Coprosma linariifolia</i>	7	53	32	1.0	8.9	2.6	1.0	1.8	2.1	1.4
<i>Coprosma microcarpa</i>	5	24	166	0.7	4.0	13.2	5.0	3.0	2.9	1.1
<i>Coprosma "taylorae"</i>	111	131	252	16.2	21.9	20.1	3.0	2.6	2.4	1.1
<i>Dicksonia lanata</i>	68	46	21	9.9	7.7	1.7	1.9	1.9	1.8	1.4
<i>Notbofagus fusca</i>	40	41	24	5.8	6.9	1.9	0.9	0.8	0.2	3.7
<i>Notbofagus menziesii</i>	81	136	193	11.8	22.7	15.4	1.4	2.1	1.5	2.2
<i>Polystichum vestitum</i>	81	30	32	11.8	5.0	2.6	1.7	1.6	1.8	2.4
<i>Pseudopanax anomalus</i>	0	10	41		1.7	3.3		0.4	1.1	1.0
<i>Rubus cissooides</i>	16	17	10	2.3	2.8	0.8	1.8	1.5	2.0	2.1
<b>Low palatability:</b>										
<i>Blechnum discolor</i>	45	7	0	6.6	1.2		0.8	1.2		1.4
<i>Gaultheria antipoda</i>	3	0	49	0.4	0.0	3.9	1.5	0.0	2.0	2.7
<i>Leucopogon fasciculatus</i>	3	25	35	0.4	4.2	2.8	0.4	1.6	0.5	1.2
<i>Neomyrtus pedunculata</i>	0	16	52	0.0	2.7	4.1	0.0	0.9	0.9	1.0
<i>Pseudowintera colorata</i>	7	2	0	1.0	0.3		0.1	0.0		1.0

the lowest and highest deer densities, respectively. While mean browse indices (MBIs) indicate overall browsing pressure, they do not take into account the variation in plant species between blocks. Species-specific browse indices (i.e., the browse index (BI), the % of total browse index (%TB), and the browse pressure index (BPI)) and susceptibility ratings (SRs) were therefore used to illustrate differences in deer impacts between areas in the Kaimanawa RHA (Table 5). For these analyses, hunting blocks were combined into 3 areas: north (Clements Road and Hinemaiaia), central (Cascade), and south (Jap Creek and Upper Oamaru). The plant species selected constituted at least 90% of the browse records in each of the areas examined.

### ***Mean browse index***

Most browse damage was observed in the 0-30 cm tier (Fig. 10), reflecting the greater abundance of palatable seedlings in this tier. The frequency and intensity of browse damage observed was higher in the southern blocks than in the northern blocks (Fig. 10), for both the 0-30 cm and the 31-200 cm tiers. Browse intensity, as indicated by mean browse indices (MBIs), for the Cascade hunting block (central part of the Kaimanawa RHA) was higher than expected in relation to the 2 southernmost blocks. The reason for this is unclear, although it may be related to the presence of greater numbers of red deer in this block. Compared with sika deer, which obtain much of their food as litterfall on the forest floor (K.W. Fraser unpubl. data), red deer are morphologically and physiologically adapted more towards browsing (Hofmann 1982; Fraser 1996b) and may exert greater browsing pressure on forage growing within the 0-2 m tier.

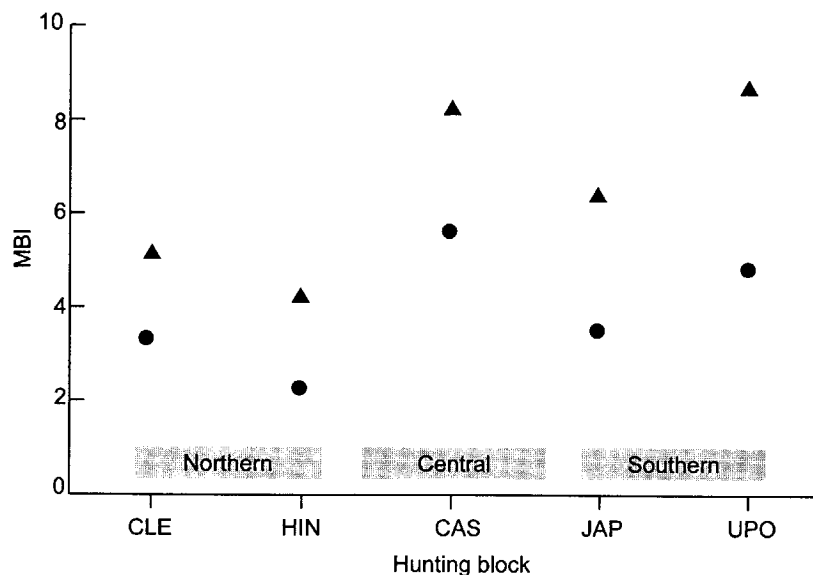


FIGURE 10: MEAN BROWSE INDEX (MBI) FOR THE 0-30 CM (▲) AND 31-200 CM (●) TIERS FOR EACH HUNTING BLOCK (CLE = CLEMENTS ROAD, HIN = HINEMAIAIA, CAS = CASCADE, JAP = JAP CREEK, UPO = UPPER OAMARU).

### ***Browse index***

In all three areas, most browse damage was observed (high BI values in Table 5) on *Coprosma "taylorae"* and *Nothofagus menziesii* (woody species), and *Polystichum vestitum* and *Dicksonia lanata* (fern species). For these species the amount of browse damage was generally higher in the southern blocks, a pattern also particularly evident for some less palatable species such as *Coprosma foetidissima*, *Coprosma microcarpa*, *Gaultheria antipoda*, *Leucopogon fasciculatus*, and *Neomyrtus pedunculata*, for which BI values were more than 10 times greater in the southern area than the northern area. This suggests a greater impact on these species because of higher deer densities or the scarcity of other foods.

Earlier qualitative observations of browse damage when deer numbers were at or near their peak suggest that browsing pressure on species such as *Nothofagus menziesii* and *Polystichum vestitum* was considerably greater than at present. For example, van't Woudt (1950, unpubl. Department of Internal Affairs report) reported that *Polystichum vestitum* is "practically eaten out", particularly in the river valleys, where only the stumps were left. However, these early observations also suggest that despite higher deer numbers, some of the moderate, and perhaps highly, palatable species must have still been reasonably common, since browse damage on species of low palatability such as *Blechnum discolor*, *Leucopogon fasciculatus*, and *Neomyrtus pedunculata* was rare (van't Woudt 1950, unpubl. Department of Internal Affairs report).

### ***Percentage of total browse***

For the moderate and highly palatable categories (all species pooled), there did not appear to be much variation in the percentage of total browse (%TB) observed between the different locations (Table 5). However, for individual species there were some marked differences. For example, *Carpodetus serratus* constituted a greater percentage of the total browse damage in the northern area and *Coprosma foetidissima* constituted a greater percentage of the total browse damage in the southern area, reflecting their differing abundance in these two areas. Some other marked differences were caused by the limited distribution of a few species. *Nothofagus solandri* var. *cliffortioides* was browsed relatively commonly in the southern area (%TB=6.5) but was not present in the northern area, and was uncommon and only lightly browsed in the Cascade hunting block (%TB=0.3). Similarly, the relatively high amount of browse damage recorded on *Blechnum discolor* in the northern area (%TB=6.6) may relate to its abundance in this area, since it is generally considered to be of low-moderate palatability. This species was much less common and unbrowsed in the southern area, and only lightly browsed in the central area (%TB=1.2).

Percent TB values generally indicated a greater reliance by deer on plant species of low-moderate palatability in the southern area (and also the Cascade block). For example, *Gaultheria antipoda*, *Leucopogon fasciculatus*, *Neomyrtus pedunculata*, and *Pseudowintera colorata* constituted c. 11% of the total browse observed in the southern area (cf. c. 7% in the Cascade block and c. 2% in the northern area). However, there were some exceptions to this pattern (including *Blechnum discolor*, *Blechnum fluviatile*, *Dicksonia lanata*,



*Nothofagus fusca*, and *Polystichum vestitum*), although the reasons for these were not clear.

### ***Browse pressure index***

When the northern and southern areas were compared, the browse pressure index (BPI) values show that, with the exception of *Pseudopanax simplex*, all the highly palatable species are browsed more heavily in relation to their availability in the southern area, where deer densities are highest. However, there did not appear to be a consistent pattern between areas for BPI values for moderately palatable species. For the 3 low-palatability species found in all areas (*Gaultheria antipoda*, *Leucopogon fasciculatus*, and *Neomyrtus pedunculata*), BPI values were higher in the southern area, consistent with the higher deer densities and greater overall browsing pressure.

Based on hunting success indices of deer density, the BPI values in the Cascade block could be expected to be intermediate between the northern and southern areas. However, this was evident for only 2 of the 8 highly palatable species recorded from the Cascade block. The reason for the remaining higher or lower than expected BPI values is unclear, but it could be partly due to the greater numbers of red deer in this block and species-related differences in dietary preferences between sika and red deer.

### ***Susceptibility ratings***

Susceptibility ratings (SRs) were calculated after pooling data from all areas. While this does not show what variation exists between areas, it does confirm the markedly greater susceptibility to browsing pressure for most high-palatability species compared with low- and moderate-palatability species. Further, it shows that some species (particularly *Coprosma robusta*, *Griselinia littoralis*, *Pseudopanax simplex*, *Fuchsia excorticata*, and *Asplenium bulbiferum*) are under severe browsing pressure. Most of these species are already relatively uncommon within the browse tier because they have been heavily browsed in the past. Under the current browsing pressure by deer (and also possums) in the Kaimanawa RHA, these species are unlikely to regenerate widely and will continue to decline in abundance. However, some seedlings establish on sites inaccessible to deer (e.g., on bluffs or as epiphytes). In contrast, species such as *Nothofagus menziesii* (and *N. solandri* var. *cliffortioides* in the southern area) and *Polystichum vestitum*, while constituting a relatively large proportion of the total browse damage, have lower SR values and thus appear more resilient to past and current browsing pressure.

Whereas some interesting patterns emerged for the various browse index results, the differences between the areas were not as great as we had expected, although larger sample sizes might have produced clearer and more consistent differences. It is also likely that litterfall in the diet of sika deer (particularly from *Griselinia littoralis* and *Nothofagus* spp.) has a “buffering effect”. Litterfall from these species is plentiful, moderately to highly palatable, and constitutes a considerable proportion of sika deer diet (e.g., for *Griselinia littoralis*: frequency of occurrence = c. 90%, % dry weight = c. 15%; K.W. Fraser,

unpubl. data). Therefore, despite the considerably higher deer densities in the southern hunting blocks, the availability of large quantities of litterfall essentially reduces the potential differences in impacts within the browse tier between areas with differing deer densities.

### ***Variation with altitude***

The intensity of browse damage appeared to increase with altitude (Fig. 11). Such a pattern would be consistent with evidence that sika deer density increases with altitude (Fraser & Leathwick 1990, unpubl. FRI contract report), which may in turn reflect lower hunting pressure at higher altitudes (Fraser & Sweetapple 1992). An increase in browse damage intensity with altitude could also be partly explained by the increase in altitude from north to south, although the same pattern exists within individual hunting blocks. The apparent increasing browse damage with altitude may also be partly a result of slower plant growth rates at higher altitudes (Wardle 1985) with the effect that deer browse damage remains visible for longer. Regression analyses showed that the relationship between browse intensity and altitude was statistically significant for both the 0-30 cm ( $R^2=0.15$ ,  $p<0.05$ ) and 31-200 cm ( $R^2=0.11$ ,  $p<0.05$ ).

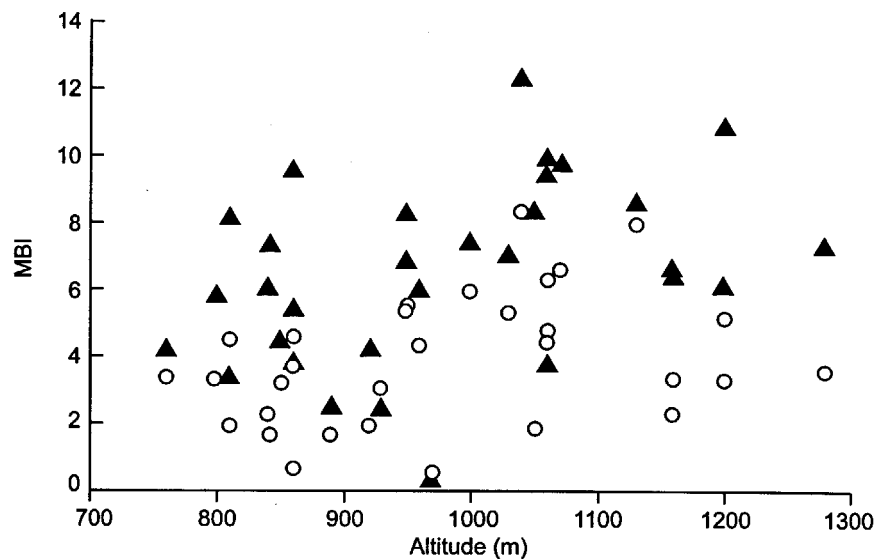


FIGURE 11: MEAN BROWSE INDEX (MBI) FOR THE 0-30 CM (A) AND 31-200 CM (O) TIERS ACCORDING TO ALTITUDE.

### **Seedling densities**

The total number of species recorded as seedlings was similar for each of the hunting blocks surveyed (Clements Road = 33 species, Hinemaiaia = 29, Cascade = 31, Jap Creek = 30, Upper Oamaru = 35). However, overall seedling density was markedly higher in the northern area (21.59 seedlings/m<sup>2</sup>) than in the southern area (13.95/m<sup>2</sup>). When *Pseudowintera colorata*, which contributed >50% of seedlings recorded in our plots, is excluded, overall seedling densities were similar in the northern (9.92/m<sup>2</sup>), central (13.26/m<sup>2</sup>),

and southern (13.87/m<sup>2</sup>) areas, although densities of individual species differed between these areas (Table 6).

Most highly to moderately palatable woody species tended to have lower seedling densities in the southern area than in the northern area (e.g., *Aristolelia serrata*, *Carpodetus serratus*, *Coprosma robusta*; see Table 6). Densities of the moderately palatable fern species (*Blechnum fluviatile*, *Dicksonia lanata*, and *Polystichum vestitum*) were approximately twice as high in the northern area as in the southern area. Although there was no difference in the density of the highly palatable *Asplenium bulbiferum* between the northern and southern areas, this species was uncommon and usually only

TABLE 6: DENSITIES FOR SELECTED FERN SPECIES AND SEEDLING (<30 CM) DENSITIES FOR SELECTED WOODY PLANT SPECIES IN THE KAIMANAWA RHA, 1995. NORTH = CLEMENTS ROAD AND HINEMAIAIA, CENTRAL = CASCADE, SOUTH = JAP CREEK AND UPPER OAMARU HUNTING BLOCKS.

Species	Seedling density (no./m <sup>2</sup> )		
	North	Central	South
<b>High palatability:</b>			
<i>Asplenium bulbiferum</i>	0.05		0.05
<i>Carpodetus serratus</i>	0.46	0.08	0.02
<i>Coprosma robusta</i>	0.57	0.14	0.08
<i>Fuchsia excorticata</i>	0.08	0.02	0.08
<i>Griselinia littoralis</i>	2.08	1.19	2.38
<i>Notofagus solandri</i> var. <i>cliffortioides</i>		0.20	2.11
<i>Pseudopanax simplex</i>	0.29	0.42	0.28
<i>Weinmannia racemosa</i>	0.01		0.01
Subtotal:	3.54	2.05	5.01
<b>Moderate palatability:</b>			
<i>Aristolelia serrata</i>	1.12		0.01
<i>Blechnum fluviatile</i>	0.47	1.01	0.22
<i>Coprosma foetidissima</i>	0.06	0.06	0.03
<i>Coprosma linariifolia</i>	0.02	0.16	0.05
<i>Coprosma microcarpa</i>		0.08	1.06
<i>Coprosma "taylorae"</i>	0.50	1.21	0.79
<i>Dicksonia lanata</i>	0.13	0.10	0.08
<i>Notofagus fusca</i>	1.73	2.55	2.80
<i>Notofagus menziesii</i>	1.54	5.30	2.40
<i>Polystichum vestitum</i>	0.17	0.14	0.08
<i>Pseudopanax anomalus</i>		0.24	0.24
<i>Rubus cissoides</i>	0.02	0.10	0.01
Subtotal:	5.76	10.95	7.77
<b>Low palatability:</b>			
<i>Blechnum discolor</i>	0.08	0.04	
<i>Gaultheria antipoda</i>	0.03		0.26
<i>Leucopogon fasciculatus</i>	0.02	0.02	0.32
<i>Neomyrtus pedunculata</i>	0.49	0.20	0.51
<i>Pseudowintera colorata</i>	11.67	1.48	0.08
Subtotal:	12.29	1.74	1.17

recorded from sites inaccessible to deer. However, the predominant canopy and subcanopy species (*Nothofagus* spp., *Griselinia littoralis*, *Weinmannia racemosa*) tended to have higher seedling densities in the southern area than in the northern area. *Griselinia littoralis* made up 59%, 58%, and 48% of seedlings of the highly palatable species in the northern, central, and southern areas, respectively. Despite seedling densities of  $>1/m^2$ , seedlings of *Griselinia littoralis*  $>20$  cm in height were rare or absent in all blocks.

Seedling densities for low-palatability species tended to be higher in the southern area than in the northern area, where, presumably, greater impact by deer on the more palatable species may have reduced competition and led to compositional changes favouring less palatable plant species. However, the presence and relative abundance of the highly palatable *Nothofagus solandri* var. *clifforttoides* in the southern area suggests that some of the compositional differences may not be animal-induced. The markedly lower density of *Pseudowintera colorata* seedlings in the southern area lends weight to this idea, and suggests that reduced competition from this unpalatable species has contributed to more 'space' being available for other species. However, since it appears that most of this 'space' had been occupied by less palatable species, higher browsing pressure in the southern area is likely to have contributed to some of these compositional differences. It is likely that some of these differences are habitat-related while others reflect previous herbivore densities and impacts.

The impact of deer is also apparent in differing height-class distributions for seedlings of some of the species common to the three areas surveyed (Fig. 12). Almost all *Griselinia littoralis* seedlings are removed before they reach 10 cm tall, and this removal (relative to initial seedling densities) appears to occur earlier (i.e., proportionately fewer seedlings  $>5$  cm) in the southern area, consistent with the higher deer densities in this area. Under the present deer densities, it is extremely unlikely that any regeneration of highly palatable species such as *Griselinia littoralis* is occurring, except in sites inaccessible to deer. Recent remeasurement of 30 permanent forest plots in the nearby Kaweka Range (where deer densities are generally higher than in the Kaimanawa RHA) showed a significant decline in the basal area for *Griselinia littoralis* (Allen & Allan 1995, unpubl. Landcare Research contract report), confirming that deer browsing is inhibiting recruitment. The full extent of deer impacts on such highly palatable species is unlikely to be evident until the present mature trees reach senescence and die.

Seedlings of *Nothofagus menziesii* (which is moderately palatable) were recorded in all height tiers suggesting that, even though this species is relatively heavily browsed by deer, sufficient seedlings and saplings are surviving for regeneration to occur. This is particularly important since *Nothofagus menziesii* is one of the dominant species in the Kaimanawa RHA and the intactness of the forest canopy depends on adequate regeneration and replacement of this and several other key species. However, remeasurement of permanent vegetation plots would be required to confirm that adequate regeneration is occurring. Early surveys carried out in the northern Kaimanawa Range indicated that at the time that deer numbers were at their peak, there was insufficient survival of seedlings of *Nothofagus* spp. for adequate regeneration

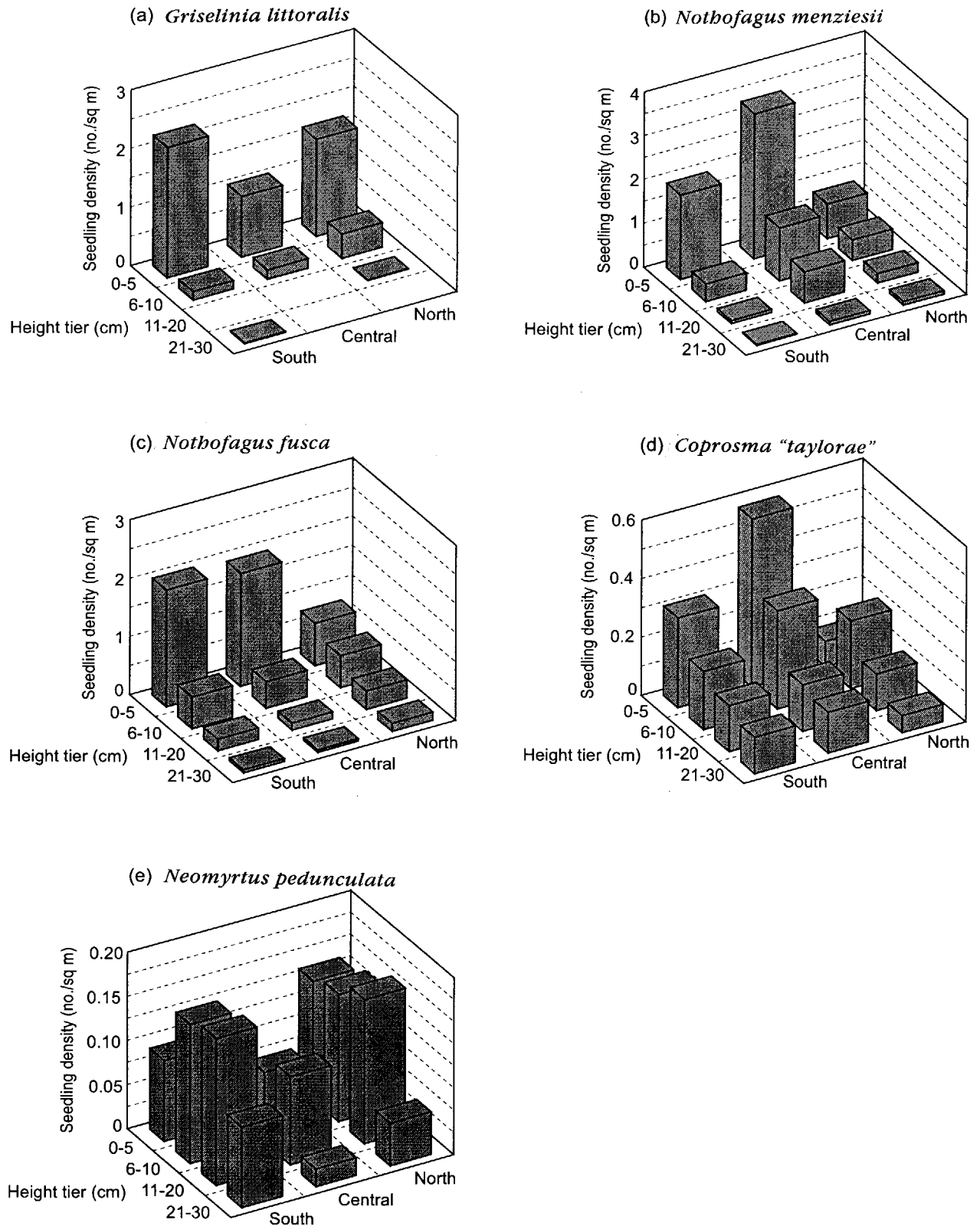


FIGURE 12: HEIGHT-CLASS DISTRIBUTIONS FOR SEEDLINGS OF HIGH PALATABILITY (a), MODERATE PALATABILITY (b, c, d), AND LOW PALATABILITY (e) IN THE KAIMANAWA RHA, 1995. NORTH = CLEMENTS ROAD AND HINEMAIAIA, CENTRAL = CASCADE, SOUTH = JAP CREEK AND UPPER OAMARU HUNTING BLOCKS.

of the forest canopy (van't Woudt 1950, unpubl. Department of Internal Affairs report; McKelvey 1957, unpubl. New Zealand Forest Service report; Elder 1962). This was most noticeable at lower altitudes and in areas close to forest margins (e.g., in the Taharua Valley) where deer densities were higher because they had access to extensive areas of open pasture. McKelvey (1957, unpubl. New Zealand Forest Service report) described the presence of *Nothofagus* spp. seedlings as “ephemeral”, being plentiful in late summer but removed entirely by deer during the winter.

*Nothofagus solandri* var. *cliffortioides*, which is only found in the southern part of the Kaimanawa RHA, showed a similar seedling height-class distribution to *Nothofagus menziesii*, again suggesting that adequate replacement is occurring for maintenance of the forest canopy, where this species is an important component. This contrasts with Allen & Allan's (1995, unpubl. Landcare Research contract report) recent findings which suggest that, in the Kaweka Range, regeneration of *Nothofagus solandri* var. *cliffortioides* appears to be insufficient for canopy replacement, particularly on a few critical sites (e.g., where extensive canopy collapse has occurred).

Height-class distributions for moderately palatable species showed more seedlings surviving into the 11-20 cm and 21-30 cm tiers than for highly palatable species. Although we did not measure seedlings >30 cm tall, a brief assessment of Brabyn's (1988) survey results suggested that the diameter size class distributions for all moderately palatable species pooled conformed to a negative exponential curve, consistent with patterns of adequate stand replacement (Wardle 1984). The resilience of particular species, even of moderate palatability, is highlighted by the seedling height-class distribution for *Coprosma taylorae* which, despite constituting c. 20% of the browse damage recorded, appears to be regenerating well (Fig. 12).

With the exception of *Neomyrtus pedunculata*, there were insufficient data to compare seedling height-class distributions for species of low palatability between the 3 areas. However, within individual areas the distributions appeared similar to that for *Neomyrtus pedunculata* (i.e., considerable numbers of seedlings surviving into the 21-30 cm tier). Brabyn (1988) showed relatively high seedling densities in all tiers (up to 135 cm), confirming that replacement of species with low palatability to deer is occurring and that such species probably benefit from reduced competition with more palatable species.

## 6. Management implications

Sound quantitative and qualitative information about the impacts of introduced deer on indigenous vegetation is an important prerequisite for assessing possible management options for deer. The need for such information prompted this investigation of the relationship between deer numbers and their relative impacts on the vegetation in different parts of the Kaimanawa RHA. Together with information from previous surveys (van't Woudt 1950, unpubl. Department of Internal Affairs report; Elder 1962; Brabyn 1988), our results indicate that selective browsing by deer has influenced and will continue to influence forest composition and dynamics in the Kaimanawa RHA, as it does elsewhere (e.g., Kaweka Range: Allen & Allan 1995, unpubl. Landcare Research contract report; Pureora Conservation Park: Nugent *et al.* 1995, unpubl. Landcare Research contract report). Furthermore, significant modification had already occurred before the original survey (Elder 1962, Brabyn 1988).

The apparent general increase in stem densities between 1978-79 and 1987-88 suggests that forest cover in the Kaimanawa RHA is not threatened. In particular, regeneration patterns for the dominant beech canopy species appear to indicate that current deer densities, even in the southern part of the Kaimanawa RHA where densities are highest and there is greater reliance by deer on species of lower palatability, do not present a threat to widespread canopy replacement. This is clearly not the case in parts of the neighbouring Kaweka Range, where heavy browsing pressure by sika deer is inhibiting mountain beech regeneration on critical sites following natural canopy collapse (Allen & Allan 1995, unpubl. Landcare Research contract report). These critical sites in the Kaweka Range are generally at higher altitudes and therefore closer to the environmental limits for mountain beech. Although our browse and seedling surveys were restricted to north-facing slopes only, deer favour this aspect (Fraser & Leathwick 1990, unpubl. FRI contract report) and therefore their impacts are potentially greatest on these sites. However, vegetation dynamics will undoubtedly be different on south-facing slopes, and lower numbers of deer may have a relatively greater impact than on north-facing slopes. Nevertheless, our findings suggest that the present level of recreational hunting in the Kaimanawa RHA has some conservation benefit, even if it is only in maintaining an intact forest canopy.

While present deer densities do not threaten the survival of a forest cover, they will continue to have an ongoing impact on forest composition, and its quality as deer habitat. These influences are most notable for highly palatable plant species, but also indirectly affect species of lower palatability through reduced competition and hence increased representation in the browse tier.

While the "ecological carrying capacity" (i.e., the maximum number of deer that the habitat can sustain) of the forests in the Kaimanawa RHA is generally higher in the northern area (lower altitude, greater species diversity, more palatable species), the highest densities of deer occur in the southern part of the RHA. The greater browsing pressure on the vegetation in the southern area is confirmed by higher MBIs and lower seedling densities for most highly and



moderately palatable species. For many highly palatable species (e.g., *Asplenium bulbiferum*, *Coprosma robusta*, *Fuchsia excorticata*, *Griselinia littoralis*, *Pseudopanax simplex*), deer impacts are severe. While these species are still present, there is little or no replacement occurring and in the longer term they are likely to disappear completely, except from sites inaccessible to deer. Even at the lowest deer densities in the northern part of the Kaimanawa RHA, where good access and facilities (roads, tracks, camp sites, huts) for hunters result in intense hunting pressure, browsing pressure is still too high for widespread regeneration of these species. This finding is consistent with previous exclosure studies (e.g., Allen *et al.* 1984; Stewart & Burrows 1989) and the model proposed in Nugent *et al.* (1995, unpubl. Landcare Research contract report). Ultimately, browsing by deer will cause a decline in the species diversity and composition of beech forests in the central North Island, although many of these changes may not be fully apparent for many years.

The variation in seedling densities and browse indices within the RHA suggests that the impact of deer can be lessened by increasing hunter access to more remote and inaccessible areas, particularly at higher altitudes. However, even if such measures resulted in a general decline in deer numbers to densities similar to those found in the northern part of the RHA, it is unlikely to lead to anything other than subtle changes, mainly in the forest understorey. Even with the relatively high hunting pressure in the northern part of the RHA, many key highly palatable species are not regenerating. Markedly lower deer densities would be required to achieve a reversal of the deer-induced modification of the vegetation that has occurred in the Kaimanawa RHA.

Despite the variation in deer density from north to south, the apparent differences in impacts on the vegetation between the areas were not as great as we had expected. This may be largely due to the “buffering effect” of food originating from above the browse tier (i.e., predominantly litterfall). Although only a small proportion of the litterfall produced is consumed, litterfall does increase the amount of food available to deer and means that carrying capacity is substantially higher than would be sustained by production within the browse tier alone (see Nugent *et al.* 1995, unpubl. Landcare Research contract report). Therefore, unless recreational hunting pressure reduces deer numbers to well below the ecological carrying capacity, this is likely to result in continued high browsing pressure on species whose seedlings (i.e., regeneration) are preferred over litterfall.

It is apparent that the current deer harvest is male-biased, with some indication that this trend is increasing. If so (and if the total harvest remains similar), the greater survival of females (the productive segment of the population) is likely to lead to population increases. However, any such increases are unlikely to lead to markedly greater deer impacts on the vegetation because of the buffering effect of litterfall. Other changes in hunting impact such as increased hunting success and a reversal of the harvest trend back towards more females could naturally follow population increase, particularly if hunters understand and support any conservation management objectives for the RHA. Further monitoring through hunter diaries and jawbone collections should ensure that if any significant changes do occur, they would be readily apparent and allow management to consider possible options for deer control.



## 6.1 OPTIONS FOR ACTIVE MANAGEMENT

Although the level of recreational hunting pressure in the Kaimanawa RHA is considerably greater than the national average, there is probably some scope for the further enhancement or manipulation of hunting pressure to achieve conservation outcomes. A number of options are possible:

- (i) Increasing access to remote and less accessible areas (particularly at higher altitudes). This would result in increased hunting pressure in these sites where deer densities are highest. Provided that such a change involved an increase in the total hunting effort rather than just a redistribution of the existing effort, this should result in an overall decrease in deer density within the Kaimanawa RHA.
- (ii) Increasing hunting pressure outside the roar period (when a significant part of the annual deer harvest occurs but is biased towards males). This would probably help to increase the female harvest. Such efforts to increase hunting pressure outside the roar would be best targeted towards spring, when females appear to be more susceptible to hunters. Increased publicity and hunting competitions are two possible options that could be used to achieve this.
- (iii) An education campaign aimed at increasing the number of female deer killed regardless of season. Publicity would be required in order to get hunters to understand and support the need to maintain high hunting pressure on breeding-aged female deer. A focus on trophy stag production in the Kaimanawa RHA rather than “deer” production could help to increase this understanding and support for such an option since the production of good trophies requires high survival of male deer in an overall lower density population.

Each of these options, if adopted and achieved, would be likely to result in only subtle changes in deer impacts. Therefore, given that any resulting conservation benefits are likely to be small, it is arguable whether the potential costs of achieving these benefits could be justified.

Recognising the significant recreational value of the deer resource in the Kaimanawa RHA, alternative goals could be (i) to increase hunting opportunities, (ii) to increase hunter satisfaction, or (iii) to reduce hunter concerns relating to safety and competition. However, the scope for achieving such goals is limited because the RHA is already highly popular and well used, and any such ‘recreation goals’ should not conflict with conservation goals for the area.

Increasing hunting opportunities is probably the most feasible and could be achieved through improved or additional access and facilities (e.g., huts, tracks, helicopter landing sites), particularly in less accessible parts of the RHA. This is likely to result in some small conservation benefits in localised areas only, although whether these could be sustained in the longer term is unclear.

Increasing hunter satisfaction is generally associated with improving individual hunting success (i.e., increasing sighting and kill rates), but alternatively could also relate to overall hunter satisfaction with the area (i.e., maximising the annual harvest by all hunters). It is possible that in parts of the Kaimanawa RHA

(e.g., those areas where deer are in poorest condition) deer density is greater than 50% of the carrying capacity and therefore the harvest is less than the maximum sustained yield (Caughley 1977). Therefore, in such areas the total harvest could be increased with presumably a resulting improvement in overall hunter satisfaction, but this would be at the expense of decreased sighting and kill rates for individual hunters.

Hunter satisfaction is also related to individuals' motivations for hunting. In particular, there is a clear distinction between hunters whose goal is to shoot a good quality trophy and those whose goal is simply to take home some venison. A survey of hunters using part of the Kaimanawa RHA in 1986 and 1987 (Fraser & Sweetapple 1992) indicated that besides the attraction of hunting sika deer (more elusive than red deer), the latter is more important. This suggests that management should focus on maximising the harvest from the RHA. It is likely that any measures designed to reduce deer numbers and improve trophy quality would be met with resistance from most hunters.

Similarly, while any restrictions on hunting pressure for reasons of safety or reducing competition between hunters to improve hunting success would be likely to meet with approval from the hunting fraternity as a whole, they would probably fail to find favour with individual hunters if they thought they would have to forego any hunting opportunities. For many hunters, the Kaimanawa RHA is one of the most easily accessible sika deer hunting areas and historically has always been an open-block, unrestricted hunting area. Furthermore, any measures which attempted to increase hunting success by reducing hunting pressure would inevitably be met with resistance both within and outside the Department since higher deer numbers are perceived to represent an increased threat to conservation values (e.g., Nelson 1979), although in reality the threat is small.

To influence the attitudes of recreational hunters and their consequent impacts on deer populations in the Kaimanawa RHA, conservation managers will require an effective rapport with hunters and hunting groups. This will be enhanced by the provision of quality access, facilities, and information. In turn, a greater understanding by hunters of the impacts of their harvesting efforts, and support and cooperation from them in the provision of quality data including hunting diaries and jawbones, will at the very least aid routine management of the RHA and could potentially provide improved conservation outcomes.

The preceding discussion presupposes that DoC's conservation goals for the Kaimanawa RHA are simply to maintain an intact forest cover. Within this context, the present hunting regime probably achieves the desired goals. However, if the goal is to restore depleted components of the ecosystem (e.g., increase regeneration of highly palatable species) and prevent any further loss of biodiversity, then significant increases in recreational hunting pressure or alternative options (e.g., official control, commercial venison recovery) would need to be considered. It is doubtful whether recreational hunting effort could ever be increased enough to achieve this, and the costs of attempting to do so are unknown. The option of official control would be expensive since deer numbers would need to be reduced to very low levels to achieve any significant vegetation recovery (see Nugent *et al.* 1995, unpubl. Landcare Research contract report). Furthermore, it is likely that there are many areas that would

far outrank the Kaimanawa RHA in terms of the conservation values at stake and priority for deer (or other ungulate) control. While removal of RHA status and allowing venison recovery by commercial operators would involve minimal economic costs to the Department, the present marginal economic viability of wild animal recovery and the smaller body size of sika deer means that such an option is unlikely to attract much interest from commercial operators. It is unlikely that changes to the present management of the Kaimanawa RHA would extend beyond improved monitoring and limited manipulation or enhancement of recreational hunting pressure only.

Clearly, there is an ecological cost in having deer present, even at low densities. However, in the absence of our ability to virtually eliminate deer from anything other than small localised sites using current conventional deer control techniques and within the present funding constraints, it is a cost that conservation managers may have to accept. Given the large areas of adjacent private land with sika deer in the central North Island, it is unlikely that any control of deer on lands administered by the Department could be sustained in the longer term.

In summary, the current hunting pressure within the Kaimanawa RHA appears sufficient to maintain a forest canopy, even in the southern part of the RHA where deer densities are highest. It is unlikely that the conservation values present within the RHA are sufficiently important to justify anything other than small changes to the present management regime. Therefore, any future changes should simply concentrate on improved monitoring (to better understand the relationships between hunters, the deer population, and the habitat) and increasing hunting opportunities (to ensure the long-term viability of recreational hunting as an animal management mechanism in this and adjacent areas).

The browse indices and seedling densities recorded in this study and the permanent plot survey data provide a benchmark for future comparisons of browsing pressure and vegetation change as the forests of the Kaimanawa RHA continue to adapt to the presence of deer. Remeasurement of the permanent plots at regular intervals would provide the most robust assessment of any vegetation change. How much more deer-induced change occurs will depend on the level of 'control' exerted by recreational hunters, which is dependent on access, facilities, the seasonal distribution of hunting effort, and perhaps more importantly, on the attitudes of hunters to the harvesting of female deer.

## 7. Summary

- The level of recreational hunting pressure in the Kaimanawa RHA is considerably greater than the national average.
- The lowest deer densities occur in the northern part of the RHA, where access is easier and hunting pressure is greatest.
- While present deer densities do not threaten forest cover, our results indicate that selective browsing by deer has influenced and will continue to influence forest composition and dynamics in the Kaimanawa RHA, as it does elsewhere.
- Despite the variation in deer density from north to south, the apparent differences in impacts on the vegetation between the areas was not as great as was expected.
- Even at the lowest deer densities in the northern part of the Kaimanawa RHA, where good access and facilities for hunters result in intense hunting pressure, browsing pressure by deer is still too high for widespread regeneration of palatable plant species.
- Ultimately, browsing by deer, even at the relatively low densities in the most intensively hunted areas, will cause a decline in the species richness (biodiversity) of beech forests in the central North Island.
- Variation in seedling densities and browse indices within the RHA suggest that the impacts of deer can be lessened by increasing hunter access to more remote and less accessible areas particularly at higher altitudes.
- However, even if some measures resulted in a general decline in deer numbers to densities similar to those found in the northern part of the RHA, it is unlikely to lead to anything other than subtle changes, mainly in the forest understorey.

## 8. Recommendations

- The 40 permanent vegetation plots in the Kaimanawa RHA should be remeasured at 5-yearly intervals to provide a robust assessment of any changes in the vegetation as the forests of the RHA continue to adapt to the presence and impacts of deer. If any active management options for the RHA are adopted in the near future, any remeasurement would also establish valuable datum points for determining any changes in deer impacts as a result of such management.
- If DoC chooses to attempt to manipulate recreational hunting pressure to reduce deer impacts where they are greatest, more hunting effort should be directed towards higher altitude areas and the less accessible hunting blocks. The provision of more helicopter landing sites, huts, and access

tracks in these areas is likely to increase recreational hunting pressure, thereby reducing deer densities and their impacts on the vegetation.

- If DoC chooses to attempt to manipulate recreational hunting pressure to reduce overall deer densities, similar measures to those recommended above could be taken but over a wider range of sites.
- The hunter diary system should continue to be used to provide information on recreational hunting pressure and hunting success, so that any changes in recreational hunting patterns can be related to deer densities and conservation impacts. Efforts should be made to increase the hunter diary return rate to >50%, in order to increase the accuracy and precision of estimates derived from these data and therefore increase the usefulness of this information to management.
- The collection and measurement of jawbones from deer shot by recreational hunters provides useful baseline demographic information and should continue. These data will be valuable for monitoring any possible future changes in herd structure, that occur either passively or as a result of active management (e.g., increasing trophy quality, lowering overall deer densities). The existing jawbone collection sites should be upgraded and additional sites considered.
- Information obtained from the analysis of this material and contained in this report should be communicated to hunters (e.g., magazine articles, posters in back-country huts, lectures to hunting groups) to illustrate how hunting data are used and to encourage greater participation by hunters in providing information for management. They should also be encouraged to understand and support the need to maintain and possibly increase hunting pressure on breeding-aged female deer.

## 9. Acknowledgements

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# 10. References

- Allen, R. 1992. RECCE: An inventory method for describing New Zealand's vegetative cover. *Forest Research Institute Bulletin No. 176*. 25 p.
- Allen, R. 1993. A permanent plot method for monitoring changes in indigenous forests. Landcare Research New Zealand Ltd, Christchurch. 35 p.
- Allen, R., and Allan, C. 1995. Mountain beech forest dynamics in the Kaweka Range and the influence of browsing animals. Landcare Research contract report (unpubl.). 21 p.
- Allen, R.B., Payton, I.J., Knowlton, J.E. 1984. Effects of ungulates on structure and species composition in the Urewera forests as shown by exclosures. *New Zealand journal of ecology* 7: 119-130.
- Bailey, A.W., and Poulton, C.E. 1968. Plant communities and environmental relationships in a portion of Tilamook burn, Northwestern Oregon. *Ecology* 49: 1-13.
- Brabyn, L.K. 1988. Resurvey of the forests of the Kaimanawa Recreational Hunting Area. Department of Conservation, Turangi. 30 p.
- Caughley, G. 1971. The season of births for northern hemisphere ungulates in New Zealand. *Mammalia* 35: 204-220.
- Caughley, G. 1977. *Analysis of vertebrate populations*. J. Wiley & Sons Ltd, Chichester. 234 p.
- Challies, C.N. 1978. Assessment of the physical well-being of red deer (*Cervus elaphus*) populations in South Westland, New Zealand. PhD thesis, University of Canterbury. 153 p.
- Davidson, M.M. 1976. Season of parturition and fawning percentages of sika deer (*Cervus nippon*) in New Zealand. *New Zealand journal of forestry science*: 5: 355-357.
- Davidson, M.M., and Fraser, K.W. 1991. Official hunting patterns, and trends in the proportions of sika (*Cervus nippon*) and red deer (*C. elaphus scoticus*) in the Kaweka Range, New Zealand, 1958-1988. *New Zealand journal of ecology* 15: 31-40.
- Elder, N.L. 1962. Vegetation of the Kaimanawa Ranges. *Transactions of the Royal Society of New Zealand (botany)* 2: 1-37.
- Frampton, C.M., and Nugent, G. 1992. Age and sex-independent comparisons of morphological measurements. *Growth, development & aging* 56: 45-52.
- Fraser, K.W. 1996a. The effect of recreational hunters on deer populations in Pureora Conservation Park. *Science for conservation* 31. 39 p.
- Fraser, K.W. 1996b. Comparative rumen morphology of sympatric sika deer (*Cervus nippon*) and red deer (*C. elaphus scoticus*) in the Ahimanawa and Kaweka Ranges, central North Island, New Zealand. *Oecologia* 105: 106-166.
- Fraser, K.W., and Leathwick, J.R. 1990. Population distribution and seasonal patterns of habitat use for sika deer, Kaimanawa RHA. Forest Research Institute contract report (unpubl.). 29 p.
- Fraser, K.W., and Sweetapple, P.J. 1992. Hunters and hunting patterns in part of the Kaimanawa Recreational Hunting Area. *New Zealand journal of zoology* 19: 91-98.
- Fraser, K.W., and Sweetapple, P.J. 1993. Assessing the age and condition of deer from jawbones. Manaaki Whenua - Landcare Research New Zealand Ltd, Christchurch. 32 p.
- Henderson, R.J., and Nugent, G. 1989. Monitoring the hunting system for red deer in the Oxford RHA. Forest Research Institute contract report (unpubl.). 18 p.
- Hofmann, R.R. 1982. Morphological classification of sika deer (*Cervus nippon*) within the comparative system of ruminant feeding types. *Deer* 5: 352-353.
- McKelvey, P.J. 1957. Damage in protection forest at Poronui (northern Kaimanawa Ra.). New Zealand Forest Service report (unpubl.). 4 p.

- Nelson, R. 1979. *Deer and resulting devastation in New Zealand*. Royal Forest and Bird Protection Society, Wellington. 71 p.
- Nugent, G. 1989. Identifying the sex of fallow deer from jawbone measurements. *Australian wildlife research* 16: 441-447.
- Nugent, G. 1990a. Monitoring the Blue Mountains Recreational Hunting Area. Forest Research Institute contract report FWE 90/24 (unpubl.). 25 p.
- Nugent, G. 1990b. Forage availability and the diet of fallow deer (*Dama dama*) in the Blue Mountains, Otago. *New Zealand journal of ecology* 13: 83-95.
- Nugent, G. 1992. Big-game, small-game, and gamebird hunting in New Zealand: hunting effort, harvest, and expenditure in 1988. *New Zealand journal of zoology* 19: 75-90.
- Nugent, G. 1993. Management issues for the Blue Mountains Recreational Hunting Area. Landcare Research contract report LC9394/30 (unpubl.). 17 p.
- Nugent, G., and Challies, C.N. 1988. Diet and food preferences of white-tailed deer in north-eastern Stewart Island. *New Zealand journal of ecology* 11: 61-71.
- Nugent, G., and Fraser, K.W. 1993. Pest or valued resource: conflicts in game management. *New Zealand journal of zoology* 20: 361-366.
- Nugent, G., Fraser, K.W., Sweetapple, P.J. 1995. Comparison of red deer and possum diets and impacts in a podocarp-hardwood forest, Waihaha catchment, Pureora Conservation Park. Landcare Research contract report LC9495/94 (unpubl.). 65 p.
- Rose, A.B., and Burrows, L.E. 1985. The impact of ungulates on the vegetation. In: Davis, M.R.; Orwin, J. (eds). *Report on a survey of the proposed Wapiti area, West Nelson*. pp. 210-234. New Zealand Forest Service, FRI Bulletin No. 84.
- Stewart, G.H., and Burrows, L.E. 1989. The impact of white-tailed deer *Odocoileus virginianus* on regeneration in the coastal forests of Stewart Island. *Biological conservation* 49: 275-293.
- van't Woudt, B.D. 1950. Damage to soil and vegetation by deer in the north-western Kaimanawa Range, New Zealand. Department of Internal Affairs, Wildlife Miscellaneous report no. 30 (unpubl.). 26 p.
- Wardle, J. 1984. *The New Zealand beeches: ecology, utilisation and management*. New Zealand Forest Service. 447 p.
- Wardle, P. 1985. New Zealand timberlines. 1. Growth and survival of native and introduced tree species in the Craigieburn Range, Canterbury. *New Zealand journal of botany* 23: 219-234.
- Wardle, J., Hayward, J., Herbert, J. 1971. Forests and scrublands of northern Fiordland. *New Zealand journal of forestry science* 1: 80-115.



# 11. Appendices

## 11.1 METHODS USED FOR CALCULATING BROWSE INDICES

The following indices were calculated (after Wardle *et al.* 1971; Rose & Burrows 1985):

- 1 Browse Index (BI): An estimate of the total amount of browsing on a species over a group of plots (vegetation type, association, or area).

$$BI = \Sigma (\text{browse scores})$$

- 2 % Total Browse (%TB): The amount of browsing on a species as a proportion of total browsing on all species over a group of plots.

$$\%TB = \frac{BI}{\Sigma (\text{BI of all species})} \times 100$$

- 3 Browse Pressure Index (BPI): A measure of the amount of browsing on a species in relation to its availability.

$$BPI = BI/n$$

where n = the number of plots in which a species is present.

- 4 Mean Browse Index (MBI): A measure of the browsing intensity on all species over a group of plots.

$$MBI = \frac{\Sigma (\text{BI of all species})}{N}$$

where N = the total number of plots in the group.

Susceptibility ratings (SRs) were also determined. The SR of a species compares its frequency in the main browse tier with its frequency in the tiers directly above and below. It is a gauge of a species' ability to regenerate under past and/or present browsing pressure. The formula used depends on the height attained by a species (Wardle *et al.* 1971). The SR of a species is >1 if it is less frequent in the main browse tier than in the tiers above and/or below.

- 1 For species that normally grow to between 0.3 and 2.0 m in height:

$$SR = \frac{\text{frequency in the 0-0.3 m tier}}{\text{frequency in the 0.3-2.0 m tier}}$$

- 2 For species that normally grow greater than 2.0 m in height:

$$SR = \frac{\text{frequency in the 0-0.3 m tier} + \text{frequency in the 2.0-5.0 m tier}}{2 \times (\text{frequency in the 0.3-2.0 m tier})}$$



## 11.2 REPORTED HUNTING EFFORT IN THE KAIMANAWA RHA ACCORDING TO HUNTING BLOCK AND YEAR (1989-1995)<sup>1</sup>

Hunting block	Area (km <sup>2</sup> )	Reported number of days hunted								Days hunted /km <sup>2</sup>
		1989	1990	1991	1992	1993	1994	1995 <sup>2</sup>	Total	
Cascade	27.50	225	109	263	111	142	132	75	1057	38.4
Clements Road	39.41	951	1238	1321	1073	1130	1013	242	6968	176.8
Hinemaiaia	38.90	246	110	105	97	56	41	18	673	17.3
Jap Creek	20.59	81	24	55	50	29	28	15	282	13.7
Merrylees	25.86	120	111	59	56	91	88	24	549	21.2
Oamaru-Kaipō	27.29	175	238	269	251	217	160	60	1370	50.2
Tikitiki	15.00	100	77	66	94	15	20	10	382	25.5
Upper Kaipō	18.89	159	107	147	81	115	123	35	767	40.6
Upper Oamaru	26.56	62	49	35	50	45	26	0	267	10.1
Totals	240.00	2119	2063	2320	1863	1840	1631	479	12315	51.3

<sup>1</sup> reported number of days hunted prior to this period are: 1983 - 2579; 1984 - 2660; 1985 - 2500; 1986 - 2585; 1987 - 3143; 1988 - 2357

<sup>2</sup> part-year only

## 11.3 HUNTING PERMIT OR HUNTER DIARY RETURN RATES AND REPORTED HARVESTS AND HUNTING SUCCESS RATES IN THE KAIMANAWA RHA ACCORDING TO YEAR (1983 - 1995)

Year	Return rate (%)	Number of deer seen			Deer seen per day	Number of deer killed			Deer killed per day
		Sika	Red	Total		Sika	Red	Total	
1983	21.7	-	-	-	-	-	-	361	0.14
1984	22.2	-	-	-	-	-	-	370	0.14
1985	19.4	-	-	-	-	-	-	303	0.12
1986	25.7	-	-	-	-	-	-	362	0.14
1987	45.5	-	-	-	-	401	33	434	0.14
1988	45.2	-	-	-	-	340	12	352	0.15
1989	32.0	1822	93	1915	0.90	385	34	419	0.20
1990	31.6	1980	99	2079	1.01	370	20	390	0.19
1991	30.8	1903	87	1990	0.86	398	25	423	0.18
1992	29.0	1522	77	1599	0.86	318	27	345	0.19
1993	26.5	1338	29	1367	0.72	308	8	316	0.17
1994	23.1	1100	61	1161	0.71	223	20	243	0.15
1995 <sup>1</sup>	n.a.	346	13	359	0.75	90	1	91	0.19

<sup>1</sup> part-year only

#### 11.4 EXPECTED HEEL AND HINGE JAWBONE LENGTHS FOR MALE AND FEMALE SIKA DEER

Based upon Weibull growth curves for each sex - see section 5.2.

### 11.5 ANOVA RESULTS FOR CONDITION INDICES IN RELATION TO SEX AND AGE (IN YEARS)

Source	Sum of squares	df	Mean square	F-ratio	p
Sex	0.002	1	0.002	1.336	0.248
Age <sup>1</sup>	0.027	12	0.002	1.431	0.146
Sex * Age	0.017	12	0.001	0.910	0.536
Error	1.255	797	0.002		

<sup>1</sup> all deer  $\geq 12$  years old were combined into a single age class to eliminate missing cells in the factorial ANOVA design

### 11.6 ANOVA RESULTS FOR CONDITION INDICES IN RELATION TO LOCATION (HUNTING BLOCK), COHORT, AND YEAR (IN WHICH THE ANIMAL WAS SHOT)

Source	Sum of squares	df	Mean square	F-ratio	p
Location	0.089	8	0.010	4.452	< 0.001
Cohort	0.040	22	0.002	1.221	0.221
Year shot	0.010	8	0.002	0.868	0.543
Error	1.154	781	0.001		

### 11.7 ANOVA RESULTS FOR MEAN AGE OF SIKA DEER SHOT IN THE KAIMANAWA RHA IN RELATION TO SEX AND LOCATION (HUNTING BLOCK)

Source	Sum of squares	df	Mean square	F-ratio	p
Sex	24335.9	1	24335.9	15.6	<0.001
Location	17534.7	9	1948.3	1.2	0.264
Sex * location	18236.2	9	2026.2	1.3	0.235
Error	1336173.3	854	1564.6		

## 11.8 WOODY AND FERN SPECIES PRESENT IN THE BROWSE TIER

(for each of the five hunting blocks surveyed in 1995; ■ = recorded in the browse tier, ✓ = evidence of browse present)

Species	Clements Road		Hinemaiaia		CascadeJap Creek		Upper Oamaru	
<i>Aristotelia serrata</i>	■	✓	■	✓	■		■	
<i>Asplenium bulbiferum</i>	■	✓	■	✓			■	
<i>Asplenium flaccidum</i>	■	✓	■		■		■	■
<i>Asplenium polyodon</i>	■	✓					■	
<i>Astelia</i> spp.	■	✓	■		■		■	
<i>Blechnum capense</i>	■		■		■		■	■
<i>Blechnum chambersii</i>			■				■	■
<i>Blechnum discolor</i>	■	✓	■	✓	■	✓	■	
<i>Blechnum fluviatile</i>	■	✓	■	✓	■		■	✓
<i>Blechnum penna-marina</i>	■				■		■	
<i>Blechnum procerum</i>	■		■		■	✓	■	■
<i>Blechnum vulcanicum</i>			■		■		■	
<i>Carpodetus serratus</i>	■	✓	■	✓	■	✓	■	✓
<i>Clematis forsteri</i>	■							
<i>Coprosma ciliata</i>							■	
<i>Coprosma colensoi</i>							■	
<i>Coprosma foetidissima</i>	■		■	✓	■	✓	■	✓
<i>Coprosma foetidissima</i> x " <i>taylorae</i> "					■	✓	■	
<i>Coprosma grandifolia</i>	■	✓	■		■		■	✓
<i>Coprosma linariifolia</i>	■		■	✓	■	✓	■	✓
<i>Coprosma lucida</i>	■	✓					■	✓
<i>Coprosma microcarpa</i>			■	✓	■	✓	■	✓
<i>Coprosma pseudocuneata</i>							■	✓
<i>Coprosma rhamnoides</i>							■	✓
<i>Coprosma rigida</i>							■	
<i>Coprosma robusta</i>	■	✓	■	✓	■	✓	■	✓
<i>Coprosma spatbulata</i>							■	
<i>Coprosma "taylorae"</i>	■	✓	■	✓	■	✓	■	✓
<i>Coprosma tenuifolium</i>	■	✓	■	✓	■		■	✓
<i>Cordyline indivisa</i>					■			
<i>Cyathea smithii</i>	■	✓	■	✓	■			
<i>Cyatbodes juniperina</i>							■	■
<i>Dacrydium cupressinum</i>	■							
<i>Dicksonia fibrosa</i>	■							
<i>Dicksonia lanata</i>	■	✓	■	✓	■	✓	■	✓
<i>Dicksonia squarrosa</i>	■		■		■	✓		
<i>Elaeocarpus bookerianus</i>	■						■	
<i>Fuchsia excorticata</i>	■	✓	■	✓	■		■	✓
<i>Gaultheria antipoda</i>			■	✓	■		■	✓

Species	Clements Road		Hinemaiaia		Cascade/Jap Creek		Upper Oamaru			
<i>Gleichenia cunninghamii</i>			■		■		■		■	
<i>Grammitis billiardieri</i>	■	✓	■	✓	■		■	✓	■	✓
<i>Griselinia littoralis</i>	■	✓	■	✓	■		■	✓	■	✓
<i>Hebe stricta</i>									■	✓
<i>Helicbrysum lanceolatum</i>									■	✓
<i>Histiopteris incisa</i>	■		■		■		■		■	
<i>Hypolepis rufobarbata</i>	■				■		■			
<i>Leptopteris hymenophylloides</i>	■	✓	■	✓	■		■	✓		
<i>Leptopteris superba</i>	■	✓	■	✓	■	✓	■	✓	■	
<i>Leupogon fasciculatus</i>	■		■	✓	■	✓	■	✓	■	✓
<i>Lycopodium</i> spp.			■						■	
<i>Melicytus lanceolatus</i>	■		■		■					
<i>Melicytus ramiflorus</i>	■	✓								
<i>Melicope simplex</i>	■		■	✓			■			
<i>Muehlenbeckia</i> spp.	■	✓	■						■	
<i>Myrsine australis</i>	■									
<i>Neomyrtus pedunculata</i>	■		■		■	✓	■	✓	■	✓
<i>Nothofagus solandri</i> var. <i>cliffortioides</i>					■	✓	■	✓	■	✓
<i>Nothofagus fusca</i>	■	✓	■	✓	■	✓	■	✓	■	✓
<i>Nothofagus menziesii</i>	■	✓	■	✓	■	✓	■	✓	■	✓
<i>Paesia scaberula</i>	■		■		■		■		■	
<i>Phyllocladus alpinus</i>							■		■	
<i>Phymatosorus diversifolius</i>	■	✓	■	✓	■		■		■	✓
<i>Pittosporum tenuifolium</i>	■									
<i>Podocarpus hallii</i>							■	✓	■	
<i>Podocarpus nivalis</i>									■	✓
<i>Polystichum richardii</i>			■							
<i>Polystichum vestitum</i>	■	✓	■	✓	■	✓	■	✓	■	✓
<i>Pseudopanax anomalus</i>	■				■	✓	■	✓	■	✓
<i>Pseudopanax crassifolius</i>	■				■					
<i>Pseudopanax edgerleyi</i>			■		■	✓	■	✓	■	✓
<i>Pseudopanax simplex</i>	■	✓	■	✓	■	✓	■	✓	■	✓
<i>Pseudowintera colorata</i>	■	✓	■	✓	■	✓	■		■	
<i>Pyrrhosia serpens</i>							■			
<i>Rubus cissoides</i>	■	✓	■	✓	■	✓	■		■	✓
<i>Weinmannia racemosa</i>			■	✓	■	✓	■	✓		
Totals	50	29 (58%)	46	29 (63%)	45	24 (53%)	51	25 (49%)	49	30 (61%)