Forest Research Institute, P.O. Box 31-011, Christchurch, New Zealand.

THE IMPACT OF THREE DEER HUNTING REGIMES IN NORTHEASTERN FIORDLAND

Summary: In late 1986 an official deer hunting regime in the Murchison Mountains, Fiordland, was compared with two commerical aerial hunting regimes in the adjacent Stuart Mountains by measuring the density of deer faecal pellet groups. Overall densities in the Stuart Mountains were twice those in the Murchison Mountains. Official hunting appeared to be more effective than commercial hunting at reducing and controlling deer densities in heavily forested catchments, but not in catchments with less extensive forest cover.

The deer density in individual catchments was determined primarily by the extent of forest cover, which controlled the vulnerability of deer to aerial hunting. The presence of the protected wapiti *(Cervus elaphus nelsoni)* in the northern Stuart Mountains resulted in higher deer densities, when differences in deer vulnerability between catchments were taken into account, than in the southern Stuart Mountains where there are only red deer *(Cervus elaphus scoticus)*. The restriction on the commercial harvesting of wapiti appears to have increased the proportion of wapiti-like deer in some catchments in the Stuart Mountains. Normal commerical hunting may provide the same level of deer control as official hunting for the management of takahe *(Notornis mantelli)* in some of the catchments studied, assuming 1986 economic conditions and hunter skills.

Keywords: Red deer; *Cervus elaphus scoticus;* wapiti; *Cervus elaphus nelsoni;* takahe; *Notornis mantelli;* control; hunting; population density; Fiordland.

Introduction

Three different deer hunting regimes operated in eastern Fiordland in 1986. In all areas red deer *(Cervus elaphus scoticus)* were hunted by commerical hunters using helicopters. The area was divided into large blocks, with only one helicopter operator per block. For most blocks there were no other restrictions on hunting pressure except for economic considerations, and hunting on foot was of minor importance. This is referred to as the' 'normal commercial hunting" regime.

In the Murchison Mountains (the Special Takahe Area; Fig. 1) the State funded hunting on foot and supervised the commercial hunting in an attempt to minimise competition between red deer and takahe *(Notornis mantelli),* a rare endemic rail. This is referred to as the "official hunting" regime.

North of the Murchison Mountains, New Zealand's only wild herd of wapiti *(Cervus elaphus nelsoni)* is regarded by recreational hunters as a unique resource (Banwell, 1966; Holden, 1987). Commercial harvesting of wapiti is prohibited in all areas with wapiti in an attempt to preserve this herd as a distinct entity, although this has long been threatened by hybridisation with red deer (Murie, 1966; Caughley, 1970; Batcheler and McLennan, 1977). This prohibition separates what is a "restricted commercial hunting" regime in areas with wapiti from the "normal commercial hunting" regime in areas without wapiti.

The primary objective of this paper is to compare deer densities in the three areas, to attempt to determine whether the additional hunting effort of the official hunting regime has had a greater impact on deer density than normal commercial hunting. A secondary objective is to determine what effect the restriction on hunting pressure in areas with wapiti is having on the impact of commercial hunters on deer densities and herd composition.

In the early 1980s, takahe occurred exclusively in or near the Murchison Mountains. However, after a prolonged public debate (e.g. McSweeney, 1987), eight takahe reared in captivity were released at the head of the Glaisnock River, in the wapiti area, in October 1987. Hunters see the requirement that takahe be protected from competition with deer conflicting with the management of the wapiti for recreational hunting. A further objective of this paper, therefore, is to evaluate the implications of this study for takahe and wapiti management.

Study areas

One block of three contiguous catchments was selected in each of three areas with different hunting regimes in late 1986.

a) Official hunting (Murchison Mts).
   Snag Burn, Ettrick Burn, and Chester Burn.

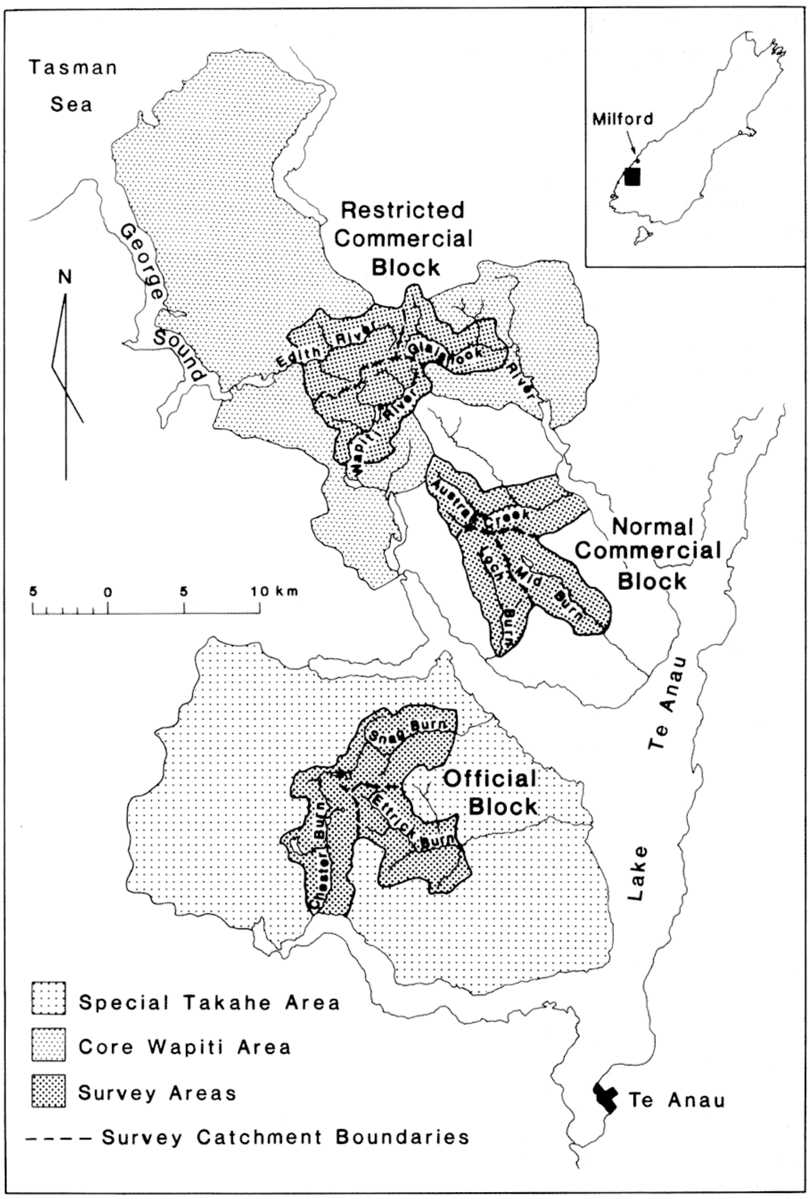

Figure 1: *The survey area, showing the core Wapiti Area defined by Nugent* et al. (1987) *and the limits of the Special Takahe Area.*

b) Normal commercial hunting (southern Stuart Mts).
Mid Burn, Loch Burn, and Austral Creek.[1]

c) Restricted commercial hunting (northern Stuart Mts).
Glaisnock, Edith and Wapiti Rivers.

The topography and climate of these catchments are broadly similar. Steep-sided glaciated valleys rise to peaks over 1500 m a.s.l. In most catchments the rivers pass through steep sided gorges, but the valley bottoms are generally flat, with terraces up to several hundred metres wide. Rainfall is frequent and heavy, and decreases markedly from west to east across Fiordland (e.g. Milford - 6000-8000 mm yr^{-1}, Te Anau - 1000-1300 mm yr^{-1}; New Zealand Meteorological Service, 1983).

Catchments are forested below 1000-1100 m a.s.l. although in some areas alpine timberlines are depressed by debris slides. Mixed silver beech *(Nothofagus menziesii)/hardwood* forests dominate in areas close to and west of the main divide, with mountain *(Nothofagus solandri* var. *cliffortioides)* and simple beech forests (mountain or silver beech forests with simple understories) more important in eastern areas, and in the Murchison Mountains.

Hunting histories

In the Murchison Mountains hunting has been controlled since the rediscovery of takahe in 1948 (Parkes, Tustin and Stanley, 1978). State culling operations have continued throughout the last four decades. State-supervised commercial hunting from helicopters began in 1976, and was followed by the introduction of commercial live trapping in 1983. Some private hunting is permitted around the fringes of the area. The hunting effort and known harvests of deer in the Murchison Mountains between 1963 and 1986 are summarised in Appendix 1.

Outside the Murchison Mountains, hunting before 1970 had little impact on deer density and distribution (Henderson, 1965; Smith, 1974; Holden, 1987; Nugent, Parkes and Tustin, 1987). Recreational hunters still hunt all areas outside the Murchison Mountains but have little impact on deer density and distribution (Smith, 1974; Nugent *et al.,* 1987). Commercial hunting during the 1970s quickly reduced deer densities, particularly east of the main divide (Nugent *et al.,* 1987). Hunting was generally restricted to red deer and wapiti-hybrids, although in 1982 and 1983 a consortium of commercial operators captured deer regardless of type. Since 1983 wapiti and wapiti-like deer have been protected from commercial hunting. One helicopter operator (R. Hayes) has been permitted to hunt red deer throughout both commercial blocks. This operator also hunted, under supervision, in the Murchison Mountains.

Deer densities prior to the 1970s are likely to have differed between the three blocks, as the mixed silver beech/hardwood forests provide better deer habitat than the mountain and simple beech forests (Stewart and Harrison, 1987). Differences in initial deer density and differing time period of operation of the three regimes are, however, unlikely to be important factors in determining 1986 deer densities for two reasons. Firstly, deer densities were rapidly and dramatically reduced following the commencement of commercial aerial hunting in the early 1970s. By 1975 deer densities in no way reflected 1969 deer density patterns (Nugent *et al.,* 1987). Secondly, all three blocks are hunted by the same commercial operator. By 1986 deer densities were so low that the commercial operator was forced to restrict his hunting effort in all blocks to maintain a deer density that would support a break-even rate of recovery (R. Hayes, pers comm.). Therefore, all deer accessible to aerial hunting in each block were subject to the same hunting pressure. Deer densities in 1986 are probably more a result of economic conditions and hunter skills, rather than historical factors.

Methods

Comparison of deer densities

The density of faecal pellet groups was used to compare 1986 deer densities between areas and deer use of different habitat types. As the disappearance rates of pellet groups in eastern and western Fiordland appear to be similar despite the marked rainfall gradient (Nugent *et al.,* 1987), we assumed that any differences in disappearance rates between blocks would be negligible. It was therefore possible to interpret pellet group density (POD) as a linear index of deer density.

The blocks were surveyed simultaneously, with each of three pairs of observers surveying one catchment in each block to minimise any observer biases. The study was restricted to the forest zone as no pellet groups were found above timberline in 1984 (Nugent *et al.,* 1987) or during a pre-survey reconnaisance of the study areas in September, 1986.

[1]Austral Creek had 17% wapiti in 1982/83 (Table 3). We included it in the normal commercial block because there was no other suitable wapiti-free catchment in the area. The resulting total of 6% wapiti for the normal block is unlikely to have had a marked impact on the results.

PGD was measured in the upper 8 km of forest in each catchment in two strata; valley bottom (0-150 m from the main river) and valley side (the remainder). To increase precision, sampling was concentrated in the valley bottoms, where the highest deer densities were recorded by Nugent *et al* (1987).

The normal and restricted commercial hunting blocks were previously surveyed in 1984 (Nugent *et al.,* 1987) by counting the number of pellet groups on 2.5 m radius plots to estimate PGD, as outlined by Baddeley (1985), and by recording the presence or absence of deer pellets on 1.14 m radius plots to estimate pellet frequency (the % of plots with pellets on them). The official block was last surveyed in 1978 when only pellet frequency on 1.14 m radius plots was recorded. Therefore, both 2.5 m and 1.14 m radii were searched on all plots in 1986, to estimate both PGD and pellet frequency respectively, so that 1986 deer densities could be compared with both the former surveys. Plots were located every 15 m along 50 transects in all catchments, five of which ran from river to timberline (22-115 plots per transect), the remainder of which stopped 150 m from the river (10 plots per transect; Fig. 2). About 700 plots were surveyed in each catchment (range 635-860), giving an average of 2263 plots per block.

The PGD derived for each stratum in each catchment was weighted by the area of the stratum to produce catchment and block PGDs. Standard errors about these estimates were derived using Snedecor and Cochran's (1980) formula.

$$\text{Standard Error (SE)}^2 = W_x^2 SE_x^2 + W_y^2 SE_y^2$$

$$[+ \text{ .. for block } SE_x^2]$$

where W_x = proportion of area in stratum x etc. and SE_x = SE about the PGD for stratum x.

PDGs are presented as groups ha^{-1} ±95% confidence limits (95% CL). Means were taken to be significantly different when these did not overlap.

The 1986 pellet frequencies were compared with those from similarly located river-to-timberline transects from both the former surveys using contingency tables.

Habitat and forest structure

The comparison of the three hunting regimes contains no treatment replication. Each treatment is confined to one block, hence block and treatment are confounded. If inherent differences exist between blocks it may be difficult to ascribe any differences in block PGD to either treatment differences or block characteristics. To determine whether habitat and forest composition differ between blocks and catchments, altitude, aspect, ground cover, forest type, land form, and slope, were recorded at each plot site. Percentage composition of these variables for each catchment and block were collated and compared. The sites most heavily used by deer were identified by comparing PGDs for each site class. The hypothesis that catchment PGD was related to the relative abundance of the most heavily used classes was then tested by correlation. The relative abundance of the different classes was estimated from the weighted percentage of plots in each class in each catchment.

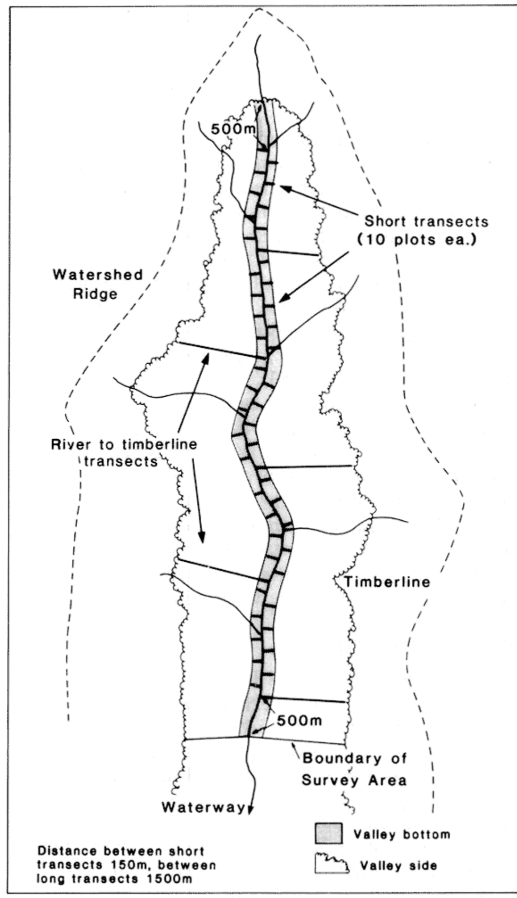

Figure 2: *A schematic diagram of the sampling design. Data from the five long transects (river-to-timberline) were later divided between the two strata.*

The relationship between catchment PGD and variables that were most likely to control the effectiveness of aerial hunting (catchment area, area above timberline, forested area below timberline, length of timberline, timberline ratio (forested area per unit of timberline length), and the 1982/83 percentage-of-wapiti) was also investigated. The last variable is the percentage of deer classed as wapiti among females older than 10 months captured in 1982 and 1983. It provided an index of the proportion of wapiti among the deer present in 1982/83, although the figures may have underestimated the true proportions (J. Bamford, pers. comm.).

Multiple linear regression models were used to explain the variation in PGD between catchments in the Stuart Mountains. These models were then used to simulate the catchment PGDs likely if all three blocks had been subjected to normal commercial hunting.

Results

1986 Deer density

The PGD in the official hunting block was significantly lower than that in both the commercial blocks, which had similar block PGDs (Table 1). PGDs were similar in all three catchments of the official block, but varied significantly from catchment to catchment in both commercial blocks (Table 1). PGD in areas immediately surrounding the site of takahe liberation in the head of the Olaisnock River was similar to those of the official block ('Catchment heads' of Table 1).

The forest type composition of the three blocks varied significantly (X^2 = 109.4, df = 10, p<0.001). Mixed silver beech/hardwood forests (C3/C4) were the most abundant forests in the restricted commercial block, while mountain and simple silver beech forest (M and E types) dominated the official block (Appendix 2). The forest composition of the normal restricted block was intermediate between these two extremes. Seral forests (P types) and forest clearings (0) are of similar abundance in each block at about 100/0 and 4% respectively. All three blocks have broadly similar percentage compositions of aspect, landform, and slope.

Pellet frequencies in the two commercial blocks were almost half those recorded the last time they were surveyed. In 1984 the pellet frequency along 10 transects surveyed in the two commercial blocks was 5.2 ± 1.7% (n = 670 plots). In 1986, the pellet frequency recorded on the 10 most equivalent transects was 2.8 ± 1.1 (n = 690 plots), and was significantly lower (X^2 = 5.2, df = 1, p<0.05).

Table 1: *The forested area and* 1986 *PGDs within the forest for each catchment. The catchment and block PODs are weighted according to the area of valley bottom and valley side strata in each catchment. (*'Catchment heads' gives the PGDs for all lines in the upper* 2.5 *km of the three catchments of the Restricted Commercial Block.)*

Catchment or BLOCK	Forested Area (ha)	Unweighted Valley Bottom PGD	Unweighted Valley Bottom 95%CL	Unweighted Valley Side PGD	Unweighted Valley Side 95%CL	Weighted Mean PGD	Weighted Mean 95%CL
Austral	2083	58	± 18	40	± 17	42	± 15
Loch	1244	57	± 20	32	± 18	36	± 15
Mid	1495	13	± 8	9	± 9	10	± 8
NORMAL COMMERCIAL	4822					30	± 8
Catchment heads*		15	± 9	14	± 16	14	± 12
Wapiti	1506	9	± 7	13	± 14	12	± 10
Edith	1944	50	± 19	42	± 20	43	± 19
Glaisnock	1190	41	± 13	15	± 15	22	± 12
RESTRICTED COMMERCIAL	4640					28	± 9
Ettrick	1591	24	± 10	6	± 6	9	± 5
Snag	1455	24	± 12	11	± 10	13	± 8
Chester	1743	25	± 11	16	± 10	17	± 9
OFFICIAL CONTROL	4789					13	± 5

Pellet frequency on all river-to-timberline transects surveyed in the official block was 2.5± 1.0% (n = 1019 plots) in 1977/78 and 1.3 ± 0.7% (n = 1111 plots) in 1986. This decrease was also significant ($X^2 = 5.2$, $p<0.05$). The known annual harvest of deer from the Murchison Mountains as a whole decreased rapidly from 1977 to 1980, but has fluctuated around 140 yr^{-1} since then (Appendix 1).

Habitat use

Deer habitat preferences were similar to those reported by Nugent *et al.* (1987). Deer tended to avoid south-facing slopes, and highest PGDs were recorded on northern aspects (Table 2). Deer made most use of gentle terrain as PGD decreased with increasing slope ($r = -0.94$, $p<0.01$; Table 2) and was higher on predominantly valley-bottom landforms (terraces and toeslopes) than on valley-side landforms (faces, gullies, and ridges; Table 2). As a consequence PGDs were higher for the valley-bottom stratum than for the valley-side stratum in all three blocks (Table 1).

Deer made greatest use of the seral forest types (P1, P2, P3) and forest clearings (O; Table 2), with grassy clearings in the valley bottom (a subset of type O) having the highest PGD estimate of any habitat (88 ± 41 groups ha^{-1}). Mixed silver beech forests and mountain beech forests both had average PGDs (24 ± 5 and 23 ±5 groups ha^{-1} respectively). Together they comprise 60% of the total survey area and therefore were the most important forest types in terms of total habitat use. PGDs were similar for the four most common ground cover classes; moss, forest litter, shield fern *(Polystichum vestitum)* and crown fern *(Blechnum discolor;* Table 2). In all three blocks, deer made little use of areas near the alpine timberline, adjacent to the main habitat of the takahe in the alpine tussock grasslands (Mills, Lavers and Lee, 1984). On the river-to-timberline transects spanning 500-1000 m a.s.l, PGD was lower (5 ± 6 groups ha^{-1}) on plots above 900 m a.s.l. than on plots 500-700 m a.s.l. (27 ± 12 groups ha^{-1}).

Table 2: *PGDs and percentages of the plots surveyed (corrected for stratification effects) for aspect, slope, landform, forest type, and ground cover classes. Except for* A *and O the forest type classes are those described* by *Wardle, Hayward and Herbert (1971), with some pooling of their types, as shown* by *the class codes.*

	PGD	±	95%CL	%plots
ASPECT CLASSES: (Slope >0°)				
East 45 - 134°	18	±	17	17
South 135 - 224°	12	±	6	28
West 225 - 314°	23	±	8	28
North 315 - 44°	31	±	11	27
SLOPE CLASSES:				
0 - 9°	41	±	9	18
10 - 19°	24	±	9	22
20 - 29°	26	±	13	22
30 - 39°	24	±	10	19
40 - 49°	7	±	8	9
50+	0	±	0	10
LANDFORM CLASSES:				
Terraces	36	±	17	9
Toeslopes	36	±	15	10
Faces	19	±	6	64
Gullies	10	±	12	5
Ridges, benches, spurs	10	±	14	4
Slips	20	±	13	8
GROUND COVER CLASSES:				
Grass	16	±	12	4
Crown fern (*Blechnum discolor)*	26	±	17	7
Shield fern	23	±	12	11
Forest litter	26	±	8	25
Moss	23	±	5	53
Bare rock/dirt/rubble	6	±	12	3

	PGD	±	95%CL	%plots
FOREST TYPE CLASSES:				
Seral forests				
P1, P2 — dominated by *Hoheria glabrata* and shield fern	40	±	11	7
P3 — dominated by *Schefflera digitata, Melicytus ramiflorus* and/or *Fuchsia excorticata*	57	±	13	3
Silver beech forests				
C1, C2 — mid-slope to timberline with a varied understorey	17	±	6	24
C3, C4 — mixed silverbeech/hardwood forest, often with *Weinmannia racemosa* or *Metrosideros umbellata* as a co-dominant	24	±	5	29
Mountain beech forests				
E types and M types — mountain and simple beech forest types	23	±	5	31
Other vegetation types				
S types — short subalpine shrubland grading into low forest	20	±	15	1
O — forest clearings below timberline, including slips	60	±	23	4
A — subalpine grassland, dominated by *Chionochloa* spp.	0	±	0	<1

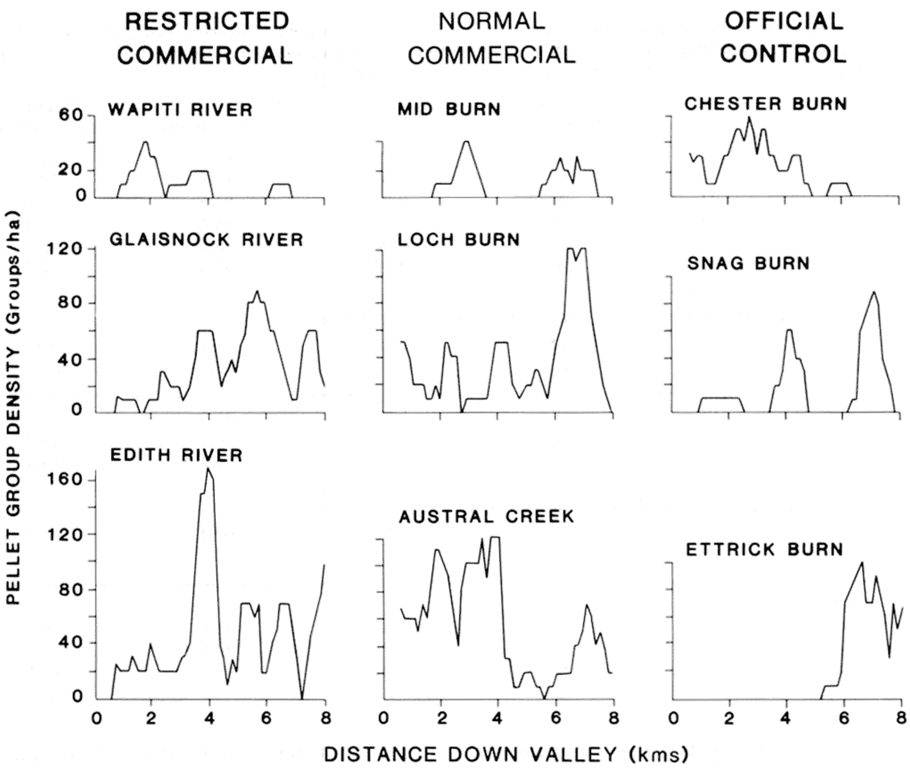

Figure 3: *PGDs in the valley bottom in relation to the distance from the upper limit of forest in the headwaters (distance down valley). Data are smoothed, each datum point representing five short transects (50 plots).*

There was no evidence of any difference in deer habitat preferences between blocks, as within each block the sample PGDs for the preferred habitats identified above were almost always higher than block averages for all habitats, and none were significantly lower than average.

Habitat preferences were reflected in variable deer distribution within each catchment. Maximum peak densities for any 50 adjacent valley-bottom plots ranged from 40 ± 39 groups ha^{-1} (Wapiti River, Mid Burn) to 163 ± 110 groups ha^{-1} (Edith River). Each catchment had at least one gap in deer distribution where no pellet groups were found on 50 adjacent valley-bottom plots (Fig. 3). Typically, peaks of PGD coincided with small pockets of preferred forest type on terraces or toeslopes, with gaps in PGDs commonly found in steep-sided gorges or in areas of simple or mountain beech forest types (E, Table 2). However, no one site factor or combination of site factors was found that could accurately account for all major peaks and gaps in PGD for all catchments.

Although habitat preferences influenced the distribution of deer within catchments, they failed to explain the variation in PGD between catchments in the two commercial blocks. There were no significant positive correlations between catchment PGD and the abundance of the most heavily used site classes. Therefore the deer density in catchments could not be attributed directly to availability of such site classes.

However, catchment PGD was significantly correlated to a number of catchment variables that describe the extent of the forest cover. The three strongest of these relationships were with timberline ratio, percentage valley-bottom plots with a forest

Table 3: *The relationship between catchment PGD, the* 1982/83 *percentage-of-wapiti, timberline ratio, and the relative abundance of variable types reflecting deer vulnerability (the percentage of valley bottom plots that were forested, and the weighted percentage of plots in both strata with grass or shield fern ground cover).*

Catchment	PGD	1982/83 % wapiti	Timberline Ratio	% forested plots in valley bottom	% grass/ shield fern plots
Mid	10	0	0.72	93.9	23.3
Wapiti	12	23	0.60	87.8	29.5
Glaisnock	22	38	0.62	91.6	31.0
Loch	36	0	0.91	98.6	8.5
Austral	42	17	0.96	98.6	5.6
Edith	43	25	0.82	97.4	4.3
Correlation coefficients against PGD for the six commercial block catchments above					
r		0.05	0.82	0.81	−0.89
p (df = 4)		ns	0.04	0.05	0.02
Chester	17	0	1.06	93.3	5.1
Snag	13	0	0.63	94.0	19.0
Ettrick	9	0	0.69	99.2	10.4
Correlation coefficients against PGD for the three official block catchments above					
r			0.79	−0.91	−0.38
p (df = 1)			ns	ns	ns
Weighted Block averages:					
Restricted commercial	28	28	0.70	92.8	19.3
Normal commercial	30	7	0.87	97.1	11.8
Official control	13	0	0.80	95.5	11.1

cover, and the percentage of plots with either grass or shield fern ground cover (Table 3). Shield fern is commonly found under low, open, or broken canopies. All three variables are measures of the extent of areas where deer are likely to be visible from the air, and therefore vulnerable to aerial hunting.

In the commercial blocks, deer densities were lowest in catchments where deer were the most vulnerable to aerial hunting (catchments with the most forest clearings, large areas of low stature or open forest types with shield fern or grass ground covers, and small forested areas to timberline length ratios). Conversely, catchments with the largest tracts of continuous dense forest cover had the highest deer densities. The large r values for the correlations indicate that all three extent-of-forest-cover variables are inter-related.

Because of the lower PGDs in the official block the correlations are calculated separately for these three catchments. Despite only one degree of freedom, the large positive result for timberline ratio indicates that similar relationships between extent of forest cover and catchment PGD exist in the official block as well.

Herd composition

The percentage of wapiti in each commercial catchment in 1982/83 did not show any correlation with the 1986 PGDs (Table 3) as any existing relationship was overridden by the strong correlation between catchment PGD and the extent of forest cover. To try and differentiate between the effect of extent of forest cover on catchment PGD and any possible effect of the 1982/83 percentage-of-wapiti, multiple linear regressions of these variables on PGD were constructed. Variables and their order were arbitrarily selected. The three equations that gave the best fit are presented in Table 4a. When the 1982/83 percentage-of-wapiti was added to the timberline ratio in regression 1 (Table 4a), it significantly added to the explanation of variation in catchment PGD at the 95% level (Table 4b). Similarly, the 1982/83 percentage-of-wapiti variable significantly contributed to the regression with percentage forested plots

Table 4: *(a) Multiple linear regression equations combining the* 1982/83 *percentage-of-wapiti with (1) timberline ratio,* (2) % *forested plots in valley bottom, and* (3) % *grass/shield fern plots for the six catchments of the two commercially hunted blocks. (b) Results from stepwise analysis of variance for the above regressions, showing the significance of the contribution of the % wapiti variable in explaining differences in PGD between catchments in the two commercial blocks. The proportion of the variation in PGD between catchments in the two commercial blocks explained by these regressions (R^2) is compared with that explained by each of the catchment attributes (uni R^2). Gain MS is the gain in Sums of Squares due to the % wapiti variable (over one degree of freedom) and is calculated by subtraction of the sums of squares attributed to the first (forest) variable from the regression sums of squares. R^2 values are adjusted for the number of degrees of freedom.*

(a) Multiple linear regression equations

		F Ratio	*P*
1.	PGD = 108 (timberline ratio) + 0.5 (% wapiti) - 66	18.2	0.02
2.	PGD = 3.5 (% forested plots) + 0.5 (% wapiti) - 316	13.1	0.03
3.	PGD = - 1.24 (% grass/shield fern plots) + 0.394 (% wapiti) + 41.8	25.7	0.01

(b) Stepwise analysis of variance

Regression	Error MS	Gain MS	F ratio gain/error	significance (l/3df)	adjusted R^2	adjusted Uni R^2
1	27.8	284	10.2	95%	0.87	0.58
2	37.6	226	6.0	90%	0.83	0.61
3	20.2	159	7.8	90%	0.91	0.75

(regression 2) and percentage shield fern or grass plots (3), at the 90% level. These results suggest that 1986 PGDs were higher in catchments which had wapiti in 1982/83 than might be expected if wapiti had not been present.

An attempt to quantify the impact of the wapiti harvesting restriction on deer densities was made by using the three multiple linear regressions (Table 4a) to predict the PGDs expected in the absence of any harvesting restriction. The 1982/83 percentage-of-wapiti term in the regressions was set to zero, and the regressions evaluated using the forest structure variables from Table 3. This simulates the PGDs expected if wapiti are as easily hunted as red deer and had not been protected since 1983. Because all three extent-of-forest-cover variables appear to be inter-related, the average result from the three regressions is calculated and presented in Table 5. These suggest that with no harvesting restriction few deer would have remained in the surveyed areas of the Wapiti and Glaisnock rivers. Therefore, most of the deer remaining in these areas in 1986 were probably wapiti or wapiti-like. Overall, these predictions suggest that deer densities could be more than halved in the restricted commercial block by removing the wapiti harvesting restriction.

Effectiveness of official hunting

Predicted PGDs under a normal commercial hunting regime are also given for the official block in Table 4b. Overall official hunting resulted in a lower PGD than that predicted for a normal commercial hunting regime in the Murchison Mountains. However, in the Snag Burn official hunting was no more effective at reducing deer densities than commercial hunting would have been. The extent of forest cover in this catchment would make deer particularly vulnerable to aerial hunting. It has a smaller forested area relative to its timberline length (small timberline ratio), a smaller percent of forested plots in the valley bottom,

Table 5: *The average catchment PGDs predicted by the three regressions (Table 4a) with the* 1982/83 *percentage-of-wapiti firstly included (Actual), and then set to zero (minus wapiti).*

Catchment/Block	Predicted PGD Actual	Predicted PGD Minus wapiti	Observed PGD
Austral	42	33	42
Loch	31	31	36
Mi	12	12	10
NORMAL COMMERCIAL	29	26	30
Edith	41	28	43
Glaisnock	22	2	22
Wapiti	10	0	12
RESTRICTED COMMERCIAL	24	10	26
Chester	32	32	17
Snag	11	11	13
Ettrick	22	22	9
OFFICIAL CONTROL	22	22	13

and a larger percentage of plots with shield fern or grass ground cover (Table 3) than in other officially hunted catchments. In contrast, in the more heavily forested Chester and Ettrick Burns, official hunting appears to be markedly more effective than commercial hunting could be.

Discussion

Forest composition

Percentage forest composition differed markedly between blocks. However, it is unlikely that these differences have a significant impact on the results for the following reasons:

1. The two most important forest type groups that differ across blocks have almost identifical overall PGDs. Therefore we would not expect any differences in deer density between blocks based solely on the distribution of these forest types.
2. Given the large reductions in deer densities since the 1960s (Parkes *et al.,* 1978; Nugent *et al.,* 1987; this paper), it is unlikely that overall deer density was regulated by environmental factors.
3. Each catchment is effectively independent as all catchments are separated by wide bands of alpine grassland onto which deer seldom venture. A recent pellet survey of 554 plots in subalpine grassland near the takahe liberation site in the Glaisnock river found no pellet groups (B. Chisholm, pers. comm.).

With virtually no difference in forest composition between blocks in terms of 1986 deer preferences, and each catchment effectively independent of each other, differences in deer density between catchments and blocks are most likely to be the result of the hunting regimes and constraints on the effectiveness of the hunters.

Official and commercial hunting

Deer densities in the official block were about half those in the commercial blocks. The measures that reflected deer vulnerability in the commercial blocks did not indicate deer in the official block were any more vulnerable to airborne hunting. The lower deer density there was therefore most probably the consequence of the additional State-funded hunting effort.

However, our results suggest that normal commercial hunting could provide the same level of deer control as official hunting in catchments with less extensive forest cover (many forest clearings, large areas of low stature or open forest types, and small forested areas to timberline length ratios), where deer are vulnerable to airborne hunters. This assumes that 1986 hunting skills and profit margins for deer recovery are maintained.

Official hunting appears to have reached its maximum effectiveness by 1980, with deer densities then being held constant up to 1986. The taking of up to 86 live deer year^{-1} in capture pens after 1983 failed to increase the total annual official 'kill' (Appendix 1). Pens therefore appear to be mainly taking deer that would otherwise have been shot by hunters.

Although deer densities in the two commercial blocks were double those of the official block, PGDs were still relatively low, particularly in areas close to and above the alpine timberline. Overall PGDs equate to about 2 deer km^{-2} (using disappearance rates from Nugent *et al.,* 1987). Deer densities were halved in the 2 years since 1984, demonstrating that commercial hunting in Fiordland is continuing to provide effective deer control despite low deer densities, and suggests that even lower deer densities than 1986 levels may be attainable, given improved economics of deer recovery or an increase in hunting skills.

Deer distribution

Deer distribution within the six commercial catchments reflects habitat preferences, but because deer were more vulnerable to aerial hunting on some preferred sites, the catchments with the highest proportions of such habitats contained the fewest deer. This suggests that hunting has not changed deer habitat preferences, and that the 1986 deer distribution is largely the result of selective removal of animals from the more open areas, rather than the active avoidance of such areas by deer. Therefore the extent of forest cover, which controls the vulnerability of deer to aerial hunting, was the primary determinant of deer density in both commercial blocks.

Alpine grasslands above the timberline were highly preferred deer habitat before intensive hunting began in the 19705 (Challies, 1977; Bennett, 1979; Nugent *et al.,* 1987). Deer probably still make occasional use of this zone, but their browse impact is negligible and PGDs are low because animals are rapidly removed from this habitat, the most vulnerable to aerial hunting. Continued constant hunting pressure is needed to prevent reinvasion of this habitat by deer.

Wapiti harvesting restriction

The similar overall PGDs for the two co,mmercial blocks suggested that the wapiti harvesting ban was having no effect on deer density. However, when differences in the vulnerability of deer to aerial hunting were taken into account, the catchments with wapiti in 1982/83 contained more deer than the densities expected under normal commercial hunting. Our models predicted that had wapiti not been protected since 1983, few deer would remain in the Glaisnock and Wapiti River survey areas, and we cautiously inferred that most deer remaining in these areas were wapiti or wapiti-like hybrids. This inference was supported by the observations of the commercial operator (R. Hayes, pers. comm.). After nearly half a century of spasmodic selective culling (Holden, 1987), there is now some evidence of an increase in the percentage of wapiti-like animals in this population, particularly where the percentage of wapiti was intially high and the red deer were most vulnerable to hunting.

It has been suggested that the higher deer densities in the restricted block than those expected under normal hunting could be the result of resource partitioning beween wapiti and red deer. However, the dispersal histories of the two species in northern Fiordland suggests that resource partitioning is not an important factor. Wapiti failed to colonise areas where red deer were already established, while there is some evidence that red deer have displaced wapiti during their dispersal northward through Fiordland (Nugent *et al.,* 1987). Both wapiti and red deer would appear then, to exploit similar resources, with red deer being the more competitive of the two species. We know of no evidence to support resource partitioning and therefore consider it to be an unlikely explanation of 1986 deer densities in the restricted commercial block.

It is puzzling that deer density has been reduced since 1984 in the northern Stuart Mountains, as this area appears to contain few legally hunt able deer. A likely explanation is that wapiti were being taken as fawns and yearlings when they are difficult to distinguish from red deer (Smith, 1974).

Implications for management

a) Red deer in the Murchison Mountains:

The vegetation in habitats favoured by both deer and takahe have shown significant signs of recovery, since 1969 in the alpine grasslands (Rose and Platt, 1987) and since 1975 in the forest understoreys (Steward, Wardle and Burrows, 1987). In 1986, the main habitat of takahe (near or above timberline) was seldom used by deer, so that direct competition between the two species was probably minimal. Some takahe utilise forested areas during winter months (Mills *et al.,* 1984). The extent to which takahe and deer compete at this time of the year is unknown. Therefore we cannot assess whether further reductions in deer densities would substantially benefit takahe.

b) Wapiti and takahe in the restricted commercial block:

The takahe liberated in the head of the Glaisnock River should not experience greater competition from deer than those in the Murchison Mountains, as deer densities in the two areas were similar. The two main deer-related causes for concern are the pockets of relatively high deer densities nearby in the Edith River, and the likelihood that vegetation recovery in the Stuart Mountains is not as advanced as in the Murchison Mountains because of the later decrease in deer density.

It appears possible that nearly all deer could be removed from parts of the Glaisnock and Wapiti catchments by airborne hunting, making these catchments the most favourable for the successful re-establishment of takahe, at least in terms of competition from deer. The same ease of control, however, also makes the two catchments the most suitable for any attempt to selectively maintain a deer population closely resembling wapiti.

Deer densities equating to PGDs of approximately 20 groups ha^{-1} (i.e., only 30-40 deer in the two catchment survey areas) are probably not acceptable to recreational hunters. With the uncertainty about the extent of competition between deer and takahe at these densities, however, any increase in deer density must be considered incompatible with the takahe liberation programme. The future of recreational hunting for wapiti therefore appears to lie mainly with the higher density hybrid populations to the west (this study; Nugent *et al.,* 1987).

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Appendix 1: *The hunting effort and known annual harvest of deer from the whole of the Murchison Mountains (source: Parkes* et al., 1978; *J. Parkes, unpubl. data).*
[a] *Kills achieved by government ground hunters employed by the New Zealand Forest Service.*
[b] *Deer killed or captured by government supervised commercial hunters using helicopters.*
[c] *Deer killed by private hunters and staff involved in takahe research.*

Year	NZFS[a]		Helicopter[b]		Other[c]	Pen	TOTAL
Ending	Kills	Effort	Harvest	Effort		captures	
31/3		(man days)		(hours)			
1963	1767	260					1767
1964	1020	575					1020
1965	1322	405					1322
1966	1195	599					1195
1967	1242	597					1242
1968	800	430					800
1969	872	446					872
1970	314	266					314
1971	368	281					368
1972	495	350					495
1973	511	252					511
1974	757	356			86		843
1975	718	407					718
1976	330	603	230	80			560
1977	282	603	302	70			584
1978	162	459	105	36			267
1979	130	361	98	59	6		234
1980	57	244	55	39			112
1981	30	209	51	43			81
1982	70	314	95	66	21		186
1983	50	263	41	31	34	12	137
1984	28	278	47	39	25	36	136
1985	20	382	60	46	8	86	174
1986	23	250	35	35	23	66	147

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Appendix 2: *The percentage composition of (a) forest type, (b) slope, (c) aspect, and (d) landform for each study block. Data are weighted by area of strata for catchments, and by area of catchments for block totals.*

(a) Major forest types: Except for 0, *the forest type classes are those described by Wardle, Hayward and Herbert (1971). M + E types = Mountain beech and simple beech forests; C3/C4 = mixed silverbeech/hardwood forests; C1/C2 = mid slope to timberline silver beech with more complex understorey; P types = seral forests; O = forest clearings including slips.*

Catchment/BLOCK	M+ E types	C3/C4	C1/C2	P types	0
Edith	0	37	49	8	3
Glaisnock	0	57	12	20	6
Wapiti	0	48	27	12	5
RESTRICTED COMMERCIAL	0	45	32	12	5
Austral	5	61	16	14	<1
Loch	52	21	19	3	<1
Mid	6	2	83	1	6
NORMAL COMMERCIAL	20	32	35	7	4
Ettrick	80	2	7	3	2
Snag	55	4	15	17	4
Chester	42	7	33	6	9
OFFICIAL HUNTING	58	4	19	8	5

(b) Slope	$0\text{-}9^0$	$10\text{-}19^0$	$20\text{-}29^0$	$30\text{-}39^0$	40^0+
RESTRICTED COMMERCIAL	20	21	18	14	27
NORMAL COMMERCIAL	12	19	22	26	21
OFFICIAL HUNTING	15	20	20	14	31

(c) Aspect	N	E	S	W
	$315\text{-}44^0$	$45\text{-}134^0$	$135\text{-}224^0$	$225\text{-}314^0$
RESTRICTED COMMERCIAL	22	22	28	28
NORMAL COMMERICAL	29	25	21	30
OFFICIAL HUNTING	23	23	23	31

(d) Landforms	Valley Bottom Landforms	Valley Side Landforms
	(terraces, toeslopes)	(faces, gullies, ridges)
RESTRICTED COMMERCIAL	23	77
NORMAL COMMERCIAL	13	87
OFFICIAL HUNTING	14	86