Impact of Himalayan thar (*Hemitragus jemlahicus*) on snow tussock in the Southern Alps

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J.P. Parkes and C. Thomson

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Impact of Himalayan thar (*Hemitragus jemlahicus*) on snow tussock in the Southern Alps

J.P. Parkes and C. Thomson

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ABSTRACT

The National Himalayan Thar Control Plan sets 'best guess' target densities for thar in various management areas that are historically low but arbitrary. When these densities are exceeded, the plan allows for intervention by the Department of Conservation to increase the harvest of thar. This study aimed to determine if indicators of alpine vegetation condition changed as expected when thar densities were below, at, or above target densities set in the plan. In all, 72 variable area plots were established in parts of five study catchments in the Southern Alps between 1990 and 1994, and remeasured between 1995 and 1997. The plots were located in snow tussock communities in parts of the catchments known to be frequented by thar. The main bioindicator chosen to assess vegetation condition was the snow tussock (*Chionochloa* spp.) because it is a dominant plant in the alpine habitat and is the main food of thar, but not of other vertebrate herbivores in the area.

Thar densities were estimated from periodic annual counts made in the study catchments, and compared with several measures of tussock condition (percentage cover, basal area, and plant density). Neither the thar density relative to the intervention density set in the plan, nor trends in thar densities, predicted the trends in the vegetation condition indices in all cases. The former was generally more useful with 40% of the predictions on vegetation trend being significantly as expected or showing no change as expected, 12% trending significantly in the unpredicted direction, and 48% showing no significant change when a significant change was predicted.

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1. Introduction

The purpose of this study was to compare densities of Himalayan thar with the condition and trend of alpine vegetation measured within their range in the Southern Alps. Landcare Research, Lincoln, and the Canterbury and West Coast Conservancies of the Department of Conservation attempted to do this by establishing 72 permanently marked plots between 1990 and 1994 in five catchments within the range of Himalayan thar, and remeasuring most of them in 1996 and 1997. The numbers of thar and other ungulates in each catchment were estimated during late summer irregularly in a few of our study catchments between 1965 and 1990, and more frequently in most of the study catchments between 1990 and 1997. The work was funded by the Science and Research Division, and Canterbury and West Coast Conservancies of the Department of Conservation.

2. Background

The National Himalayan Thar Control Plan (Department of Conservation 1993) set maximum densities for thar which, when exceeded, would trigger extra hunting effort either by encouraging more recreational hunting, allowing more commercial harvesting, or by imposing official culling. These trigger or 'intervention densities' range from <1 to 2.5 thar/km^2. The intervention densities were set conservatively to protect conservation values, but not so low as to be unachievable largely by recreational and commercial hunters, i.e. without too much government intervention. They were therefore generally set at <10% of the densities observed in the late 1960s before commercial hunting removed most thar (Parkes and Tustin 1985), and for a total population of no more than 10 000 thar. This population could be maintained by an annual harvest of about 2000 animals (Parkes 1993) which was thought to be achievable by hunters (Nugent 1992).

However, the targets set were not based on any experimental data that related the densities to the impacts of thar, so the plan required that these intervention densities be tested and refined so that the plan could be reviewed.

The plan did not consider what plant species might be most useful as bioindicators of thar impacts, direct how impacts were to be assessed, or specify what state of vegetation should be considered 'ecologically acceptable'. In the absence of such guidelines we selected snow tussocks (*Chionochloa* spp.) as the main bioindicators, and used a modified variable-area plot method to assess vegetation parameters (Rose and Platt 1992). Other plant species were also monitored to a lesser degree. While recognising that we cannot prescribe what vegetation condition might be considered 'ecologically acceptable', for the purposes of this report we consider any trend towards more or bigger tussocks, or at least no declining trend when thar densities are low, to be acceptable.

The main hypothesis tested was that the indices of vegetation condition should remain constant, or improve in areas where the average thar densities between vegetation surveys did not exceed the intervention density. More broadly, we also tested whether, regardless of absolute thar densities, the condition of the vegetation improved when thar numbers decreased, and vice versa.

3. Objectives

- To determine changes in the condition of alpine tussock grasslands in five catchments in the thar range in the Southern Alps between 1990 and 1997.
- To relate any changes in the vegetation to the densities and trends in densities of thar in order to evaluate the level set for intervention densities under the National Thar Control Plan.
- To recommend the most efficient field methods and statistical techniques for using the variable-area plot method to assess tussock condition and thar impacts.

4. Methods

4.1 STUDY CATCHMENTS

Permanent vegetation plots were established in five study catchments (Table 1) located in each of the management units where thar densities were set above zero in the National Thar Control Plan (Fig. 1), and where thar have been regularly counted.

TABLE 1. SITE CHARACTERISTICS OF STUDY CATCHMENTS.

	HOOKER	NORTH BRANCH	CARNEYS	WHYMPER	LANDSBOROUGH
Area surveyed (km^2)	22	19	19	29[a]	18[a]
Plan Unit	4	3	1	2	6
Year thar established[b]	1904	1948	1948	1960s	1947
Intervention density	< 1.0	2.0	2.5	2.0	1.5
Tenure	National Park	Pastoral lease retired to DOC	Other DOC	Other DOC	Other DOC
Dominant tussock spp.	*C. pallens*	*C. rigida*	*C. pallens*	*C. pallens*	*C. pallens*
No. Plots	9	16	18	12	17
Years established	1992	1990/1992	1992	1993	1992/1994
Year remeasured	1995	1996	1997	1997	1997

[a] The areas surveyed for thar numbers differed between years (see text for details).

[b] Year breeding populations established; males often preceded this date by a decade (Caughley 1970).

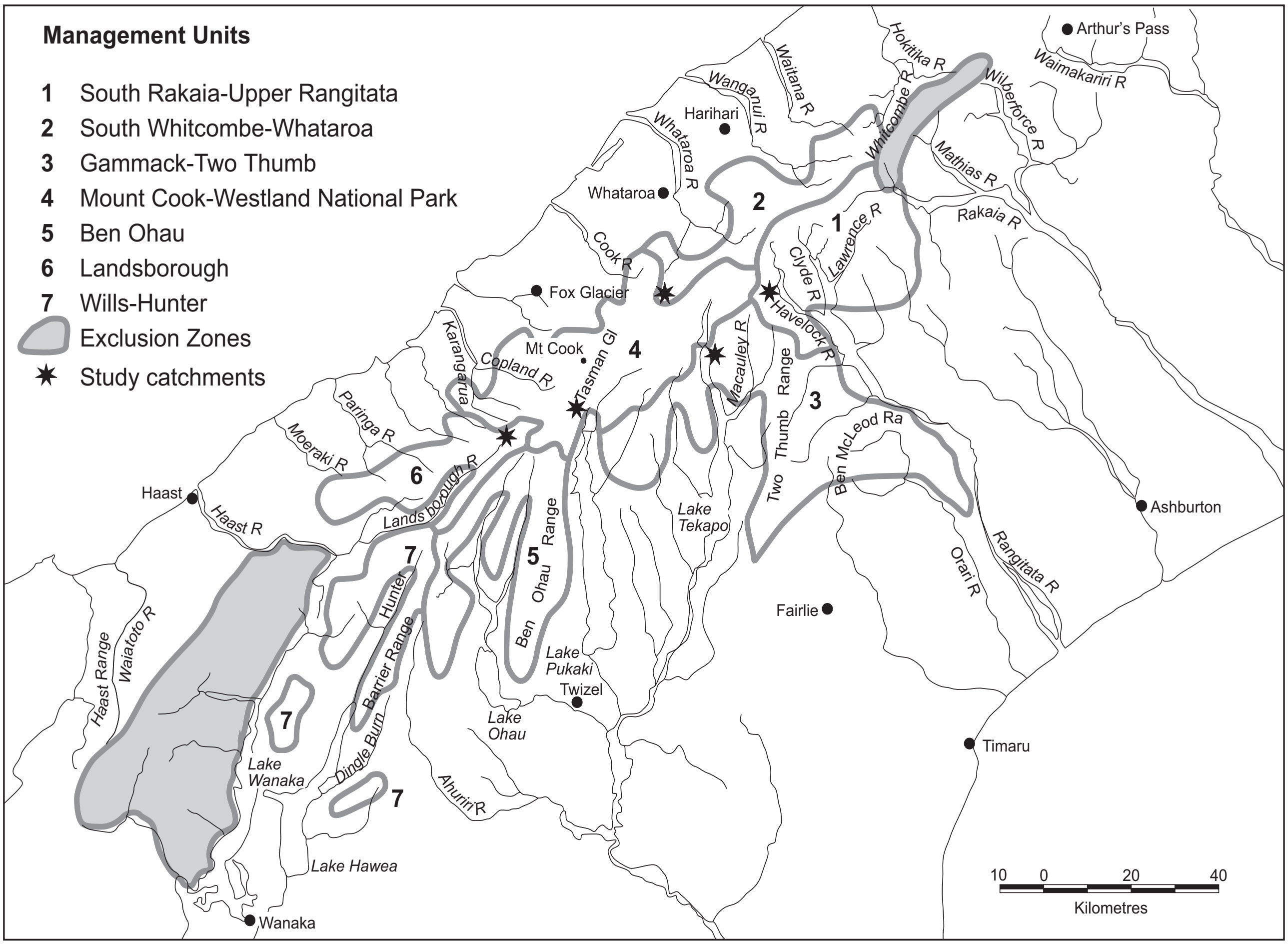


Figure 1. Location of study catchments within the thar range and management units defined in the National Thar Control Plan.

4.1.1 Hooker Valley

The Hooker study area (NZMS 260, H36, 780 210) is part of the Mt Cook range on the true left of the Hooker Valley in Mount Cook National Park from Hooker Corner up to Mt Mabel. The study area extends from newly deposited moraine at c. 800 m a.s.l. through a band of subalpine scrub up to c. 1300 m a.s.l., through tall tussock grasslands and herbfields interspersed with bare rock and scree on steep faces and basins up to the limit of vegetation at c. 1850 m a.s.l., and to the top of the range at 2000 m a.s.l.

The nine plots, established in February 1992 and remeasured in February 1995, were sited on colluvial sideslopes above the Hooker glacier from the ridge below Mt Mabel to just below Billiken Pass at altitudes of between 1250 and 1650 m a.s.l. All plots were in areas dominated by *Chionochloa pallens*; six in alpine grassland habitats and three within the scrub zone.

Other common species on the plots (>10% average cover) were *C. crassiuscula*, *Celmisia verbascifolia*, *C. lyallii*, *C. walkeri*, *Hebe macrantha*, *H. treadwellii*, *Coprosma cheesemanii*, and *Microlaena colensoi*.

4.1.2 North Branch

The North Branch (NZMS 260, I36, 100 310) is a tributary of the Godley River. The vegetation plots are sited on the true left of the catchment within the system of bluffs in which a previous detailed study of thar behaviour was conducted in the 1970s (Tustin and Parkes 1988) and with a history of being favoured thar habitat. The site is steep and dissected by bluffs, rocky outcrops, avalanche chutes, and screes, and ranges from 800 m a.s.l. to 2200 m a.s.l. Most plots were sited on colluvial side slopes, the exceptions being four plots in *Discaria toumatou* scrub/short tussock associations sited on a debris cone. Four main vegetation associations have been described in the area (Tustin and Parkes 1988): a short tussock grassland association dominated by *Festuca novae-zelandiae* and a scrub association dominated by *D. toumatou* at lower altitudes, a short podocarp scrub association on the steeper slopes, and snow tussock grasslands dominated by *Chionochloa rigida* at higher altitudes.

Fifteen plots were established in February 1990 (Rose and Allen 1990) and a further six plots in February 1992, sixteen of which were remeasured in February 1996: ten from the 1990 survey and all six from 1992. *C. rigida* was the main snow tussock and dominant plant on all the plots remeasured. Nine plots were entirely dominated by tussock, five were in *D. toumatou* scrub, and two were in podocarp scrub.

4.1.3 Carneys Creek

Carneys Creek (NZMS 260, I35, 210 430) is a tributary of the Havelock branch of the Rangitata River. It is deeply dissected with extensive bluff systems, screes, and avalanche chutes, at elevations from 760 to 2150 m a.s.l. Subalpine scrub and forest cover some of the lower slopes but the dominant vegetation is snow tussock grasslands and herbfields, with the dominant species being *Chionochloa pallens*. Detailed descriptions of the catchment are given in Forsyth (1997).

Twenty plots were established throughout the catchment in January 1992, eighteen of which were remeasured in March 1997. Ten plots were sited in areas dominated by *C. pallens*, five in areas co-dominated by *C. pallens* and *C. crassiuscula*, and three plots were sited in areas dominated by *C. flavescens*.

4.1.4 Whymper

The Whymper study site (NZMS 260, I35, 970 470) is located below the glacier at the headwaters of the Whataroa River in Westland between 1100 and 1420 m a.s.l. No detailed description of the vegetation types and distribution patterns exists for this study area.

Twelve plots were established in the area in March 1993 and remeasured in January 1997. Eight of these were sited on the true left of the Whataroa River and four in the tributary creek below Mt Barrowman. Nine plots were established in sites where *Chionochloa pallens* was the dominant snow tussock, and three in sites where both *C. pallens* and *C. crassiuscula* were dominant.

4.1.5 Landsborough

The Landsborough study site (NZMS 260, H37, 590 105) is on the true right headwater of the Landsborough River in South Westland between 1020 and 1350 m a.s.l. No detailed description of the vegetation types and distribution patterns exists for this study area.

Nine plots were established in the area in February 1992 and a further eight plots in February 1994. All plots were remeasured in February 1997. Seven plots were at sites where *Chionochloa pallens* is the dominant snow tussock, nine at sites with both *C. pallens* and *C. crassiuscula*, and one at a site with both *C. pallens* and *C. oreophila*.

4.2 ESTIMATING ANIMAL DENSITIES

Thar and other ungulates (chamois, sheep, and red deer) that are sometimes present, were counted in each study catchment usually annually in late February/early March, i.e. before the start of the thar rut when adult males disperse into female ranges. Counts were made from fixed viewing points during the late afternoon/evening and (for some catchments) during the early morning, using 20× spotting scopes and 8–10× binoculars (see Challies (1992) for a detailed description of the method used in Carneys Creek). The whole area of each catchment was used to calculate animal densities.

To estimate changes in animal use on each vegetation plot between vegetation surveys we noted the frequency of faecal pellets of ungulates, hares, and possums on each quadrat (see below). Differences in pellet frequencies between years were tested using contingency tables. The frequency of ungulate pellets per quadrat was compared with the estimate of ungulate densities from the animal counts to see if the simpler pellet count index matched the count-based estimates of thar density in the catchment.

4.3 PERMANENT PLOT FIELD METHODS AND ANALYSES

We adapted the variable-area permanently marked plot method developed by Rose and Platt (1990, 1992) and Rose and Allen (1990) to measure trends in vegetation condition. Rectangular plots were located in areas dominated by snow tussock and known from our census observations to be used by thar, i.e. they were not located at random and can only be used to infer impacts in tussock areas used by thar. The plots varied in size so as to contain at least 20 snow tussocks of the dominant palatable species: *Chionochloa pallens, C. flavescens,* or *C. rigida*. The top left plot corner was marked with a steel stake, and the other three corners with aluminium pegs.

At each measurement the plot was divided with tape measures and string into 1×1 m quadrats and a vegetation survey (a 'recce description'; Allen 1992) was carried out for the whole plot as follows: the percentage cover of all plant species present was estimated within four height tiers (<0.1, 0.1 to 0.3, 0.3 to 1.0, and >1.0 m) using six cover classes (<1, 1 to 5, 6 to 25, 26 to 50, 51 to 75, and 76 to 100%).

Tussocks were assigned to one of four age-state classes based on their size and degree of morbidity. Seedlings were ≤1 cm basal diameter, juveniles were 1.1 to 5 cm basal diameter, mature tussocks were >5 cm basal diameter and less than 50% crown death, and senescent tussocks were mature plants showing more than 50% crown death. On each tussock we measured:

- The basal diameter of green tillers (except for the 1990 North Branch survey when all parts of the tussock, dead or alive, were measured).
- The maximum leaf length on tussocks made by pulling a handful of tillers to their maximum height.
- The amount of browse present in four classes (1, no browse; 2, low = <33% of leaves with browse; 3, medium = 34–66% browsed; and 4, high = >66% browsed). The differences in the amount of browse between years were analysed for each age-state class and tested using contingency tables. An index of browse on each tussock species at each study site was constructed by summing the weighted proportions browsed in two age-size groups (seedlings/juveniles and mature/senescent). Each proportion in the low, medium, and high browse classes was weighted by 1, 2, and 3, respectively. Thus if all tussocks were heavily browsed the index would be 12, if 10% of all age-size plants were browsed the index would be 1.2.

We also measured the percentage of each crown dead, the number of flowering culms, and described the substrate on which tussock seedlings were growing, but have not included these parameters in this report.

The data from individual tussocks were summarised by year, plot, and age-state class to provide estimates of total tussock densities (number/ha), basal area (m^2/ha), and mean tussock height (cm). Differences between years were compared from the square roots of the data and tested using chi-squared and paired t-tests that assumed all age-states were possible for all plots. The density data are presented in the tables as plants per 100 m^2.

Also, numbers of individuals, crown diameters, and standing heights were measured on each quadrat for *Aciphylla aurea, A. crenulata, A. montana, A. divisa, Carmichaelia grandiflora, Coprosma cheesemanii, Dracophyllum longifolium, D. pronum, D. uniflorum, D. kirkii, Hebe lycopodioides, H. treadwellii, H. macrantha, Podocarpus nivalis, Discaria toumatou, and Leucopogon colensoi,* in areas where these species occurred. Differences between years were compared using paired t-tests.

From these measurements we derived three measures of vegetation condition for tussock habitat used by thar for each catchment:

- Changes in the percentage of ground covered by vegetation.
- Changes in the state of snow tussocks, i.e. percentage cover, basal area, tussock density, and tussock height.
- Changes in the state of other species measured as individuals.

These measures were then compared with two potential predictors of trend derived from the counts of thar:

- The average thar density between surveys in relation to the intervention density for that area (the primary aim of the study).
- The trend in thar densities.

We also explored relationships, on a plot-by-plot basis, between the log-transformed percent changes in the four measures of snow tussock condition and an index of thar density (and its trend) provided by the frequency of faecal pellets on quadrats on each plot. The pellet indices were transformed by $-\ln(1-f)$, a standard transformation for such frequency data (Grieg-Smith 1967).

We used two models, a General Linear Model (GLM) analysis, where:

change in tussock index = change in pellet index + area + (index * area),

and a simple linear regression model, where:

change in tussock index = a + b(change in pellet index).

We took oblique colour photographs of each plot at each survey, and a selection is reproduced in Appendix 1.

5. Results

5.1 CHANGES IN UNGULATE DENSITIES

5.1.1 Hooker Valley

Thar and chamois were liberated near the Hooker Valley study site in 1904 and reached 'very high densities' within a few decades (Caughley 1970). Disease (Daniel and Christie 1963), official culling, and commercial exploitation between 1971 and 1983 (Parkes and Tustin 1985) had reduced the population to near-zero by 1984, and subsequent recreational and official hunting has kept the population to low densities. For the five years they were counted between the establishment and remeasurement of the vegetation plots, densities (±SE) averaged 0.3 ± 0.09 thar/km^2 (Fig. 2). We saw no chamois or other ungulates on the study site after 1984.

The National Thar Control Plan specifies an intervention density for the Hooker Valley (as part of Management Unit 4) of one thar/km^2, so we predicted either no change or an improvement in the condition of the vegetation given that thar had not exceeded 1/km^2 for at least the last thirteen years.

5.1.2 North Branch

Breeding populations of thar reached the Godley catchment in the late 1940s and by 1952/53 there were enough for government hunters to shoot about 800 animals (Caughley 1970). Large numbers of thar were shot in the Godley catchment in the 1960s by government cullers, and in the 1970s by commercial meat hunters, but thar on Lilybank Station (of which North Branch was part until 1996) were always afforded more protection than their neighbours—depending on how enthusiastically the Forest Service and the lessees fulfilled the wild animal control provisions of the Lands Act. No recreational hunting was permitted in the North Branch between about 1983 and 1996, except for safari hunting of bulls during the winters.

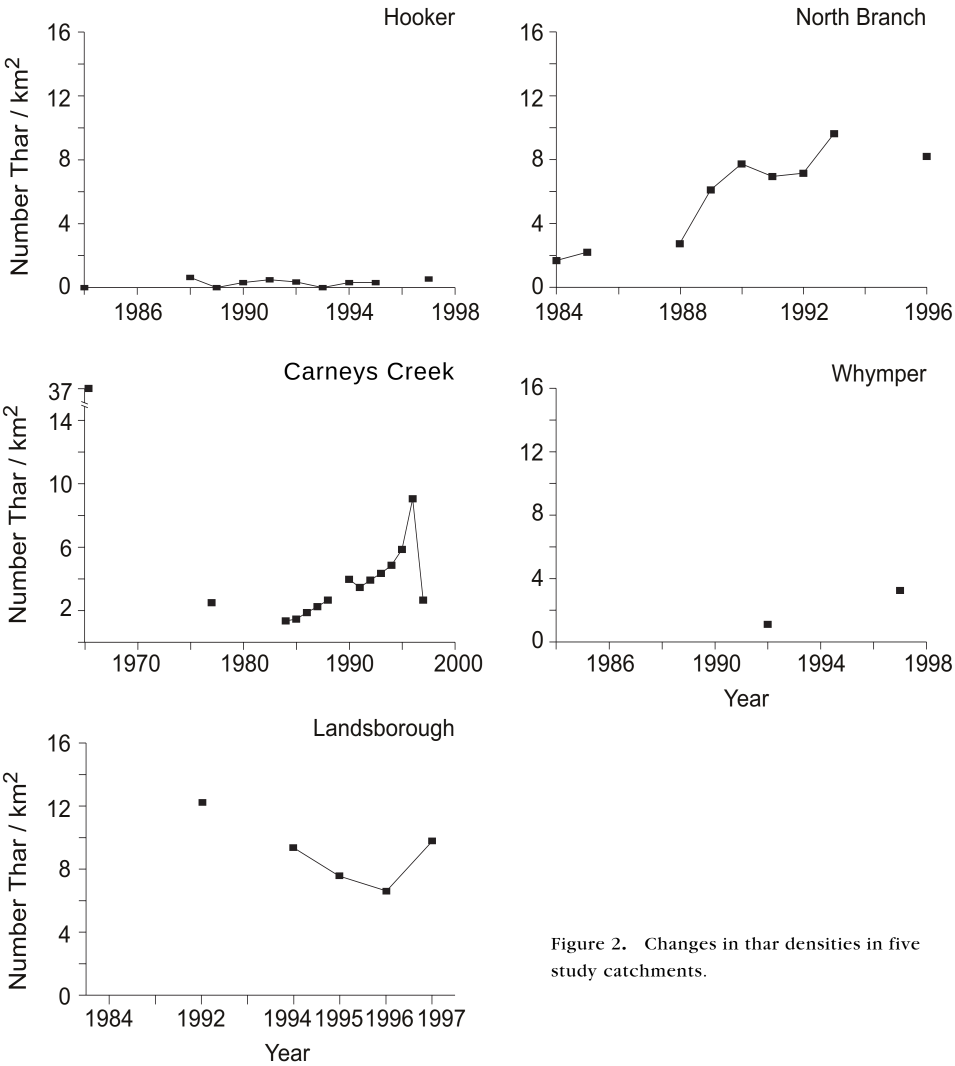


Figure 2. Changes in thar densities in five study catchments.

During the late 1970s, about thirty thar inhabited the bluff systems (c. 6 km²) at the mouth of North Branch (Tustin and Parkes 1988), and this bluff is still the core habitat for thar in the catchment and is the site of our plots. Since the 1970s, thar numbers have increased on the bluff system and spread into the whole catchment reaching an average density of about 8 thar/km² between the 1990 and 1996 surveys (Fig. 2). Densities have been consistently above the intervention density of 2.0 thar/km² since 1988, so we expected tussock condition to be declining if the intervention densities have some biological basis.

5.1.3 Carneys Creek

Thar established breeding populations in Carneys Creek in about 1948, some twenty years after chamois. They reached densities of over 30/km² by the mid-1960s, but were reduced to low densities during the 1970s by commercial meat hunting. The catchment is a popular hunting area for recreational hunters, but was closed to hunters (although some illegal hunting did occur) during a research study in the area between 1993 and 1996. Thar and other ungulates have been counted in the catchment periodically since 1965 (Tustin and Challies 1978) (Fig. 2).

The thar population exceeded the intervention density of 2.5 animals/km^2 every year since 1988, reaching a maximum density of 9.1 thar/km^2 in 1996 but falling to 2.6 thar/km^2 in 1997 after the area was opened to recreational hunters. However, the average density of 5.1 thar/km^2 between the two vegetation surveys would lead us to predict that the condition of the vegetation should have declined between 1992 and 1997.

5.1.4 Whymper

Thar probably established breeding populations in the southern headwaters of the Whataroa after 1960 from animals that settled in the Perth River to the north in the mid-1950s (Caughley 1970). Ungulate numbers have been counted in the area below the Whymper Glacier in 1992 and 1997, and additionally in the adjacent side catchment under Mt Barrowman in 1997 (Fig. 2). Ungulate numbers in the main valley (17 km^2) doubled between 1992 and 1997 from nineteen thar and one chamois to thirty-six thar and four chamois in 1997. A further fifty-five thar were counted in the 12 km^2 area under Mt Barrowman surveyed in 1997. We have vegetation plots in both areas.

Thar in the area have probably never reached very high densities because their natural irruption was interrupted by commercial harvesting in the 1970s. It is likely they have only recently exceeded the intervention density of 2 thar/km^2, so we predicted no changes in the condition of the vegetation.

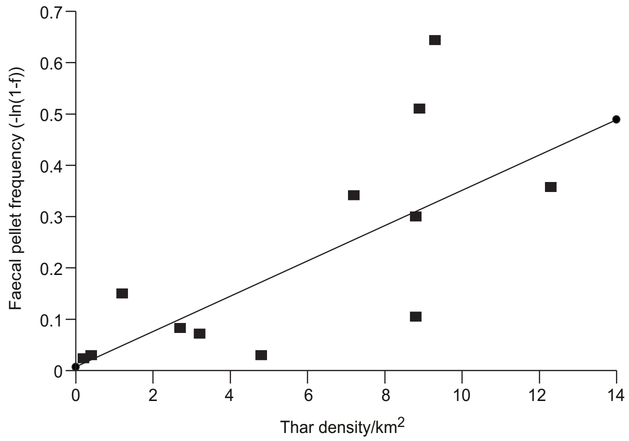
5.1.5 Landsborough

Thar established breeding populations at the head of the Landsborough Valley by 1947 (Caughley 1970). No thar were seen in a ground census of Zora Creek, a side creek further down the Landsborough, in 1984 (Parkes 1984), and only ten thar (plus sixteen chamois) were seen in the headwaters of the Landsborough during an aerial hunt in 1984 (J. Parkes, pers. obs.). However, large numbers were seen in the study area during ground counts made between 1992 and 1997 (Fig. 2). Estimating trends in thar numbers is confounded by inconsistencies in the areas surveyed between years. What is clear is that thar densities have exceeded the intervention density of 1.5 thar/km^2 since at least the time of the first survey in 1992 when they were at a density of 12.1 thar/km^2. Numbers may have been reduced subsequently to 9.8 thar/km^2 in 1997 but because this is still well over the target density we predicted that the condition of the vegetation should still be declining.

5.2 COMPARISON OF PELLET FREQUENCIES WITH UNGULATE COUNTS

As might be expected there was a significant ($P < 0.01$) but rough ($r^2 = 0.53$) relationship between the number of ungulates counted in each study catchment in the years the vegetation was measured and the frequency of ungulate faecal pellets found on the vegetation plot quadrats (Fig. 3). This means that the effects of changing ungulate densities on vegetation condition could be interpreted, to some extent, without having to do separate thar census surveys, and of course the index of pellet frequency on each plot is logically more closely related to animal use of that plot and thus their impact on the plot (see section 5.6).

Figure 3. Relationship between the density of thar in each catchment and the frequency of faecal pellets on the vegetation plot quadrats for each year they were measured in five study sites. Note: the extra two points are because of the two-year establishment phase for plots in the North Branch and Landsborough.



5.3 CHANGES IN CONDITION OF SNOW TUSSOCK SPECIES

5.3.1 Changes in browse levels on snow tussock species

The frequencies of three different browse classes on *Chionochloa pallens* or *C. rigida* differed between surveys for most study sites (Fig. 4), and our predictions of a change in browse because of increasing or decreasing thar densities was always supported by the data. However, where no change in thar densities was observed between surveys (Hooker and North Branch) the browse index increased significantly, suggesting the method to measure browse may be too subjective to ensure repeatability.

Nevertheless, when the amount of browse was pooled as an index for all plots in each catchment in each survey there was a significant relationship ($P = 0.01$, $r^2 = 0.44$) with the density of thar for the more palatable species, i.e. *C. flavescens, C. pallens,* and C. *rigida* (Fig. 5).

5.3.2 Changes in tussock population structure

The proportions of tussocks in each age-state class differed significantly between surveys for all study catchments (Fig. 6). Generally, the largest changes were seen in the Landsborough, where the number of tussocks increased by 30% and the proportion of senescent tussocks declined with a corresponding increase in the numbers of plants classed as juveniles and mature.

5.3.3 Changes in indices of snow tussock biomass

Changes in the indices of tussock biomass (percent cover, height, basal area, and plant density) were generally consistent with changes in thar densities and their absolute number. In the Hooker Valley, where thar always remained at low densities, all indices improved or remained the same, with significant increases in the percent cover and density of *Chionochloa pallens* (Table 2). In North Branch, where thar numbers increased between the surveys and were always above the intervention density, all indices decreased, with height and percent cover showing significant reductions. In the Whymper, where thar numbers increased slightly but remained at modest densities, there were no consistent

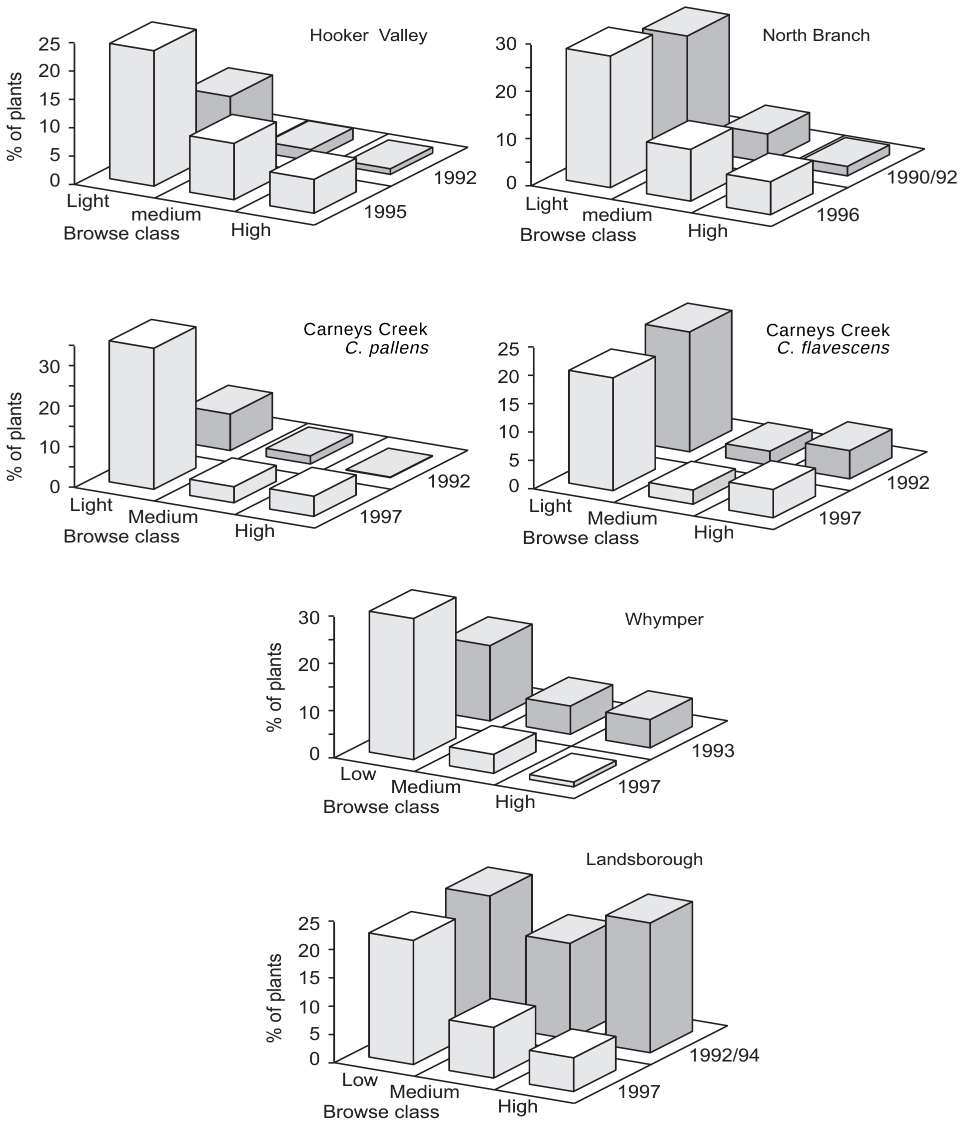


Figure 4. Changes in the percentage of tussock species browsed in three classes between surveys in five study catchments.

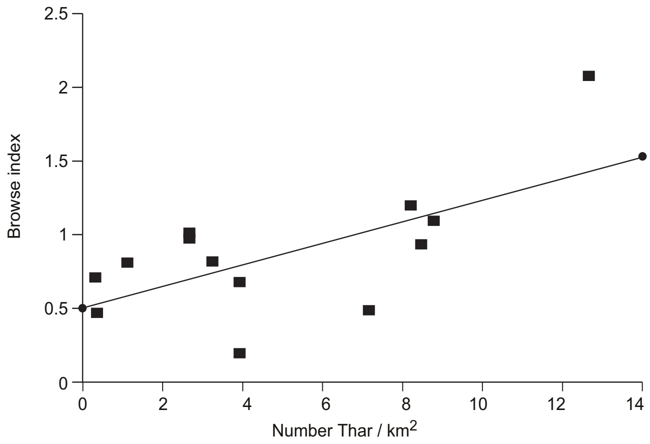
trends or significant changes in the indices. In the remaining two areas, Carneys and Landsborough, thar were at high densities at some part of the survey interval but had generally declined in 1997, albeit not to the intervention densities. The trends in indices in these catchments were not consistent, although basal area and height in Carneys and in density in the Landsborough showed significant increases (Table 2).

5.4 CHANGES IN CONDITION OF OTHER SPECIES

5.4.1 Hooker

Of the 102 plant species recorded on the Hooker plots, only *Chionochloa pallens, C. crassiuscula, Celmisia lyalli, C. walkeri* and *Poa colensoi* exceeded 5% average cover. No species other than *C. pallens* showed any change in cover. *Aciphylla divisa* was common in the area and this species showed a significant increase in average crown area per plot from 32 to 46 m^2/ha ($P = 0.01$). None of the subalpine shrub species showed any significant change in density, height, or percentage cover.

Figure 5. Relationships between browse indices for snow tussock species and measures of thar densities pooled for five study sites over two surveys.



5.4.2 North Branch

Of the 81 plant species recorded on the North Branch plots, only *Chionochloa rigida* and *Celmisia lyallii* exceeded 5% average cover. *Aciphylla aurea, Podocarpus nivalis, Hieracium pilosella, Discaria toumatou, Poa colensoi,* and *Leucopogon colensoi* were major components of the cover on some plots. Generally there were few changes in the condition indices or densities of any species, but the two large *Aciphylla* spp. (*aurea* and *montana*) each showed a significant decline in density (P = 0.01) although the condition of individual plants remained unchanged. There were no changes in condition or density of the three shrub species measured (*D. toumatou, L. colensoi,* and *Dracophyllum uniflorum*).

5.4.3 Carneys Creek

Eighty-eight plant species were recorded on the Carneys Creek plots, with only *C. pallens, C. crassiuscula, Celmisia lyallii*, and *Poa colensoi* exceeding 5% cover. Generally, there was an increase in condition and density of shrub

TABLE 2. CHANGES IN MEAN INDICES OF BIOMASS OF *Chionochloa* spp. IN FIVE STUDY CATCHMENTS.

	HOOKER *C. pal.*	N. BRANCH *C. rig.*	CARNEYS *C. pal.*	CARNEYS *C. fla.*	WHYMPER *C. pal.*	LANDS. *C. pal.*
% tussock cover						
Survey 1	21	33	38	22	55	17
Survey 2	28**	30**	42	30	55	19
Tussock height (cm)						
Survey 1	48	81	72	94	59	39
Survey 2	46	74*	75*	98	63	41
Basal area (m^2 /ha)						
Survey 1	671	1444	828	963	1754	744
Survey 2	796	1351	1146***	1048	1615	854
Tussock density (plants/100 m^2)						
Survey 1	279	212	335	74	895	382
Survey 2	315**	192	333	147	904	496**

*P<0.05, **P<0.01, ***P<0.001

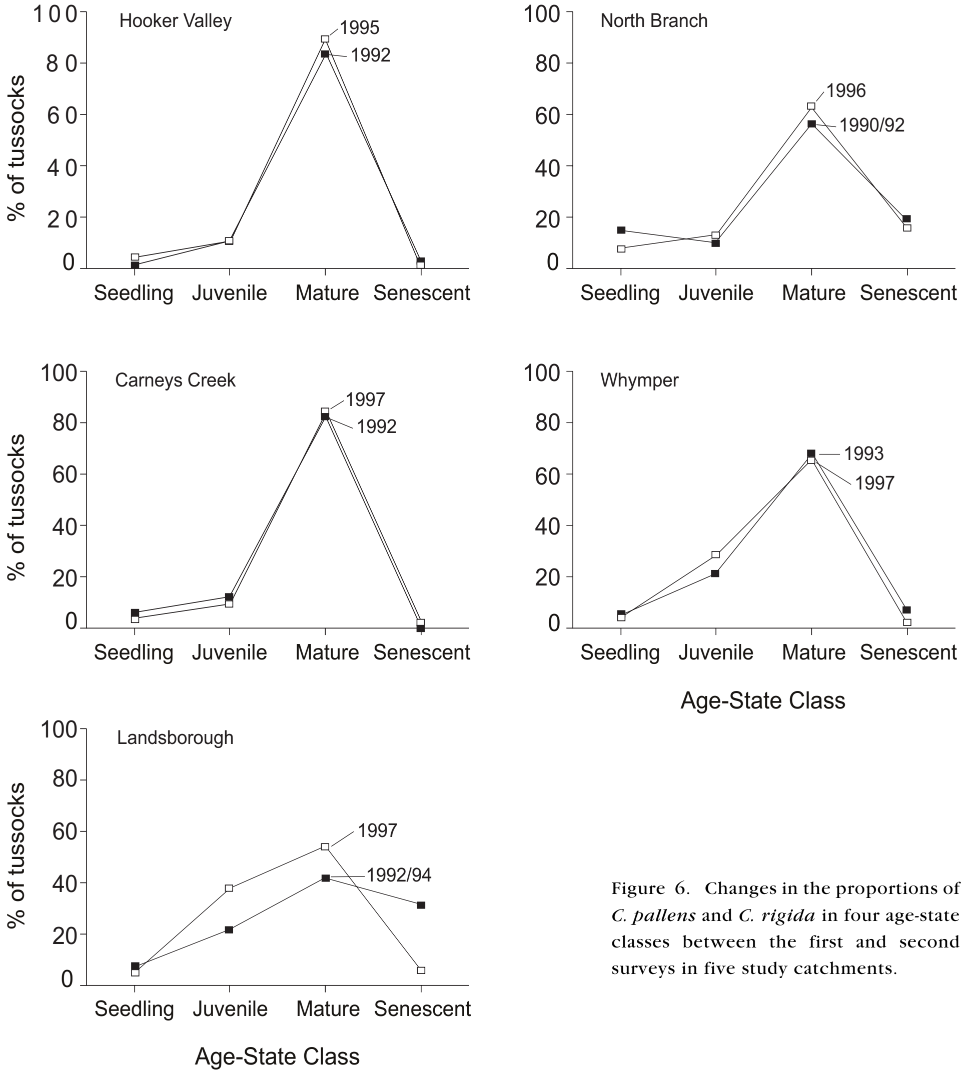


Figure 6. Changes in the proportions of *C. pallens* and *C. rigida* in four age-state classes between the first and second surveys in five study catchments.

species, particularly on the lower altitude plots where scrub was naturally more common. For example, the average density of all *Coprosma* spp. combined increased from 35 to 71 plants/100 m^2 ($P < 0.05$), and the average crown area from 111 m^2/ha to 376 m^2/ha ($P < 0.05$) between 1992 and 1997. Other shrub species that showed significant increases in one or more indices were *Carmichaelia grandiflora, Dracophyllum longifolium,* and *Hebe lycopodioides*.

The weed, *Hieracium pilosella,* was common in four plots in tall tussock and significantly increased its cover from an average of 3% in 1992 to 12% in 1997 ($P < 0.05$).

5.4.4 Whymper

Of the 108 plant species recorded on the plots, *C. pallens, C. crassiuscula, Poa colensoi, Schoenus pauciflorus, Celmisia petiolata, C. walkeri, Coprosma depressa, C. pumila, Coriaria plumosa, Muehlenbeckia axillaris, and Blechnum penna-marina* averaged over 5% cover in either survey, and none showed any change between surveys.

The average crown areas and heights of *Aciphylla crenulata, A. divisa,* and *Carmichaelia grandiflora* remained similar between surveys, but the density of the latter increased significantly on the two plots where it occurred—from 84 to 150 plants/100m^2 ($P < 0.05$).

5.4.5 Landsborough

Of the 94 plant species recorded on the plots, *C. pallens, C. crassiuscula, Poa colensoi, Celmisia walkeri, Coprosma pumila, Dracophyllum uniflorum, Gaultheria depressa, Oreomyrrhis colensoi, Plantago novae-zelandiae, and Lycopodium fastigiatum* averaged over 5% cover in either survey. Apart from the snow tussock species, only *Oreomyrrhis colensoi* changed significantly between surveys, increasing from an average 2% cover in 1992/94 to 7% in 1997 ($P < 0.05$).

For species that were measured individually (*Aciphylla crenulata, A. divisa, Carmichaelia* sp., *Dracophyllum uniflorum,* and *Podocarpus nivalis*), no changes in crown area or density were measured.

5.5 TUSSOCK CONDITION INDICES AND FAECAL PELLET FREQUENCIES ON THE PLOTS

We found differences between the vegetation indices between areas (as expected) using the GLM model, but could not relate these consistently with either thar pellet frequencies or the change in pellet frequencies between vegetation surveys at each study site using the regression model.

For example, using change in pellet frequency we found a significant relationship only for percentage cover in the Whymper; all other relationships in all other areas were non-significant. Similarly, using the index of pellet frequency at the first survey we found significant relationships for basal area in Carneys Creek, tussock density for the Hooker Valley, and percent cover for the Whymper; all others were non-significant.

5.6 PREDICTED VERSUS OBSERVED TRENDS IN TUSSOCK CONDITION

5.6.1 Predicting trend in tussock condition from the intervention density

The first index to measure tolerable densities of thar is the 'intervention density'. The thar plan sets average densities of thar for each management unit above which it is expected thar impacts will be unacceptable. When thar exceed these densities the plan demands intervention to control the population.

In the Hooker Valley, thar were at about 30% of the intervention density and we expected the indices of tussock condition to improve, if the intervention densities are set correctly. Two of the five indices of tussock condition increased significantly with the rest remaining unchanged (Table 3). In the Whymper, thar remained at about the intervention density and, as expected, no tussock indices changed significantly. In the remaining three catchments, thar were always above the intervention densities during the survey period and we expected tussock condition indices to decline. Of the fifteen predictions possible in these three catchments, three went significantly as expected, three went significantly in the unexpected direction, and nine showed no change (Table 3).

Of the 25 predictions possible for all five catchments, ten went significantly as expected or showed no change as expected, three went significantly in the unexpected direction, and twelve showed no change when a change was expected (Table 3).

5.6.2 Predicting trend in tussock condition from the trend in thar densities

A second approach to validating some simple index of impact is to compare the condition of vegetation with the trends in thar densities observed in each catchment. The untested assumption we make is that the vegetation would remain unchanged if thar densities did not change. This is unlikely to be true, even at the generally low thar densities experienced, not least because of lags in the system from the much higher ungulate densities in the past.

In the study catchments where thar densities did not change between surveys (Hooker and North Branch) we would expect indices of vegetation condition to remain the same. In both catchments 50% of the predictions were wrong. In study catchments where thar densities increased between surveys (Whymper and Carneys Creek) we would expect the indices to decrease. Of the twelve predictions, only three were significant as expected, while the rest either did not change or went in the opposite direction to that expected. In the Landsborough, where thar densities decreased between surveys, the condition indices went significantly as expected in two cases or showed no significant change (Table 4).

TABLE 3. PREDICTED VERSUS OBSERVED TRENDS IN TUSSOCK CONDITION INDICES IN FIVE STUDY CATCHMENTS FROM LOWEST TO HIGHEST DENSITY OF THAR.

	HOOKER	WHYMPER	CARNEYS	NORTH BRANCH	LANDSBOROUGH
PREDICTOR:					
Actual thar density/ Intervention density	0.3	1.1	2.0	4.0	5.7
CONDITION INDEX:					
Vegetative cover					
Predicted	increase	none	decrease	decrease	decrease
Observed	NS (–)	NS (+)	decrease	NS (+)	NS (+)
Mature Tussock height					
Predicted	increase	none	decrease	decrease	decrease
Observed	NS (–)	NS (+)	increase	decrease	NS (+)
Tussock cover					
Predicted	increase	none	decrease	decrease	decrease
Observed	increase	NS (0)	NS (+)	decrease	NS (+)
Tussock basal area					
Predicted	increase	none	decrease	decrease	decrease
Observed	NS (+)	NS (–)	increase	NS (–)	NS (+)
Mature tussock density					
Predicted	increase	none	decrease	decrease	decrease
Observed	increase	NS (+)	NS (–)	NS (–)	increase

NS = not significant but the trend is noted as + or – in brackets .

Note: we have omitted percentage browse as an index here as it is clearly a more short term event and more likely to be related to trends in density.

In general, of the 30 predictions possible, eleven went significantly as expected, eight went significantly in the unexpected direction, and eleven showed no change when a change was expected (Table 4). However, six of the 'errors' in prediction were from the two areas where no change was expected but could be accounted for by the actual density of thar. The vegetation improved in the low-density Hooker and declined in the higher-density North Branch despite no trend in density.

6. Discussion

The primary management aim of this study was to determine whether the intervention densities for thar set in the National Thar Control Plan are at a level that allows tolerable impacts on the vegetation. The series of surveys reported here are observational rather than experimental. We had no control over how many thar were present in each study catchment, and no experimental controls of the cause (thar density) and effect (impact on vegetation). This lack of experimental control means our conclusions must be tentative, as only weak inference is possible from studies of this type.

The plan noted snow tussocks and 'vulnerable species' as possible bioindicators of vegetation condition. We have concentrated on snow tussocks (*Chionochloa* spp.) because they form a significant part of the diet of thar, but not of other

TABLE 4. TRENDS PREDICTED IN TUSSOCK CONDITION AND BROWSE INDEX COMPARED WITH TRENDS IN THAR DENSITIES BETWEEN SURVEYS.

	HOOKER	WHYMPER	CARNEYS	NORTH BRANCH	LANDSBOROUGH
PREDICTOR:					
Trend in thar density between surveys	none	increase	increase?	none	decrease
CONDITION INDEX:					
Vegetative cover					
Predicted	none	decrease	decrease	none	increase
Observed	NS (–)	NS (+)	decrease	NS (+)	NS (+)
Browse index					
Predicted	none	increase	increase	none	decrease
Observed	increase	increase	increase	increase	decrease
Mature Tussock height					
Predicted	none	decrease	decrease	none	increase
Observed	NS (–)	NS (+)	increase	decrease	NS (+)
Tussock cover					
Predicted	none	decrease	decrease	none	increase
Observed	increase	NS (0)	NS (+)	decrease	NS (+)
Tussock basal area					
Predicted	none	decrease	decrease	none	increase
Observed	NS (+)	NS (–)	increase	NS(–)	NS (+)
Mature tussock density					
Predicted	none	decrease	decrease	none	increase
Observed	increase	NS (+)	NS (–)	NS(–)	increase

NS = not significant but the trend is noted as + or – in brackets .

herbivores in the thar range (Parkes et al. 1997). Tussocks were also chosen because a method to measure changes in their density and condition had been developed (Rose and Allen 1990), although not adequately tested for the specific purpose of comparing the vegetation changes with changes in thar densities.

Vulnerable species mentioned in the plan, *Ranunculus godleyanus* and *R. lyallii*, are probably more vulnerable to chamois judging by that species' dietary preferences (Parkes et al. 1997) and the former is too rare to be useful as a bioindicator (Harding 1996).

Neither thar density in relation to the intervention densities nor the trend in thar densities predicted all the trends observed in the condition indices used. The intervention density generally predicted trends in vegetation condition better than did trends in thar densities. We suspect this is because of lags in responses, particularly in areas that supported very much higher numbers of thar before our first surveys (e.g. in Carneys Creek), where it is possible that the vegetation is still improving from the reductions in thar achieved in the 1970s and 1980s irrespective of the relatively minor changes in densities in the 1990s.

7. Recommendations

- Thar should continue to be counted in the five study catchments at least once every 2 years.
- Thar densities should be held at about the intervention densities in the five study catchments by official hunting if needed, and an experiment designed to manage thar at near-zero and higher densities in adjacent similar catchments so that a better measure of the thar density / impact relationship can be made.
- The current vegetation plots should not be remeasured until 2002.
- Refer to Parkes et al. 1999 for methods for counting thar and remeasuring the vegetation plots.

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The original data sheets and photographs are held at Landcare Research, Lincoln, with copies to be sent to the relevant Conservancies. Detailed descriptions of each plot, and results on condition indices for each plot, are available for the eastern study sites in a series of unpublished reports to Conservancies, and data on the West Coast study sites are held by Landcare Research and the West Coast Conservancy. Electronic copies of the data in Quattro Pro are held by Landcare Research, Lincoln.

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