The effect of rabbits on conservation values

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Dale Norbury

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CONTENTS

Abstract

The impacts of rabbits on indigenous flora and fauna are reviewed. Most of the published literature relates to short tussock grasslands where rabbits are most abundant. Otherwise, there is little published information and so this review relies heavily on people's observations.

In tall tussock grassland, grazing by rabbits reduces tussock cover and stature, and may adversely affect some inter-tussock species.

In short tussock grassland, and other plant communities where exotic weeds are prevalent, rabbits in low numbers may be beneficial to some conservation values. Rabbit grazing reduces the spread of exotic grasses and herbs and provides niches for less competitive native species. However, palatable native plants are adversely affected by rabbit grazing.

Rabbit browsing of seedlings appears to limit regeneration of many native shrubs. However, a few indigenous shrub species appear to increase under rabbit browsing. Rabbits also browse shrub foliage, and ring-bark some species of native shrubs and trees.

Rabbits, even in very low numbers, are a serious conservation pest on sandy soils, which are prone to erosion resulting from their activity. Rabbits also graze many native plants of sand dunes and sandy soils - a problem particularly for revegetation programmes.

Most native invertebrate fauna appear to cope well in the presence of rabbits, but this is based on little experimental research. Rabbit predators have significant impacts on many threatened vertebrate species. The influence of rabbit abundance on these predatory impacts is largely unknown.

Leaving aside the possibility of increased predation on native fauna, rabbit control is likely to directly benefit native flora and fauna in most habitats of New Zealand. However, where exotic weeds are prevalent, such as in the short tussock grasslands, flora and fauna may be adversely affected by rabbit control. Contingency plans need to be in place prior to any widespread reduction in rabbit numbers to guarantee the conservation of the full range of native biota. Monitoring of native flora and fauna should coincide with any future management strategies to assess their effectiveness in achieving conservation objectives.

1. Introduction

1.1 PROJECT AND CLIENT

This review was commissioned by The Department of Conservation to summarise information and identify research gaps on the impacts of rabbits on New Zealand's native flora and fauna.

1.2 OBJECTIVES

- To report on direct effects of rabbits on indigenous flora and fauna, and indigenous communities.
- To report on indirect effects of rabbits on indigenous flora and fauna as a result of:
  - modification of habitat
  - suppression or spread of weeds
  - support of rabbit predators which prey on indigenous fauna
  - establishment of introduced fauna
  - any other environmental changes
- To report on any positive or negative effects that a reduction in rabbit numbers may have on conservation values (excluding the possible effect of prey switching of rabbit predators from rabbits to indigenous species).
- To identify information gaps relating to the effects of rabbits on conservation values.

1.3 HISTORY

The European rabbit (*Oryctolagus cuniculus*) was introduced into New Zealand by European settlers from about 1838. Rabbits were initially difficult to establish, presumably due to scarcity of suitable habitat (Gibb and Williams 1994). Deterioration of the South Island's tussock grasslands, caused by sheep grazing and associated management practices (particularly burning), opened up the tall or rank grasslands and shrublands creating favourable rabbit habitat (e.g., Cockayne 1919, Zotov 1938, The Parliamentary Commissioner for the Environment 1991). The early distribution of rabbits, therefore, followed the development of farming, spreading rapidly from Otago and Marlborough (Gibb and Williams 1990). By 1900 most of the suitable habitat in the South Island was occupied by rabbits. The spread of rabbits in the North Island was slower, but by 1948 rabbits had occupied most of their present range (Gibb and Williams 1994).

1.4 RABBIT DISTRIBUTION AND HABITAT

Rabbits occur over 150 000 km^2 in both the North and South Islands, and on 21 smaller islands (Parkes 1995). The highest densities of rabbits occur in Central Otago and the Mackenzie Basin, where the climate most resembles that of their native home in the western Mediterranean. Preferred habitats are characterised by free draining soils supporting dry, open grassland with adjacent taller vegetation such as scrub for cover (Gibb and Williams 1990). Warm, sunny aspects with low to moderate rainfall (<1000 mm) and altitudes of less than 1000 m are preferred. Rabbits can tolerate wetter climates and higher altitudes provided other factors such as soils and vegetation are suitable.

1.5 ECOLOGICAL IMPACTS OF RABBITS WORLDWIDE

Whilst there is abundant literature on the impacts of rabbit grazing from other parts of the world, particularly from Britain and Australia (see reviews in Thompson and King 1994), this review concentrates on rabbit impacts in New Zealand. Overseas literature is referred to where general principles apply to New Zealand.

1.6 INFORMATION SOURCES FOR THIS REVIEW

A search of the published literature yielded little research that could directly attribute grazing impacts to rabbits. A similar review was recently compiled for the Canterbury and Otago Regional Councils, but concentrated on impacts relevant to pastoral and farming country (Allen *et al.* 1995a). Because of the lack of published information, this review largely relies on unpublished reports and observations made by DOC staff and other scientists within New Zealand. While reference is made to some of the historical accounts of the impacts of early rabbit infestations, this review concentrates on current rabbit impacts.

Information from each plant community (Section 2) is summarised in Tables 1 - 7, which also list threatened native species that rabbits are suspected of affecting. These tables were compiled with the assistance of botanists Amanda Baird, Peter de Lange, Peter Johnson and Brian Rance. Other people have also contributed and have been acknowledged throughout the text.

2. Impacts of rabbits on indigenous vegetation communities

2.1 TALL TUSSOCK GRASSLAND

Rabbits are usually absent from or occur in very low numbers in relatively unmodified tall tussock *(Chionocbloa* species) grassland where there is good tussock cover and where it is above the altitudinal limits of their range (C. Jenson, pers. comm.). Rabbit densities are greatest where the plant community has been modified by sheep grazing and burning, producing a shorter more open sward, or where the climate is quite dry (e.g., eastern Mackenzie Basin).

2.1.1 Casual observations

The effects of rabbits were observed on high altitude vegetation as early as 1883. Petrie (1883) noted the decline of Colenso's speargrass *(Aciphylla* *colensoi)* and three species of alpine daisy *(Celmisia lyallii, C. viscosa* and *C. haastii)* which he attributed to rabbit browsing. These observations may not be relevant today because much higher rabbit densities were present in the mid to late nineteenth century. Even so, rabbits are likely to be having a negative impact on the indigenous flora, particularly on inter-tussock herb species (G. Walls and C. Jenson, pers. comm.). Native flora may be vulnerable to rabbit grazing where they occur around cushion bog communities. For example, the comb sedge *(Oreobolus pectinatus) is* occasionally heavily browsed by rabbits (M. Davis pers.comm.).

2.1.2 Exclosure studies

Rogers (1994) examined the combined effects of rabbits and hares in red tussock/hard tussock grassland at three sites in the central North Island. Vegetation was monitored in three paired exclosure plots open to all grazing in the control plots, and the exclosures subdivided to exclude all herbivores (including horses) on one side, and all herbivores, except rabbits and hares, on the other.Results from only two of the three sites are repoted here, because at one site horses broke through the exclosure fence.

At one site, rabbits and horses reduced (but not significantly) the rates of recovery of red tussock *(Chionochloa rubra),* hard tussock *(Pestuca novae-zelandiae)* and exotic grasses over five years. At the other site, rabbit and hare grazing over fifteen years did not significantly affect the biomass, stature or recruitment of either hard tussock or red tussock. At this site, rabbits and hares fed primarily on exotic grasses. Despite this, the development of a dense inter-tussock sward of exotic grasses may have helped deflect rabbit and hare impacts on red tussock recruitment (G. Rogers, pers. comm.). The conflicting evidence from the two sites may also be due to other factors, such as length of exclusion time and the relative densities of hares and rabbits (not reported at the sites).

A field experiment was established in the Mackenzie Basin in 1990 to measure the impact of sheep and rabbits on conservation values in the high country grasslands (Espie *et al.* 1995). Four sites contained tall tussock grasslands, and six sites contained short tussock grasslands. Each site was divided into three treatments: ambient sheep and rabbit grazing levels; sheep grazing excluded; and all grazing mammals excluded. Vegetation species composition, cover and structure were monitored annually until 1993. It is planned to remeasure the plots in 1996/7 and then every five years, at least for the immediate future. There was very little change in plant cover for any plant group or change in species richness during the four years of the Mackenzie Basin study, therefore results from similar sites were pooled to analyse grazing effects. In the tall tussock grasslands, no significant differences in percentage ground cover or species richness occurred between grazing treatments (Espie *et al.* 1995). In the absence of all grazing, there were non-significant trends for increasing cover of snow tussock *(Chionochloa rigida),* hard tussock, native shrubs e.g., manuka *(Leptospermum scoparium)* and matagouri *(Discaria toumatou),* and a slight increase in exotic grasses e.g., browntop *(Agrostis capillaris)* and sweet vernal *(Anthoxanthum odoratum).* Hawkweed *(Hieracium pilosella)* increased across all treatments but at a rate inversely proportional to the grazing pressure. There

TABLE 1 NATIVE FLORA AFFECTED BY RABBITS IN THE TALL TUSSOCK GRASSLANDS. PLANT STATUS IS AFTER CAMERON *ET AL.* (1995). 'TAX. INDETERM.' = TAXONOMICALLY INDETERMINATE; 'INSUFF. KNOWN' = INSUFFICIENTLY KNOWN; 'EXTINCT ?' = PRESUMED EXTINCT. SPECIES NOT ON THE THREATENED SPECIES LIST ARE REFERRED TO AS 'SECURE'. IMPACTS OF RABBITS ARE INDICATED AS EITHER BENEFICIAL (+), DETRIMENTAL (-) OR A COMBINATION OF BOTH (+/-), AND ATTRIBUTED TO BROWSING (BR), HABITAT MODIFICATION (HM), OR WEED SUPPRESSION (WS).

SPECIES	FAMILY	STATUS	IMPACT	SOURCE
Aciphylla montana var. *gracilis*	Apiaceae	local	-	pers.comm.
Gingidia montana	Apiaceae	secure	-(br)	Allen *et al.* 1995
Oreobolus pectinatus	Cyperaceae	secure	-(br)	pers.comm.
Swainsona novae-zelandiae	Fabaceae	rare	-	pers.comm.
Luzula crenulata	Juncaceae	rare	-	pers.comm.
Chionochloa rigida	Poaceae	secure	-	Espie *et al.* 1995
Chionochloa rubra	Poaceae	secure	-	Rogers 1994
Descbampsia caespitosa var. *macrantha*	Poaceae	vulnerable	-	pers.comm.
Festuca novae-zelandiae	Poaceae	secure	-	Rogers 1994

were no consistent trends in species richness across different grazing treatments, although there were indications in the last sampling period that protection from all grazing may be promoting an increase in the total number of species. The authors were reticent to ascribe any general trends to rabbit grazing only, because these plots were exposed to very low rabbit numbers after an unforseen rabbit control programme in the second year. In addition, rabbits were able to enter the rabbit exclosures in the first year. Hence the 'ungrazed' treatments and the rabbits only treatments were functionally very similar. The authors point out that the results are only preliminary, and that the study needs to run for a longer period. Higher rabbit numbers are required and the total grazing exclosures need to be better managed to exclude rabbits. For the tall tussock grassland sites, the authors hypothesise that over a longer period of no grazing, exotic grasses may be suppressed by recovering tussock plants, resulting in greater diversity of native species. Table 1 lists native flora of the tall tussock grasslands that are affected by rabbits.

Summary:

Rabbits, even in low numbers, may be a conservation pest in tall tussock grassland communities where grazing reduces tussock cover and stature.

2.2 SHORT TUSSOCK GRASSLAND

2.2.1 Past vegetation change

Probably the only significant areas of short tussock grasslands existing a thousand years ago were in the intermontane basins in Central Otago, Mackenzie and Marlborough under annual rainfalls less than 500 mm. Today, short tussock grasslands occur mostly in subhumid districts formerly supporting forest and shrubland that were burnt by early Maori (Wardle 1991). Early European pastoralists and explorers, therefore, encountered grasslands greatly expanded by Maori activity. Large *Chionochloa* tussocks were widely dominant on the older, more acid soils, down to lower altitudes than today. Hard tussock, the most important tussock of inland short tussock grasslands, was scarcely mentioned in early accounts. The suitability of the tussock grasslands for rabbits was greatly enhanced by sheep grazing and burning in the mid to late nineteenth century which reduced tall tussock (*Chionochloa* species) cover, producing a shorter more open sward of hard and blue tussocks (*Poa colensoi)* Zotov 1938; McKendry and O'Connor 1990). In this modified environment, rabbits rapidly increased in numbers and compounded the effects of pastoralism on native flora (Petrie 1883). Mather (1982) described the depletion of Central Otago's tussock grasslands as one of the most dramatic examples of land degradation as a result of European colonisation during the nineteenth century. The extent to which rabbits contributed to this degradation is unclear from historical accounts, but direct observations at the time suggest their impact was devastating when rabbit numbers were high. For example, Cockayne (1919) described various stages of vegetation depletion in the Awatere valley, Marlborough, which he directly attributed to rabbits. These included destruction of tussocks and more palatable plants, and soil erosion which resulted in bare ground and subsequent colonisation by scabweeds.

2.2.2 Present community structure

The vegetation that exists today in the short tussock grasslands consists mainly of low growing browse resistant plants, such as the native scabweeds (*Raoulia* species), and introduced stonecrop (*Sedum acre*), thyme (*Thymus vulgaris*) and hawkweeds (*Hieracium* species). The tussock cover (*Festuca, Flymus* and *Poa* species) is much reduced, and exotic grasses such as browntop and sweet vernal are dominant over native grasses e.g., *Rytidosperma* and *Dichelachne* species. Native flora affected by rabbits in the short tussock grasslands are shown in Table 3.

Some species that are presumed extinct and for which rabbits have been implicated in their demise include *Logania depressa, Myosotis laingii* and *Stellaria elatinoides* (P. de Lange, pers. comm.). Other species once widespread in the short tussock grasslands, e.g., the highly palatable *Gingidia montana*, are restricted to rocky refugia that are inaccessible to grazing mammals (Allen *et al.* 1995a). The relative contribution of rabbit grazing in the above examples is unknown.

Some native plants, particularly small annual herbs, fare well in the open, disturbed ground induced by grazing. For example, the rare native ephemerals, *Myosurus minimus* subsp. *novae-zelandiae, Ceratocephalus pungens* and *Myosotis pygmaea* var. *minutiflora* occur on Flat Top Hill near Alexandra despite a history of high stocking rates and high rabbit numbers (Walker *et al.* 1995). Similarly, another threatened species, *Myosotis colensoi*, occurs in disturbed open ground in the Castle Hill conservation area in inland Canterbury (A. Baird, pers. comm.). At both sites it is likely that rabbit grazing is beneficial to the conservation of these species by suppressing the spread of exotic grasses and herbs which might otherwise colonise the bare ground that these native annuals require. At Flat Top Hill, sheep were removed from the reserve in 1992 and rabbit control was conducted in 1992 and 1993, dramatically reducing rabbit numbers (Walker *et al.* 1995). Walker *et al.* (1995) caution that if this present management continues on Flat Top Hill, an increased cover of exotic species may be expected, as has occurred elsewhere following a release from grazing (e.g., Moore 1976; Meurk *et al.* 1989; Lord 1990). This is likely to result in a decrease in native species diversity, with the native ephemeral species being particularly at risk.

On a nearby property on Conroys Road, Alexandra, Patrick (1994a) recorded a high plant species diversity (261 vascular plants, 56% native) despite a long history of sheep grazing and fluctuating rabbit numbers. He also noted that adjacent roadside vegetation, which is grazed by rabbits only, contained much healthier short tussock grassland (e.g., regenerating hard tussock and blue tussock) than paddocks with sheep and rabbits. He suggests that although rabbits are probably having some impact on the plant communities, they appear to be much less a threat to conservation values than sheep.

2.2.3 Vegetation trends following rabbit control

Mason (1967) investigated trends in coastal silver tussock *(Poa cita)* grassland in relation to changing rabbit populations on Motunau Island in Canterbury. Prior to rabbit control in 1958, high rabbit numbers resulted in dead tussock stumps, bare ground and barley grass. In comparison, areas with low rabbit numbers supported healthy tussocks, a dense litter cover and a diversity of intertussock species. After rabbit control, existing tussocks recovered and tussock seedlings were evident. There was also an increase in the native ice plant *(Disphyma australe)* and exotic perennial herbs and grasses e.g., ryegrass *(Lolium perenne)* and clover *(Trifolium* species).

Rabbit grazing also undermines and destroys silver tussocks, and was considered to be a possible cause of seedling loss in the Cromwell Chafer Beetle Reserve in Central Otago (Barratt and Patrick 1992). *Luzula celata,* a small rare sedge that occurs on the sandy soils within the reserve, may have also been at risk from rabbit burrowing which can uproot the plant (B. Rance pers.comm.). Rabbits are currently being controlled to low levels in the reserve.

On Molesworth Sation, Marlborough, Moore (1976) described the sequences of vegetation change after reductions in sheep and rabbits. On the most rabbit-prone land, scabweed and sheep's sorrel *(Rumex acetosella)* coexisted with high rabbit numbers. Moore (1976) observed rabbits killing tussocks *(Festuca novae-zelandiae)* by eating tillers and by physically uprooting plants. Following rabbit control, exotic grasses such as cocksfoot *(Dactylis glomerata),* Yorkshire fog (*Holcus lanatus),* sweet vernal and browntop grew unhindered. Of the natives, the palatable blue tussock recovered the best. Hard *tussock (Festuca novae-zelandiae)* also began to recover in post-rabbit years. Other notable changes were increases in the woody weeds sweet briar *(Rosa rubiginosa)* and broom *(Cytisus scoparius).* These results should be treated cautiously because they also coincided with reductions in sheep numbers.

Vegetation trends were assessed on pastoral land in Canterbury and Otago during rabbit control that occurred with The Rabbit and Land Management

Programme (RLMP) between 1990 and 1995 (Rabbit and Land Management News, June 1995). Percentage grass and herb cover increased and there was a corresponding decrease in bare ground. Tussock cover and hawkweed cover remained relatively constant. Analysis of species frequency data showed that the grasses, browntop, sweet vernal and the native, blue wheat grass *(Elymus solandri)*, all increased significantly. Only the results for the three most common herbs (all exotic species) were reported. Frequency of occurrence of haresfoot trefoil *(Trifolium arvense)* remained relatively constant over time, whereas white clover *(Trifolium repens)* and sheep's sorrel increased significantly. Frequency of occurrence of hard tussock and silver tussock remained unchanged; however, in Canterbury there was a significant increase in the frequency of blue tussock during the final year. In Canterbury only, the frequency of mouse-ear hawkweed *(Hieracium pilosella)* was significantly higher in the final year compared with previous years. These results should be interpreted cautiously because they also coincided with improved grazing management and above average rainfall. Therefore, the extent to which vegetation recovery was attributable to lower rabbit numbers is difficult to determine.

Two years after the removal of sheep and the reduction of rabbit numbers in the Tekapo Scientific Reserve in the Mackenzie Basin, there was a significant decrease in bare ground and a corresponding increase in mouse-ear hawkweed and introduced grass cover (browntop and sweet vernal) (Espie 1995). Native species such as hard tussock, blue tussock and the grass *Pyrranthera exigua* increased slightly. The primary objective of the study, however, was to investigate the effectiveness of re-establishing native species in degraded short tussock grassland by direct drilling of seed and by transplanting seedlings. The impact of rabbits on the seeded grasses could not be ascertained because of the absence of an experimental control. However, Espie (1995) was able to compare the survival of the transplanted grasses with those in a rabbit-free exclosure on the nearby Mt. John Research Station (Table 2). Ten months after

TABLE 2 SURVIVAL OF TRANSPLANTED NATIVE GRASSES IN THE TEKAPO SCIENTIFIC RESERVE WHERE ONLY RABBITS WERE PRESENT, AND IN THE MT. JOHN EXCLOSURE WHERE RABBITS WERE ABSENT. -' INDICATES NOT TRANSPLANTED AT THIS SITE. VALUES FOR THE TEKAPO SITE ARE AVERAGES AND THE NUMBER OF SITES ARE INDICATED IN BRACKETS. AFTER ESPIE (1995).

SPECIES	TEKAPO SITE (RABBITS)	MT. JOHN (NO RABBITS)
Plume grass	0.7% (n=2)	-
Blue wheat grass	0.3% (n=2)	64%
Hard tussock	17.7% (n=4)	-
Silver tussock	-	92%
Blue tussock	-	81%
Snow tussock	-	64%

planting, blue wheat grass and plume grass *(Dichelachne crinita)* had been almost entirely removed by rabbits. Hard tussock fared only slightly better with survival ranging between 0% and 29%, and all plants were being severely browsed. Survival within the rabbit-free exclosure ranged between 64% for snow tussock and 92% for silver tussock. This example clearly demonstrates that even low numbers of rabbits can seriously reduce the success of revegetation programmes. While it may be invalid to extrapolate these results directly to natural regeneration of grasses, rabbits clearly have a negative impact on native grass and tussock regeneration.

At Flat Top Hill, Walker *et al.* (1995) reported an apparent southward spread of thyme through the Flat Top Hill reserve after rabbit numbers were reduced. Morgan (1989) associated a dramatic increase in the extent of thyme in Central Otago with the reduction of rabbit populations in the 1950s. Rabbits are reported to feed on new growth and seedlings of thyme (Wilkinson *et al.* 1979), but they rarely browse adult foliage (Fraser 1985). Therefore, rabbits may help to prevent the establishment and spread of thyme. Rabbits also appear to be beneficial in controlling the spread of other woody weeds such as sweet briar and introduced broom. Moore (1976) and Ogle (1990) noted increases in sweet briar after rabbit control on Molesworth Station and Motuhora Island, respectively. Moore (1976) also noted increases in broom.

2.2.4 Exclosure studies

Exclosure studies have been used for assessing long term ecological change in tussock grasslands. A review of monitoring studies in the South Island (Allen 1993) showed that many studies were unable to differentiate between the effects of different grazing animal species and the effects of season. Three recent studies (Allen *et al.* 1995b; Espie *et al.* 1995; and Norbury and Norbury in press) were able to isolate rabbit impacts.

Allen *et al.* (1995b) examined changes in vegetation in a highly depleted short tussock grassland over a six year period on Earnscleugh and Galloway Stations, near Alexandra. Five plots were established in 1986 on sunny and shady aspects at altitudes ranging from 325m to 575m. Each plot was subdivided into three contiguous sub-plots. One sub-plot excluded sheep (grazed by rabbits only), one excluded both sheep and rabbits (ungrazed) and the third remained open to both grazers, thus acting as an experimental control. Within each sub-plot an index of plant species biomass, percentage ground cover, and frequency was estimated annually until 1992. Yearly vegetation changes were erratic, irrespective of grazing. These changes did not appear to be related to rabbit densities which seemed to have little effect on plant cover or frequency. The authors concluded that the most likely cause of change was climate. The yearly fluctuations in species composition were greatest in grazed sub-plots indicating the susceptibility of heavily grazed vegetation to changes in environmental stress. Therefore, sheep and rabbit grazing are major factors in maintaining vegetation depletion in this environment. The general trends following cessation of grazing were for perennials to increase in frequency and for annuals to decline. The relative importance of sheep and rabbits differed between sites and depended on whether the vegetation was mainly composed of perennial or annual species. Where the vegetation was composed primarily

TABLE 3 NATIVE FLORA AFFECTED BY RABBITS IN THE SHORT TUSSOCK GRASSLANDS. PLANT STATUS IS AFTER CAMERON *ET AL.* (1995). 'TAX. INDETERM.' = TAXONOMICALLY INDETERMINATE; 'INSUFF. KNOWN' = INSUFFICIENTLY KNOWN; 'EXTINCT ?' = PRESUMED EXTINCT. SPECIES NOT ON THE THREATENED SPECIES LIST ARE REFERRED TO AS 'SECURE'. IMPACTS OF RABBITS ARE INDICATED AS EITHER BENEFICIAL (+), DETRIMENTAL (-) OR A COMBINATION OF BOTH (+/-), AND ATTRIBUTED TO BROWSING (BR), HABITAT MODIFICATION (HM), OR WEED SUPPRESSION (WS).

SPECIES	FAMILY	STATUS	IMPACT	SOURCE
Gingidia montana	Apiaceae	secure	-(br)	Allen *et al.* 1995
Brachyglottis saxifragoides	Asteraceae	tax.indeterm	-	pers. comm.
Senecio dunedinensis	Asteraceae	rare +	-	pers. comm.
Myosotis "glauca"	Boraginaceae	rare	+(ws)	pers. comm.
Myosotis colensoi	Boraginaceae	vulnerable	+(ws)/-(br)	pers. comm.
Myosolis laeta	Boraginaceae	tax.indeterm	-	pers. comm.
Myosotis laingii	Boraginaceae	extinct?	-	pers. comm.
Myosotis pygmaea var. *minutiflora*	Boraginaceae	local	+(ws)	Walker *et al.* 1995
Iscbnocarpus novae-zelandiae	Brassicaceae	endangered	-(br)	Allen *et al.* 1995
Lepidium sisymbrioides subsp. *kawarau*	Brassicaceae	vulnerable	-	pers. comm.
Lepidium sisymbrioides subsp. *sisymbrioides*	Brassicaceae	rare	+(ws)	pers. comm.
Notothlaspi "Red Hills"	Brassicaceae	local	-	pers. comm.
Stellaria elatinoides	Caryopyhilaceae	extinct?	-	pers. comm.
Ipbigenia novae-zelandiae	Colchicaceae	vulnerable	+(ws)	pers. comm.
Carex inopinata	Cyperaceae	endangered	-	pers. comm.
Uncinia purpurata	Cyperaceae	insuff.known	-	pers. comm.
Uncinia strictissima	Cyperaceae	insuff.known	-	pers. comm.
Carmichaelia hollowayii	Fabaceae	tax.indeterm	-	pers. comm.
Geranium "Red Hills"	Geraniaceae	tax.indeterm	-	pers. comm.
Luzula celata	Juncaceae	vulnerable	-(hm & br)	pers. comm.
Luzula crenulata	Juncaceae	rare	-	pers. comm.
Logania depressa	Loganiaceae	extinct?	-	pers. comm.
Botrychium aff. *lunaria*	Ophioglossaceae	vulnerable	-	pers. comm.
Descbampsia caespilosa var. *macrantba*	Poaceae	vulnerable	-	pers. comm.
Dichelacbne crinita	Poaceae	secure	-(br)	Espie 1992
Elymus solandri	Poaceae	secure	-(br)	Espie 1992
Festuca novae-zelandiae	Poaceae	secure	-(br)	e.g., Moore 1976
Poa cita	Poaceae	secure	-(br)	Mason 1967
Poa colensoi	Poaceae	secure	-(br)	e.g., Moore 1976
Pyrranthera exigua	Poaceae	secure	-(br)	Espie 1992
Simplicia laxa	Poaceae	endangered	-	pers. comm.
Stipa petriei	Poaceae	local	-	pers. comm.
Ceratocephalus pungens	Ranunculaceae	local	+(ws)	Walker *et al.* 1995
Myosurus minimus subsp. *novae-zelandiae*	Ranunculaceae	rare	+(ws)	Walker *et al.* 1995

of annual species, rabbit grazing had a more important effect than sheep grazing (four out of five sites). The effects of sheep grazing predominated only where the perennial grass cocksfoot dominated.

Espie *et al.* (1995) examined the impacts of sheep and rabbit grazing in tall tussock grassland and short tussock grassland (see section 2.1). In short tussock grassland the trends in the ungrazed treatments were similar to that found in the tall tussock grasslands. At some sites, where *Hieracium pilosella* was initially well established, hard tussocks were outcompeted by rapidly spreading *H. pilosella* in the absence of grazing. In addition, native grasses and herbs did best with highest grazing pressure, presumably because grazing suppressed the spread of introduced species. For the reasons outlined in section 2.1, the next round of monitoring in the summer of 1996/7 should provide results from the rabbit only treatments, which will be more indicative of rabbit impacts.

An eight month grazing trial was conducted on a destocked block on Earnscleugh Station where high numbers (30-76 rabbits/spotlight km) of rabbits grazed (Norbury and Norbury 1996). Forty small exclosures ($1 m^2$) were used to protect vegetation from rabbit grazing and were compared with plots open to grazing. The primary objective of the study was to measure biomass gain resulting from the exclusion of rabbits. After one spring growing season, a six-fold increase in pasture yield was observed. The majority of the biomass consisted of exotic grasses (chewings fescue, *Festuca rubra;* browntop; sweet vernal; and Yorkshire fog) and herbs (tussock hawkweed, *Hieracium lepidulum).* Of the native species, there was a significant increase in hard tussock and blue tussock. It was also noted that with protection from grazing, there was prolific flowering of grasses and hawkweed whereas no flowering was observed in the grazed plots. Therefore, rabbits were probably restricting the spread of exotic grasses and hawkweed, and the regeneration of palatable native tussocks.

Summary:

- **Rabbits in low numbers may be beneficial to some conservation values in short tussock grassland communities. Grazing reduces the spread of exotic grasses and herbs, providing niches for less competitive native species.**
- **Palatable native plants, such as blue tussock (*Poa colensoi*) and hard tussock (*Festuca novae-zelandiae*) are adversely affected by rabbits.**

2.3 SHRUBLAND

Ogle (1990) described vegetation change on Motuhora Island in the Bay of Plenty between 1970 and 1986. Rabbits were released on the island in 1968 and this was followed by several rabbit poisoning operations to control their numbers and limit the damage to the vegetation. Native plants which expanded their range under high rabbit numbers included species unpalatable to rabbits such as kanuka *(Kunzea ericoides)* (Table 4) and bracken *(Pteridium esculentum).* However, pohutukawa *(Metrosideros excelsa)* and mahoe *(Melicytus ramiflorus)* seedlings, and sweet briar were all browsed. The only mahoe seedlings seen during periods of high rabbit numbers were in areas

TABLE 4 NATIVE FLORA AFFECTED BY RABBITS IN THE SHRUBLANDS. PLANT STATUS IS AFTER CAMERON *ET AL.* (1995). SPECIES NOT ON THE THREATENED SPECIES LIST ARE REFERRED TO AS 'SECURE'. IMPACTS OF RABBITS ARE INDICATED AS EITHER BENEFICIAL (+), DETRIMENTAL (-) OR A COMBINATION OF BOTH (+/-), AND ATTRIBUTED TO BROWSING (BR), HABITAT MODIFICATION (HM), OR WEED SUPPRESSION (WS).

SPECIES	FAMILY	STATUS	IMPACT	SOURCE
Pseudopanax arboreus	Araliaceae	secure	-(br)	Mason 1967
Cordyline australis	Asphodelaceae	secure	-(br)	pers. comm.
Cassinia leptophylla	Asteraceae	secure	?	Meurk (unpubl. data)
IIelichrysum dimorphum	Asteraceae	endangered	-(bra	pers. comm.
IIelichrysum aggregatum	Asteraceae	secure	-	pers. comm.
Olearia avicenniifolia	Asteraceae	secure	+(?)	pers. comm.
Olearia fragrantissima	Asteraceae	vulnerable	-	pers. comm.
Olearia hectorii	Asteraceae	endangered	-(br)	Meurk (unpubl.data)
Olearia lineata	Asteraceae	secure	-	pers. comm.
Olearia odorata	Asteraceae	secure	-	pers. comm.
Olearia paniculata	Asteraceae	secure	+(?)	pers. comm.
Carex inopinata	Cypercaeae	endangered	-	pers. comm,
Carmichaelia compacta	Fabaceae	local	-	Walker *et al.* 1995
Carmichaelia curia	Fabaceae	vulnerable	-	Allen *et al.* 1995
Chordospartium murilai	Fabaceae	endangered	-	pers.comm.
Chordosparlium stevensonii	Fabaceae	vulnerable	-	pers. comm.
Notospartium torulosum	Fabaceae	rare	-(br)	pers. comm.
Sophora microphylla	Fabaceae	secure	-	Walker *et al.* 1995
Phylloglossum drummondii	Lycopodiaceae	rare	-	pers. comm.
Iloheria sp.	Malvaceae	secure	-(br)	Mason 1967
Plagianthus divaricatus	Malvaceae	secure	-(br)	Mason 1967
Hedycarya arborea	Monimiaceae	secure	-(br)	pers. comm.
Kunzea ericoides	Myrtaceae	secure	+(ws)	Ogle 1990
Leptospermum scoparium	Myrtaceae	secure	+(?)	pers. comm.
Metrosideros excelsa	Myrtaceae	secure	-(br)	Ogle 1990
Caladenia aff. *iridescens*	Orchidaceae	local	-	pers. comm.
Calochilus paludosus	Orchidaceae	rare	-	pers. comm.
Calochilus roberlsonii	Orchidaceae	local	-	pers. comm.
Pterostylis puberula	Orchidaceae	critical	+(ws)/-(br)	pers. comm.
Pterostylis tasmanica	Orchidaceae	rare	-	pers. comm.
Thelymitra tholiformis	Orchidaceae	rare	-	pers. comm.
Pittosporum crassifolium	Pittosporaceae	secure	-	Ogle 1990
Pittosporum tenuifolium	Pittosporaceae	secure	+(?)	pers. comm.
Podocarpushallii	Podocarpaceae	secure	+(?)	pers. comm.
Clematis afoliata	Ranunculaceae	secure	-(br)	Mason 1967
Discaria toumatou	Rhamnaceae	secure	-(br)	Meurk (unpubl.data)
Coprosma lucida	Rubiaceae	secure	-(br)	Mason 1967
Coprosma propinqua	Rubiaceae	secure	-(br)	Mason 1967
Coprosma robusla	Rubiaceae	secure	+(?)	pers. comm.

SPECIES	FAMILY	STATUS	IMPACT	SOURCE
Coprosma violacea	Rubiaceae	vulnerable	-	pers. comm.
Hebe armstrongii	Scrop hulariaceae	endangered	-(br)	pers. comm.
Hebe cupressoides	Scrophulariaceae	endangered	-(br)	pers. comm.
Melicytus "Egmont"	Violaceae	vulnerable	-	pers. comm.
Melicytus "flexuose"	Violaceae	vulnerable	-	pers. comm.
Melicytus ramiflorus	Violaceae	secure	-(br)	e.g., Ogle 1990

inaccessible to rabbits such as amongst kanuka scrub. Other shrubs that are presumed to be palatable to rabbits are restricted to cliffs on the island. These include *Pittosporum crassifolium* and *Cassinia leptophylla.* Mason (1967) reported the re-establishment of mahoe, five finger *(Pseudopanax arboreus),* karamu *(Coprosma lucida), Coprosma propinqua, Plagianthus divaricatus,* and *Clematis afoliata* after rabbit control on Motunau Island.

Observations from mainland sites also indicate that rabbits are a conservation pest where they browse native shrub seedlings and ringbark adult plants. In the Mohi Bush Reserve near Napier, rabbits are reported to browse seedlings and ringbark adult plants of mahoe, pigeonwood *(Hedycarya arborea),* lacebark *(Hoheria* sp.), and cabbage trees *(Cordyline australis)* (G. Walls, pers. comm.).

In the dryland area of Flat Top Hill, isolated mature trees of kowhai *(Sophora microphylla)* and the shrubs native broom *(Carmichaelia compacta), Cassinia leptophylla, Helichrysum aggregatum, Olearia lineata,* and *O. odorata* occur only on isolated rock tors and on steep moist slopes (Walker *et al.* 1995). Recruitment of these species may have declined following environmental modification caused by fires and continual grazing (Walker *et al.* 1995), presumably by both sheep and rabbits. Native shrubs that appear to be resistant to browsing by rabbits include manuka, kanuka, *Pittosporum tenuifolium, Coprosma robusta,* Hall's totara *(Podocarpus hallii), Olearia paniculata, O. avicenniifolia* and, with low rabbit numbers, *Cassinia leptophylla* (C. Meurk pers. comm.). At a research site in the Mackenzie Basin where rabbit numbers were low, *Cassinia leptophylla* was the only native shrub to survive and continue to grow. The native broom *(Carmichaelia* sp.), matagouri, *Coprosma propinqua* and the endangered *Olearia hectorii* were all heavily browsed (C. Meurk unpubl. data). In the Bendigo Conservation Area, Central Otago, a healthy stand of kanuka exists in this highly rabbit prone area. Regeneration of kanuka is apparent by the presence of seedlings and shrubs of all sizes (author's personal observations). Grazing of herbaceous vegetation by rabbits may benefit the spread of an unpalatable species such as kanuka, by suppressing herbage which might otherwise compete for space.

Rabbits have been implicated in the restricted range of several threatened shrub species. *Carmichaelia curta is* found in sparse grass swards under matagouri where presumably it escapes grazing (Allen *et al.* 1995a). Isolated populations of *Hebe armstrongii* and *Helichrysum dimorphum* arc protected within the Enys Scientific Reserve near Castle Hill in Canterbury, and a population of *Hebe cupressoides* occurs in the Cave Stream Reserve also in Canterbury. Rabbit netting around the perimeter of these reserves and rabbit and hare control maintain the reserves as relatively mammal-free (R. Smith, pers. comm.).

However, follow up shooting within the reserves is periodically required as rabbits and hares either get through or over the fence after heavy snow fall. The largest known wild population of *Hebe armstrongii* occurs on a pastoral lease near Arthurs Pass. This species does not appear to be regenerating and the plant tips are noticeably browsed (R. Smith pers. comm.). To differentiate between the impacts of stock and lagomorphs (rabbits and hares), DOC staff have erected exclosures that exclude all grazing mammals, and that exclude stock only. Another plot, open to grazing by all herbivores, will serve as an experimental control. The plots were established two years ago but data are not yet available. Revegetation programmes of these species and others, e.g., Canterbury Pink Broom *(Notospartium torulosum)* and *Carex inopinata* (a rare sedge that grows under matagouri and *Copposma* bushes), are particularly prone to rabbit and hare browsing as nursery raised seedlings appear to be especially favoured by lagomorphs (A. Baird, pers. comm.).

Summary:

- **Rabbits appear to limit the regeneration of many native shrubs by browsing seedlings. Rabbits also browse shrub foliage, and ring-bark some species of native shrubs and trees.**
- **A few indigenous shrubs appear to increase under rabbit grazing.**

2.4 COASTAL SAND DUNE

Given their suitability for burrowing, sand dunes are particularly vulnerable to erosion from rabbits. Coastal dune areas are also mined, and grazed by stock, contributing to degradation of the habitat. Marram grass *(Ammophila arenaria)* was introduced to stabilise sand dunes, but it now outcompetes the native sand-binding plant, pingao, *Desmoschoenus spiralis.* This native sedge, while no longer threatened, still does not occupy anywhere near its natural range. Pingao was particularly valued by Maori who used the bright orange strips for weaving. Kaitorete Spit near Christchurch and Spirits Bay in Northland are rated as the two best examples of pingao covered dunes in the country (A. Baird, pers. comm.). Pingao seedlings and adult plants are reportedly highly palatable to rabbits (Courtney 1983). Courtney (1983) studied the ecology of pingao on Kaitorete Spit. He found that unprotected plants of pingao were not recruiting, despite seed germination, because they were browsed by rabbits and hares (Table 5). Revegetation of pingao is currently being undertaken at several coastal sites around New Zealand. These include Fortrose Spit in Southland (C. West pers. comm.), Kaitorete Spit in Canterbury (A. Baird, pers. comm.), Ocean Beach in Hawkes Bay (G. Walls, pers. comm.), and Waipu Wildlife Refuge in Northland (R. Pierce, pers. comm.). At all of these sites rabbit browsing has been a major problem even after rabbit control. For the revegetation programmes to succeed, areas need to be fenced off and the rabbits eradicated (B. Rance pers. comm.). Seedlings of another native sand-binding plant, *Spinifex hirsutus,* have also been observed to be browsed by rabbits (Ogle 1990; G. Walls, pers. comm).

Gunnera bamiltonii is one of the rarest wild plants in New Zealand. There are two natural populations, one at the mouth of the Oreti river in Southland, and

TABLE 5 SPECIES OF NATIVE FLORA AFFECTED BY RABBITS ON SAND DUNES. PLANT STATUS IS AFTER CAMERON *ET AL.* (1995). SPECIES NOT ON THE THREATENED SPECIES LIST ARE REFERRED TO AS 'SECURE'. IMPACTS OF RABBITS ARE INDICATED AS EITHER BENEFICIAL (+), DETRIMENTAL (-) OR A COMBINATION OF BOTH (+/-), AND ATTRIBUTED TO BROWSING (BR), HABITAT MODIFICATION (HM), OR WEED SUPPRESSION (WS).

SPECIES	FAMILY	STATUS	IMPACT	SOURCE
Atriplex billardierei agg.	Chenopodiaceae	endangered	-	pers. comm.
Desmoschoenus spiralis	Cypercaeae	secure	-(br)	Courtney 1983
Eleocharis neozelandica	Cypercaeae	vulnerable	-(br;	pers. comm.
Euphorbia glauca	Euphorbiaceae	rare	-(br) & hm)	pers. comm.
Carmichaelia appressa	Fabaceae	local	-(br)	Courtney 1983
Sebaea ovata	Gentianaceae	critical	+(ws)	Ogle (unpubl. data)
Gunnera hamiltonii	Gunneraceae	endangered	-(br & hm)	pers. comm.
Austrofestuca littoralis	Poaceae	rare	-	pers. comm.
Spinifex hirsutus	Poaceae	secure	-(br)	pers. comm.
Muehlenbeckia astonii	Polygonaceae	endangered	-(br)	pers. comm.
Muehlenbeckia ephedroides	Polygonaceae	local	-	pers. comm.

the other on Stewart Island. It is a small herb that grows in flat rosettes in spreading colonies on sand dunes. Because of its prostrate habit it is unlikely rabbits browse the plant to any great extent, however rabbit scratchings are thought to uproot the plants (B. Rance, pers. comm.). *Euphorbia glauca* is a plant of similar habit and occurs at isolated coastal sites between Northland and Stewart Island. Rabbits have been observed browsing the plant (B. Rance, pers. comm.). It is unlikely that browsing has a major effect on adult plant survival as the plant is quite robust (B. Rance, pers. comm.) and the white, milky sap contained within the plant is usually disliked by herbivores (P. Johnson, pers. comm.). Browsing damage may, however, cause significant damage to seedlings and transplanted plants (B. Rance, pers. comm.). For adult plants, the greatest damage is caused by rabbits uprooting them. *Eleocharis neozelandica* is a threatened sedge that occurs on damp coastal sand and tidal creek banks. It is restricted to sites in Northland, Auckland,one site in Manawatu and one site at Farewell Spit. Flowers and seed heads that occur at the tips of erect branches are browsed by rabbits and therefore the regeneration of the plant is adversely affected (C. Ogle, pers. comm.). A rare prostrate broom species, *Carmichaelia appressa, is* endemic to Kaitorete Spit near Christchurch. It is browsed by rabbits and hares (Courtney 1983) and its roots are undermined by burrowing (A. Baird, pers. comm.). The largest population in New Zealand of another threatened shrub species, *Muehlenbeckia astonii,* also occurs on Kaitorete Spit. It grows on the gravelly soils behind the dunes where its seedlings are browsed by rabbits, hares and possibly sheep (A. Baird, pers. comm.). This impact may be offset to some extent by rabbits browsing weeds, thus creating space for other plants to establish.

Sebaea ovata is a rare native gentian whose current status is 'critical' on the threatened plant list (Cameron *et al.* 1995). It was once found on coastal dune hollows and lowland swampy ground between Northland and Canterbury. It is now restricted to a site near Wanganui at the mouth of the Whangaehu river. The habitat supports many competing exotic plants such as strawberry clover *(Trifolium fragiferum)* and Yorkshire fog. *Sebaea* is unpalatable to most mammals, as are other members of the Family Gentianaceae (C. Ogle, pers. comm.). *Sebaea* plants live for only 8-10 weeks during which time they seed. Provided there is damp bare sand for seed germination, they survive to repeat the process several times between October and March/April. A rabbit exclosure was set up to examine the role of rabbits in *Sebaea* survival. The exclosure soon became choked with exotic plants and all *Sebaea* plants disappeared (C. Ogle, unpubl. data). This simple experiment demonstrates that rabbit grazing probably benefits the survival of *Sebaea* by suppressing the spread of exotic plants, thus maintaining habitat suitable for *Sebaea* seedlings.

Summary:

- **Rabbits, even in very low numbers, are a serious conservation pest on sandy soils which are highly prone to erosion caused by rabbit activity.**
- **Rabbits also graze many native plants, and are particularly damaging where revegetation programmes are undertaken.**

2.5 SALT PAN

Salt pans support flora (e.g., *Atriplex*, *Chenopodium* and *Puccinellia* species) that are adapted to saline conditions. Saline soils that may have provided suitable habitat for these species once covered a much larger area, but the area is now much reduced because of farming and mining (Allen 1992). Salt pan habitat is protected in the Chapman Road Scientific Reserve and two conservation covenants on Galloway Station, near Alexandra, Central Otago. An endemic species of salt grass, *Puccinellia raroflorens (= P.* "Central Otago" of Cameron *et al.* 1995) occurs only in these areas. Although the salt grasses are palatable to rabbits, they appear to be coping with the current grazing pressure as indicated by their ability to flower and seed (B. Patrick, pers. comm.). Two threatened species, *Lepidium kirkii*, and *L. sisymbrioides* subsp. *matau* occur within the Galloway Station covenants. The latter species is restricted to about 200 plants at a single locality (Allen 1996). Until recently, both species were assumed to prefer saline soils because these soils occur at the Galloway locality. However, analysis of soils indicate that the plants avoid the salty soils and grow only on adjacent non-salty substrate, although *L. kirkii* occupies soils of relatively high alkalinity (Allen and McIntosh 1993). Allen's (1996) research showed that following protection from grazing, survival of adult *L. sisymbrioides* subsp. *matau* plants was unaffected by increased growth of weeds. This was attributed to the fact that this species is the only deep-rooted, perennial herb in the local flora. Almost all plant losses were clearly the result

TABLE 6 NATIVE FLORA OF SALT PANS AFFECTED BY RABBITS. PLANT STATUS IS AFTER CAMERON *ET AL.* (1995). 'TAX. INDETERM.' = TAXONOMICALLY INDETERMINATE; 'INSUFF. KNOWN' = INSUFFICIENTLY KNOWN. IMPACTS OF RABBITS ARE INDICATED AS EITHER BENEFICIAL (+), DETRIMENTAL (-) OR A COMBINATION OF BOTH (+/-), AND ATTRIBUTED TO BROWSING (BR), HABITAT MODIFICATION (HM), OR WEED SUPPRESSION (WS).

SPECIES	FAMILY	STATUS	IMPACT	SOURCE
Lepidium kirkii	Brassicaceae	endangered	-	Allen 1992
Lepidium sisymbrioides subsp. *matau*	Brassicaceae	critical	-(hm)	Allen 1996
Cheopodium detestans	Chenopodiaceae	vulnerable t	-	pers. comm.
Chenopodium pusillum	Chenopodiaceae	tax.indeterm	-	pers. comm.
Puccinellia raroflorens	Poaceae	rare	-	pers. comm.
Polygonum plebeium	Polygonaceae	insuff.known	-	pers. comm.

of burial from soil thrown up by rabbit burrowing. Table 6 provides a list of plants of salt pans that are affected by rabbits.

Summary:
The limited information available from salt pan habitats suggests that rabbits are not a serious conservation pest here, although they do adversely affect some species.

2.6 WETLAND MARGINS

2.6.1 Casual observations

Rabbits browse the leaves and flower buds of many orchids (e.g., *Pterostylis micromega*) (Table 7) thereby preventing seed set and dispersal, and inhibiting the spread of orchid populations (C. Ogle, pers. comm.). Continued removal of leaves may deplete food reserves in orchid tubers, leading to the death of the whole plant (C. Ogle, pers. comm.). The recovery of orchids (*Thelymitra species*) following rabbit control at Lake Ohia in Northland, is further evidence that rabbits can have a detrimental impact on orchids (R. Pierce, pers. comm.).

Native flora may be vulnerable to rabbit grazing where it occurs around cushion bog communities, e.g., the comb sedge (*Oreobolus pectinatus*) is occasionally heavily browsed by rabbits (M. Davis, pers. comm.).

In open situations where weeds from damp pastures are growing, rabbit grazing may benefit orchids and other native plants of smaller stature, such as the sedge, *Isolepis basilaris*, by reducing competition and preventing the small natives from being shaded out (C. Ogle and B. Rance, pers. comm.). The positive and negative impacts of rabbit grazing on adders tongue fern, *Ophioglossum petiolatum*, are likely to be similar to those for orchids, except that it is the erect spore bearing fronds that are eaten (C. Ogle, pers. comm.).

TABLE 7. NATIVE FLORA AFFECTED BY RABBITS ON WETLAND MARGINS. PLANT STATUS IS AFTER CAMERON *ET AL.* (1995). 'TAX. INDETERM.' = TAXONOMICALLY INDETERMINATE; 'INSUFF. KNOWN' = INSUFFICIENTLY KNOWN. SPECIES NOT ON THE THREATENED SPECIES LIST ARE REFERRED TO AS 'SECURE'. IMPACTS OF RABBITS ARE INDICATED AS EITHER BENEFICIAL (+), DETRIMENTAL (-) OR A COMBINATION OF BOTH (+/-), AND ATTRIBUTED TO BROWSING (BR), HABITAT MODIFICATION (HM), OR WEED SUPPRESSION (WS).

SPECIES	FAMILY	STATUS	IMPACT	SOURCE
Carex "tenuiculmis"	Cypercaeae	insuff.known	-	pers. comm.
Isolepis basilaris	Cypercaeae	vulnerable	+(ws)	pers. comm.
Oreobolus peclinatus	Cypercaeae	secure	-(br)	pers. comm.
Ophioglossum peliolatum	Ophioglossaceae	vulnerable	+(ws)/-(br)	pers. comm.
Caleana minor	Orchidaceae	critical	+(ws)/-(br)	pers. comm.
Calochilus herbaceus	Orchidaceae	insuff.known	-(br)	pers. comm.
Chiloglottis valida	Orchidaceae	rare	+(ws)/-(br)	pers. comm.
Cryptostylis subulata	Orchidaceae	local	-(br)	pers. comm.
Pterostylis micromega	Orchidaceae	endangered	+(ws)/-(br)	pers. comm.
Spiranthes "Motutangi"	Orchidaceae	tax.indeterm	-(br)	pers. comm.
Thelymitra "Ahipara"	Orchidaceae	insuff.known	-(br)	pers. comm.
Thelymitra malvina	Orchidaceae	local	-(br)	pers. comm.
Amphibromus fluitans	Poaceae	critical	-	pers. comm.
Anogramma leptopbylla	Pteridaceae	endangered	+/-	pers. comm.

2.6.2 Exclosure studies

Rogers (1994) examined the combined effects of rabbits and hares at a wetland site in the central North Island. The dominant vegetation was the native sedge, *Schoenus pauciflorus,* with a diverse mix of other sedges, herbs, and scattered red tussock. Vegetation was monitored in a control plot open to all grazing, and in an exclosure plot subdivided to exclude horses (rabbit and hare grazing only) on one side and all herbivores on the other side. Rabbits and hares appeared to reduce (but not significantly) the recovery of native and exotic sedges, exotic grasses and native herbs.

Summary:

- **Rabbits graze many native wetland species, particularly orchids. However, where wetlands border exotic pastures, rabbits may have a positive role in suppressing weeds.**

3. Impacts of rabbits on indigenous fauna

3.1 INVERTEBRATES

Valley floors of Central Otago that have a history of high stock and rabbit numbers have a distinctive and rich native moth fauna (384 species, 97% native) (Patrick 1994b). This is also likely to be true for other insect orders (B. Patrick, pers. comm.). Although this fauna now inhabits a modified range of communities, it has, on the whole, survived either in refugia such as tiny salt pans, shrubby gullies and isolated tors, or has adapted to the new situation, sometimes by enlarging its host range to include exotic species (Patrick 1994b). Exotic pasture, with its poor diversity of plant species, contributes to low moth diversity (White 1991). White (1991) observed that controlled sheep grazing benefited moth populations by maintaining a diversity of plant species. The evidence presented above (section 2.2) suggests that low numbers of rabbits would have a similar effect on vegetation structure and therefore moth diversity.

Rabbits have been found to indirectly affect the rare Cromwell Chafer Beetle *(Prodontria lewisi)*. The Cromwell Chafer is restricted to the inland sand dunes that occur near the Cromwell township. The survival of the beetle is to a large extent dependent on the native silver tussock that inhabits the area. The roots of the tussocks are the primary food supply and habitat of the larvae (Barratt and Patrick 1992). Rabbits undermine the tussocks and compete with adult beetles for food (Barratt and Patrick 1992). Current rabbit numbers within the reserve are very low as a result of successful rabbit poisoning and exclusion fencing that surrounds the reserve (B. Patrick, pers. comm.). However, vigilance will be required to maintain rabbits at their current levels or to eradicate them completely.

White (1994) hypothesised that rabbits indirectly affect populations of the rare robust grasshopper *(Brachaspis robustus)* in the Mackenzie Basin. He associated trends in grasshopper numbers with rabbit numbers. When rabbit numbers were high, peaks in grasshopper numbers also occurred. The trend was reversed following effective rabbit control. The author suggested the reason for the decline in grasshopper numbers when rabbit numbers were low was a result of increased predation pressure by ferrets and cats which were deprived of their usual food source.

There is no evidence that rabbits have contributed to the establishment of introduced invertebrate fauna, as New Zealand's invertebrate fauna is predominantly native (B. Patrick, pers. comm.).

3.2 VERTEBRATES

Rabbits are known to indirectly affect vertebrate populations through habitat modification. Breeding success of nesting sea birds such as petrels is adversely affected by rabbit burrowing which disturbs the birds' nesting chambers (M. Imber, pers. comm.). However, rabbits have now been eradicated from New Zealand's offshore islands where petrel breeding sites occur.

The main perceived threat that rabbits pose to vertebrate populations is through the predator/prey relationship such as that described for the robust grasshopper. Even where rabbits are the primary prey source for predators, such as in areas of high to moderate rabbit densities, predators consume a range of other prey species (e.g., Gibb *et al.* 1978). The indigenous fauna most likely to be at risk of predation from rabbit predators (ferrets, cats, harriers, and to some extent stoats) have been reviewed by Norbury and Murphy (1996). They identified five major habitat types that contain a total of 23 native vertebrate species that co-exist with rabbits and that may be at risk from rabbit predators (Table 8).

Predation is the main cause of nest failure for the rare black stilt *(Himantopus novaezelandiae)* which inhabits the braided river beds in the Mackenzie Basin (Pierce 1986). Pierce (1987) found that predation pressure on nesting black stilts was greatest when rabbit numbers were low after rabbit control. Other river bed species that could be at risk include the wrybill *(Anarhynchus frontalis)*, black-fronted tern *(Chlidonias albostriatus)*, banded dotterel *(Charadrius bicinctus)*, and caspian tern *(Hydroprogne caspia)* (Norbury and Murphy 1996).

TABLE 8 NATIVE VERTEBRATES MOST LIKELY TO BE AT RISK FROM PREDATION BY RABBIT PREDATORS. NATIVE SPECIES ARE ONLY LISTED IF THEY CO-EXIST WITH RABBITS. (FROM NORBURY AND MURPHY 1996).

HABITAT	PREDATORS	SPECIES CURRENTLY AT RISK
Semi-arid tussock grassland/river bed	Ferret, cat, harrier	Black stilt, wrybill, banded dotterel, black-fronted tern, caspian tern, grand skink, Otago skink, scree skink
Semi-improved pasture bordering dune	Ferret, cat, stoat, harrier	NZ dotterel, NZ fairy tern, caspian tern, yellow-eyed penguin, royal albatross
Open forest valley	Stoat	Yellowhead, kaka
Forest/scrub/pasture mosaic	Ferret, cat, stoat, harrier	Brown teal, North Island weka, brown kiwi, NZ pigeon, small-scaled skink
Wetland	Ferret, cat	Brown teal, southern crested grebe, NZ scaup

Predation of eggs and chicks of ground-nesting shore birds is a major concern, particularly in the North Island. Species known to be at risk are the NZ dotterel *(Charadrius obscurus),* fairy tern *(Sterna nereis)* and caspian tern (Norbury and Murphy 1996). Predation is believed to be the principal cause of chick mortality in South Island yellow-eyed penguin *(Megadyptes antipodes)* breeding areas (Darby and Seddon 1990). Ferrets are known to kill yellow-eyed penguin chicks on the Otago Peninsula (Moller *et al.* 1995). Ferrets are also thought to prey on the chicks of the royal albatross *(Diomedea epomophora)* at Taiaroa Head on the Otago peninsula. Current predator numbers at Taiaroa Head are quite low as a result of predator control (B. Patrick, pers. comm.), thereby minimising the threat to nesting albatross.

Stoat predation is thought to be a significant} factor in the decline of the yellowhead *(Moboua ochrocephala)* (O'Donnell *et al.* 1992) and possibly the kaka *(Nestor meridionalis).* Other forest-dwelling birds that are prey for rabbit predators include the NZ pigeon *(Hemiphaga novaeseelandiae)* (Clout *et al.* 1995) and brown kiwi *(Apteryx australis)* (G. Walls, pers. comm.).

Rabbit predators prey on the eggs of the southern crested grebe *(Podiceps australis)* in wetland areas of Canterbury. Other wetland bird species that may be at risk from predation are the NZ scaup *(Aythya novaeseelandiae)* and the brown teal *(Anas chlorotis)* (Norbury and Murphy 1996).

Of the reptile fauna, the grand skink *(Leiolopisma grande)* of eastern Otago, the scree skink of inland Marlborough *(Leiolopisma* sp.), and possibly the small-scaled skink *(Leiolopisma* sp.) and Otago skink *(Leiolopisma otagense)* are believed to be vulnerable to predators (Norbury and Murphy 1996).

Summary:

- **Invertebrate fauna on the whole appear to cope well in the presence of rabbits, although there is little direct research to support this observation.**
- **Predators of rabbits have significant impacts on many threatened vertebrate species. The influence of rabbit abundance on these predatory impacts is largely unknown.**

4. Likely effects of reducing rabbit numbers on conservation values

4.1 TALL TUSSOCK GRASSLAND

Rabbits are not a significant conservation pest in the tall tussock grasslands, particularly where a good cover of tussock remains. However, damage to tussock regeneration and grazing of inter-tussock species has been reported in some instances. Any reductions in rabbit numbers will only benefit conservation of these areas.

4.2 SHORT TUSSOCK GRASSLAND

The situation in the short tussock grassland is more complex. Because this community has been highly modified in the past, it is now dominated by exotic grasses and herbs. Rabbit grazing (and stock grazing where applicable) may enhance the survival of some native annual species. It may also maintain a high floristic diversity by suppressing the spread of exotic herbaceous and woody weeds which are aggressive competitors that rapidly colonise bare ground. In these cases, reduction in rabbit numbers may be detrimental to conservation values. A similar sequence of events was witnessed in Britain after rabbit numbers were reduced dramatically by the introduction of myxomatosis (Watt 1971, Sumpton and Flowerdew 1985). In these examples, some small annual plants became locally extinct or rare, and the once floristically rich vegetation became dominated by a few grass and shrub species. If rabbit reductions in New Zealand lead to a dominance of a few introduced plant species, then this may also have a negative impact on the diversity of invertebrate fauna, particularly if host plants are eliminated.

On the other hand, there are some potential benefits for conservation if rabbit numbers are reduced in the short tussock grasslands. Grazing reduces or eliminates palatable native species that have evolved in a mammal-free environment (Meurk *et al.* 1989). Many of these species are limited to sites that are inaccessible to rabbits. Following a reduction in grazing pressure, some palatable natives are likely to increase in number and regain some of their former range, as has occurred in Britain (Sumpton and Flowerdew 1985) and on Round Island, Mauritius (.North *et al.* 1994). The success of this recovery, however, may be weakened by simultaneous growth of exotic weeds. If native vegetation recovers, habitat for some endangered reptiles may improve. For example, reptile populations recovered on Round Island after rabbits were eradicated (North *et al.* 1994).

Grazing compromises natural successional changes in plant communities (Meurk *et al.* 1989). Rabbit reductions in the longer term (provided stock grazing has been removed) will most likely result in a succession towards perennial grasses and shrubland as demonstrated by a number of studies (e.g., Sumpton and Flowerdew 1985; Allen *et al.* 1995b).

4.3 SHRUBLAND

Reductions in rabbit numbers will generally benefit conservation values as indicated by the extensive list of native shrubland species thought to be affected by rabbits (Table 4). However, there will be exceptions. For example, kanuka appears to increase with grazing, and it is likely that woody weeds, particularly thyme, sweet briar, and broom will spread even further under reduced grazing pressure.

4.4 SAND DUNE

Rabbits are particularly destructive in sand dune habitat. Their digging erodes the dunes and modifies the habitat for plant communities. Rabbits also graze a range of nationally important plant species. Clearly, any reductions in rabbit numbers will be a benefit to conservation. However, threatened plant species, and species transplanted in revegetation programmes, will remain at risk even with very low rabbit numbers. In these cases, only eradication will fully alleviate the negative impacts of rabbits. Where rare plants, such as *Sebaea ovata,* co-exist with exotic weeds, reductions in rabbits will be detrimental.

4.5 SALT PAN

Some native plants of salt pan communities may benefit from reduced rabbit numbers because plant deaths have been attributed to rabbits. On the other hand, native plants may suffer from increased competition from exotic weeds.

4.6 WETLAND MARGINS

Plants of the wetland margins, particularly orchids, will most likely benefit from reductions in rabbit numbers. Species that border exotic pastures, however, will be at risk from weed invasion and being shaded out by the weeds' more vigorous growth.

4.7 SUMMARY

In most habitats, conservation is likely to benefit from widespread reductions of rabbit numbers. This may not be the case in areas where threatened plant species co-exist with exotic weeds. Weed growth may be only a temporary phenomenon with native species ultimately dominating. However, it would be unwise to take this for granted. Contingency plans need to be in place prior to any widespread reduction in rabbit numbers to guarantee the conservation of the full range of native biota. Active management will be required to control the spread of weeds, particularly in the short tussock grasslands. Where sites of special interest occur, for example the small area on Flat Top Hill which supports rare ephemerals, and the dune hollows near Wanganui which support the only known population of *Sebaea ovata,* intensive management such as weeding may be necessary.

On a broader scale, it has been suggested by Wardle (1989) that New Zealand's native grassland flora has evolved in the presence of significant grazing pressure from moas, therefore some grazing pressure may be appropriate for conserving native grassland flora. In addition, he argues that grazing is the cheapest tool available to control weed infestation over large areas of short tussock grasslands. This view is particularly relevant now that some areas of this vegetation type are being incorporated into the conservation estate under the pastoral lease tenure review process (R. Wardle, pers. comm.). Meurk *et al.*

(1989) reported that management of pervasive weeds by mowing, cutting, burning and grazing are routine management tools in the Northern Hemisphere. It is apparent that a range of management strategies will be required to preserve the full diversity of the different components of tussock grassland ecosystems. Monitoring of native flora and fauna should be conducted under a range of management strategies to assess their effectiveness in achieving conservation objectives. Adaptive management may then be implemented on the basis of sound data.

5. Information gaps relating to the effects of rabbits on conservation values

This review has revealed a lack of published literature on the effects of rabbits on conservation values. The majority of the information has come from unpublished reports and personal observations of DOC staff, land management agency staff, and other scientists around the country. In some cases, observations are based on unpublished monitoring data, but in the majority of cases, impacts of rabbits are presumed without any supportive data. Information gaps include:

- The role of rabbits in suppressing weeds, and in maintaining native species diversity. Given the possible introduction of Rabbit Calicivirus Disease (RCD) into New Zealand, a variety of alternative management strategies should be trialled in regard to the above.
- Studies of rabbit diet in different vegetation types.
- The role of rabbits in suppressing the regeneration of native shrubs.
- Whether removal of livestock promotes recovery of sufficient vegetation to suppress rabbit abundance.
- The role of rabbits in modifying vegetation and the implications for native fauna.
- How predation pressure on native fauna varies with different rabbit densities.

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