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Impacts of rabbit grazing on pasture in Hawke's Bay, New Zealand

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Running head: Rabbit grazing impacts on pasture

Abstract

Context. Introduced rabbits (*Oryctolagus cuniculus*) compete with livestock for pasture in New Zealand; however, the economic value of the resulting losses is poorly understood.

Aims. We aimed to (1) estimate the impact of rabbit grazing on pasture biomass in Hawke's Bay, North Island, New Zealand, (2) estimate the cost of rabbit grazing in terms of lost livestock production, and; (3) compare this with the cost of rabbit control.

Methods. We used a grazing exclusion experiment to measure pasture growth under three treatments: rabbits and livestock excluded; livestock excluded; no grazers excluded. We then estimated the number of additional sheep that could have been grazed per hectare if rabbit grazing was reduced by lethal control. Finally, we compared the cost of rabbit control with expected increases in stock yield to determine whether rabbit control is economically beneficial.

Key results. Depending on their relative abundance, rabbits consumed enough pasture to support an additional 6.2–17.5 ewes ha^{-1}. For sheep graziers this translates to an annual loss of income of NZ\$620–1750 ha^{-1}. The estimated net annual benefit of controlling rabbits ranged from NZ\$577 ha^{-1} at low rabbit abundance to NZ\$1707 ha^{-1} at high abundance.

***Conclusions*.** Rabbit control is economically justified in Hawke's Bay even when rabbit abundance is relatively low.

Implications. Graziers should not wait until rabbit abundance is high before conducting rabbit control. As well as increasing livestock production, maintaining low rabbit abundance may also prevent invasive predators from reaching high population densities.

Introduction

In New Zealand, introduced European rabbits (*Oryctolagus cuniculus*) damage pasture and native vegetation (Norbury 1996; Scroggie *et al.* 2012), and support inflated numbers of invasive predators (Cruz *et al.* 2013). However, few studies have measured the biological and economic impacts of rabbit grazing in New Zealand (Lough 2009). Domestic sheep (*Ovis aries*) are the main farmed animals, but wild rabbits may reduce the amount of pasture available to them (e.g. Norbury *et al.* 2002; Norbury and Reddiex 2005). Rabbits reportedly impose significant costs on agricultural production, with annual damage estimates ranging from NZ\$10 to 100 million (Norbury and Reddiex 2005). The variability in estimates is due to a lack of experimental data, as well as variation in rabbit abundance.

Assessing the economic viability of rabbit control is currently hindered by a lack of quantitative information on the impacts of rabbits in different parts of New Zealand. There have been few studies on the diet of rabbits in New Zealand (but see Fraser 1985; Reddiex 1998), or on the relationship between rabbit abundance and pasture growth (Norbury and Norbury 1996; Scroggie *et al.* 2012). These studies all took place on the South Island.

We assessed the impact of various rabbit densities on pasture biomass in Hawke's Bay using a grazing exclusion experiment in which we measured biomass consumption by livestock and rabbits. Assuming pasture consumed by rabbits would otherwise have been available to livestock, we then estimated the number of additional sheep that could have been grazed per hectare in the absence of rabbits. Finally, we compared the cost of rabbit control with expected increases in stock yield to determine whether rabbit control is economically beneficial.

Methods

Study site and experimental design

Opouahi Station is a 2000-ha grazing property in Hawke's Bay, North Island, New Zealand (39º 08' 25" S, 176º 48' 02" E). Starting in May 2012, Hawke's Bay Regional Council (HBRC) controlled rabbits across 260 ha of Opouahi Station using a combination of burrow fumigation and shooting. Rabbit numbers were monitored in this area before and after control using spotlight counts conducted along an 18-km route. During the post-control period, spotlight counts were also conducted along a 13-km route in an adjacent area of similar habitat where no rabbit control had taken place. Each spotlight count was repeated a few nights later, and rabbit abundance was estimated for each 1-km section as the mean number of animals seen across both counts.

In October 2012, we established 45 monitoring sites on Opouahi, both within and outside the rabbit control area. Sites were at least 100 m apart, and were assumed to be spatially independent. Based on spotlight counts, each site was designated as having low (<5 km^{-1}), medium (5–15 km^{-1}) or high (>15 km^{-1}) rabbit abundance (n = 15 sites in each category). Each site had four plots measuring 250 × 250 mm. One plot was surrounded by a cage excluding all grazers, and one plot had a cage that excluded livestock but not rabbits. The other two plots were un-caged experimental controls. All plots were clipped to sample the dry weight of pasture. Sampling was repeated four times at monthly intervals (November 2012 –

February 2013) to measure pasture growth. For temporal independence, the locations of the plots were changed each month. Samples were oven-dried for 48 hours at 80º C and then weighed using a digital balance.

Data analysis

Pasture weight data were analysed with mixed effects models using the REML procedure in GenStat (VSN International, 14th edn). Sites were treated as random effects in the modelling process, and month and treatment as fixed effects. The effect of excluding grazers on pasture growth was measured by estimating the interaction between month and treatment. This was estimated separately for areas of high, medium, and low rabbit abundance.

Economic impact

We used published data to estimate the economic impact of grazing by rabbits. Pasture consumption by an average ewe was estimated at 1.6 kg dry matter per day, and we assumed an average stocking rate of 15 ewes ha^{-1} (Beef & Lamb NZ 2012). Average pasture growth was estimated at 48 kg dry matter ha^{-1} day^{-1}. The sale price of an average ewe was assumed to be NZ$100 (Beef & Lamb NZ 2012). The impact of rabbit grazing was estimated in terms of 'ewe equivalents', which is the number of additional ewes that could be grazed per hectare in the absence of rabbits.

The cost of controlling rabbits using 1080 poison (sodium fluoroacetate) was estimated using records of previous control operations by HBRC. These were set at \$150 ha^{-1} for knock-down, and \$30 ha^{-1} for annual maintenance, giving an average cost of \$43 ha^{-1} yr^{-1} over 10 years.

Results

Rabbit abundance

Before rabbit control, spotlight counts in the rabbit-removal area ranged from 1.5–58 rabbits km^{-1} (mean 17.9). Between May and July, 673 rabbits were shot and 747 burrows gassed. Spotlight counts along the same route in August ranged from 0 to 3.5 rabbits km^{-1} (mean 0.6). In the non-treatment area, spotlight counts in August ranged from 0 to 52.5 rabbits km^{-1} (mean 10.3).

Hares (*Lepus europaeus*) were detected in very low numbers (0.08 km^{-1}) before rabbit control, and eight individuals were removed opportunistically during rabbit shooting. No hares were detected after control. Other pests opportunistically removed were 13 cats (*Felis catus*), 10 possums (*Trichosurus vulpecula*), and a ferret (*Mustela furo*) (HBRC, unpublished data).

Pasture growth

Pasture weight was significantly affected by treatment in areas of high ($\chi^2_3 = 365.17$, $P < 0.001$), medium ($\chi^2_3 = 155.16$, $P < 0.001$) and low rabbit abundance ($\chi^2_3 = 69.74$, $P < 0.001$). Dry weight of pasture was highest in the plots where both rabbits and livestock were excluded, lower in plots where only livestock were excluded, and lower still on the control plots where no grazers were excluded. However, the treatment effect diminished with rabbit abundance (Fig. 1).

There was a significant interaction between month and treatment on pasture weight in areas of high ($\chi^2_9 = 41.50$, $P < 0.001$) and medium rabbit abundance ($\chi^2_9 = 20.63$, $P = 0.014$). For areas of low rabbit abundance the interaction was not significant ($\chi^2_9 = 10.38$, $P = 0.32$).

Economic Impact

Pasture consumption by rabbits was greatest in areas of high abundance, but there was little difference between areas of medium and low abundance (Table 1). Rabbits were estimated to consume 10–28 kg dry matter ha^{-1} day^{-1}, equivalent to 6.2–17.5 ewes ha^{-1}. This translates to an estimated loss of income for sheep graziers of \$620–1750 ha^{-1} yr^{-1}. Therefore, the net benefit of controlling rabbits is estimated at \$577–1707 ha^{-1} yr^{-1}.

Discussion

Our results show that rabbit control is likely to be economically beneficial across the range of rabbit densities encountered in this experiment. In areas where rabbits were abundant, their exclusion had a marked effect on pasture biomass. Although the size of this effect decreased with rabbit abundance, even at low abundance the projected benefits of rabbit control outweighed the cost by an order of magnitude.

Our results support the findings of previous studies in New Zealand. For example, Barlow (1987) estimated the loss to sheep grazing systems caused by rabbits in New Zealand at $1.1–$2.1 per rabbit, while Allen *et al.* (1995) estimated that the grazing effect of 8–15 rabbits is equivalent to that of one sheep. Norbury and Norbury (1996) excluded rabbits from experimental plots in Central Otago, then compared pasture composition and biomass with matched plots that were open to rabbits. During spring, when plant growth was most rapid, exclusion of rabbits increased pasture yield six-fold (Norbury and Norbury 1996).

Strong impacts of rabbit grazing have also been documented on Australian pasture. For example, Gooding (1955) estimated that light to moderate densities of rabbits consumed 10–47% of pasture biomass in Western Australia. At very high densities, rabbits ate 86–100% of pasture biomass (Gooding 1955). Similarly, in semi-arid South Australia, Mutze (1991) estimated that rabbits consumed seven times the biomass eaten by sheep at average stocking rates. The economic benefit of rabbit biocontrol in Australia over the 60 years to 2011 has been estimated at AUS$70 billion (Cooke *et al.* 2013).

In central and eastern Otago, Scroggie *et al.* (2012) found that pasture growth was largely unaffected by low rabbit and hare densities. Grazing by rabbits and hares began to have a noticeable effect on pasture growth when spotlight counts reached 5 km^{-1} in the most degraded areas, or 20 km^{-1} in the least degraded areas (Scroggie *et al.* 2012).

Other studies have used spatial and/or temporal variation in rabbit numbers to investigate their impacts on vegetation. For example, after rabbit haemorrhagic disease was illegally introduced in 1997, reduced rabbit abundance in tussock grasslands in Otago caused an increase in vegetation cover. This was mainly due to highly palatable introduced plant species (Norbury *et al.* 2002).

Our experiment could potentially have been influenced by some confounding effects that are difficult to eliminate. The fact that rabbits had access to the caged plots that were designed only to exclude livestock leads to the possibility of a 'pantry effect' (Batzli 1983). Because more pasture was available in these plots, rabbits may have fed preferentially in them. This would exaggerate the difference between these and the plots from which all grazers were excluded, thus under-estimating the impact of livestock and over-estimating the proportion of total grazing pressure that was due to rabbits.

Although our results suggest rabbit control is likely to be economically viable across a wide range of rabbit densities, the magnitude of benefits is likely to vary in space and time. For example, in eastern Australia modelling suggests economic gains from rabbit control are likely to be greatest in dry periods when competition for pasture is most intense (Thompson 2000).

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Table 1. Estimated impact on pasture of European rabbits (*Oryctolagus cuniculus*) at high, medium and low relative abundance in Hawke's Bay, North Island, New Zealand

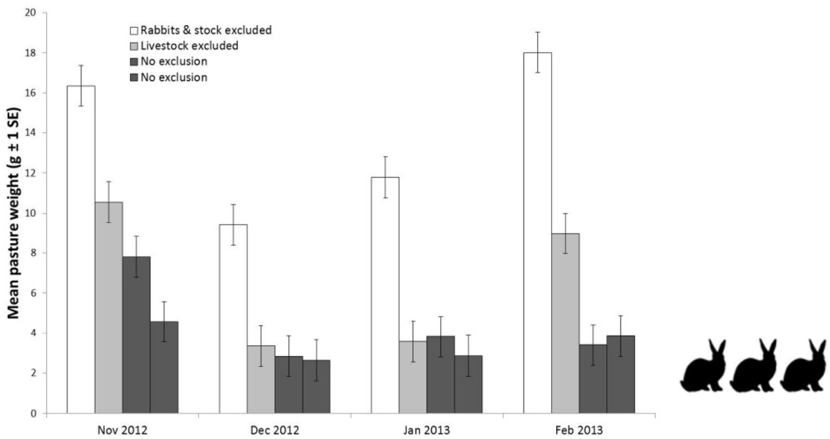
Rabbit abundance	Daily consumption (kg dry matter/ha/day)	Equivalent Ewes
High	28	17.5
Medium	9	5.6
Low	10	6.2

Figure captions

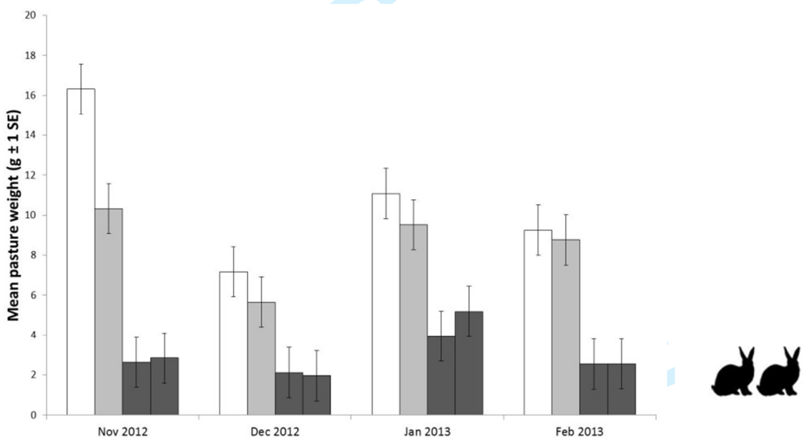
Figure 1. Mean dry weight of pasture samples by month and treatment in areas of (a) high, (b) medium, and (c) low rabbit abundance.

Figure 1

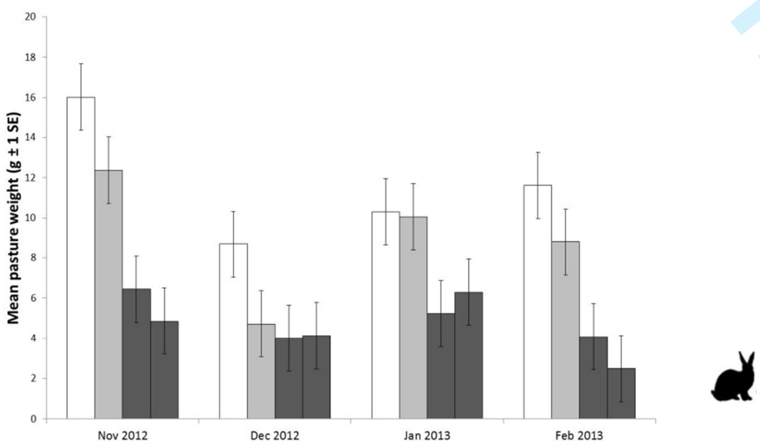
(a)


Rabbits & stock excluded
Livestock excluded
No exclusion
No exclusion
Mean pasture weight (g ± 1 SE)
0
2
4
6
8
10
12
14
16
18
20
Nov 2012
Dec 2012
Jan 2013
Feb 2013

(b)


Mean pasture weight (g ± 1 SE)
0
2
4
6
8
10
12
14
16
18
20
Nov 2012
Dec 2012
Jan 2013
Feb 2013

(c)


Mean pasture weight (g ± 1 SE)
0
2
4
6
8
10
12
14
16
18
20
Nov 2012
Dec 2012
Jan 2013
Feb 2013