

EXCLOSURES MAY OVERESTIMATE THE IMPACT OF RABBITS ON THE VEGETATION OF LUNDY

by

CATHERINE A. SMITH & STEPHEN G. COMPTON

Faculty of Biological Sciences, University of Leeds, Leeds, LS2 9JT

Corresponding author, e-mail: S.G.A.Compton@leeds.ac.uk

ABSTRACT

Rabbits are amongst the most prominent herbivores on Lundy. Here we describe their effects on the island's vegetation, based on measurements from exclosures carried out in 2004, a period when rabbit numbers were very high. Above-ground biomass was compared in five control, large-grazer only, and rabbit-proof plots. Biomass was substantially higher in all the exclosures, with the majority of the losses attributable to rabbits in most plots. Plant functional groups (mosses, herbs, grasses, shrubs) also showed some changes in relative abundance, suggesting that plant community effects are also taking place. The recorded differences in plant biomass were very large, possibly as a result of rabbits being attracted to partial exclosures where stock were absent.

Keywords: *Lundy vegetation, exclosures, plant biomass, rabbits*

INTRODUCTION

Rabbits (*Oryctolagus cuniculus*) are one of the most prominent species on Lundy, and when their numbers are high are likely to have a significant impact on the island's vegetation. This makes them important from the point of view of the management of the island because Lundy's rare plants, its plant communities in general and the rate of vegetation regeneration following rhododendron clearance are all potentially influenced by rabbit grazing. Rabbits are also competitors with other grazers, including domestic sheep, and decisions on the optimum densities of domestic and feral stock on the island, including the extent of any culling needed, must necessarily take account the island's carrying capacity for livestock. Until the recent myxomatosis outbreak in 2006, rabbit numbers had been high for several years. This resulted in extensive areas of bare ground and increased soil erosion, and their burrows have also been damaging the island's architectural heritage. Since the samples described here were taken the numbers of rabbits has fallen considerably, though long term control is notoriously difficult to achieve (Williams *et al.*, 1995).

Here, we assess the impact of rabbits on the vegetation of Lundy in the late winter and summer of 2004, the third year in a row when rabbit numbers were high. The amount of plant material being removed by rabbits and other large grazers was estimated by comparing the quantity of plant biomass in control areas with nearby exclosures that

were either accessible to rabbits, but not stock ('partial enclosures') or inaccessible to both stock and rabbits ('complete enclosures'). An estimate of biomass loss across the island as a whole was then produced based on the relative abundance and distribution of rabbits that year. Biomass was assessed as dry weight and included both fresh and dead/dying plant material.

Rabbits and plants on Lundy

Along with the island's deer, goats and sheep, rabbits were introduced to Lundy by man, and have been present continuously since the thirteenth century (Bullock & Codd, 2003). Today, their warrens are situated mainly around the fringes of the plateau (Linn, 1997), but in years when their numbers are high rabbits can be seen almost anywhere on the island. Rabbits do well on Lundy thanks to a combination of few predators and a mild climate that allows almost all-year reproduction. Based on winter pellet counts, rabbit numbers were estimated to be greater than 15,000 in 1996, a year when rabbit densities were clearly high, after which their numbers dropped to below 2,000 (in 1997) after an outbreak of myxomatosis (Compton *et al.*, 2004; D. Petterson, S.G. Compton and C.A. Smith, unpublished), but they recovered quickly and stayed at high levels until the 2006 myxomatosis outbreak.

Because they often manage to reach very high densities, rabbits can have significant detrimental impacts on islands, in some cases even leading to the extinction of endemic plants and animals (Williams *et al.*, 1995). At high densities, they reduce the quantity of vegetation and change its composition, eliminating palatable plants while favouring less palatable species (Phillips, 1953). *Festuca rubra*, a prominent grass on Lundy, is an example of a plant that is known to decline appreciably in the presence of rabbits (Hambler *et al.*, 1995). The perceived harmful effects of rabbits are reduced or absent when they are at lower densities, and moderate rabbit grazing can even increase biodiversity by favouring less competitive plants.

Lundy is home to several plants of conservation concern. These 'Lundy Specials' include small adder's-tongue fern (*Ophioglossum azoricum*), balm-leafed figwort (*Scrophularia scorodonia*) and Lundy cabbage (*Coincya wrightii*) (Compton & Key, 2000; Compton *et al.*, 2002; Key *et al.*, 2000). Each species has its own habitat requirements and is likely to respond differently to grazing. Balm-leafed figwort appears to be relatively unpalatable to rabbits, while small adder's-tongue fern requires a very short sward and consequently is likely to be dependent on the activities of grazers, possibly including rabbits. Lundy cabbage, in contrast, is highly palatable to rabbits (and other grazing mammals) and grazing enclosures on the eastern Sidelands have demonstrated that grazing can eliminate the plant from certain areas (Compton *et al.*, 2004). These enclosures also showed that the rate of vegetation succession following rhododendron clearance was being inhibited by grazing pressure (Compton *et al.*, 2002). The numbers of Lundy cabbage in flower can change greatly from year to year, and Compton *et al.* (2004) have speculated that these fluctuations may follow trends in the numbers of rabbits present, with reduced numbers in years when rabbits are abundant and peaks in cabbage numbers in the years following myxomatosis outbreaks.

METHODS

Five exclosures were monitored in 2004. Three were situated along the eastern Sidelands (north of St Helena's Combe, at Halfway Wall and above Gull Rock), one on the cliffs below Hammers, and one on the plateau near the Rocket Pole. The latter three exclosures were erected in early 2003, the Halfway Wall exclosure was erected in 1999 (though it was temporarily compromised for a few months due to a rock fall) and the St. Helena's Combe exclosure was erected in 2001. Most of the exclosures are sited in areas with abundant signs of rabbit activity, while both domestic sheep and rabbits graze in the vicinity of the Rocket Pole exclosure. The exclosures are in two parts, each about 4m by 4m. There is also a demarcated control area nearby that is fully accessible to animals. One half of each exclosure has a large wire mesh that allows access by rabbits, but not stock (partial exclosures), while the other half has fine wire netting dug into the soil to prevent rabbit (and stock) entry (complete exclosures).

Above-ground biomass within each section of the exclosures, and the controls, was estimated by taking three randomly-situated 15cm x 15cm vegetation samples in January and again in June 2004. Each sample consisted of all the above ground green vegetation. The plant material was separated from any soil or roots, placed into labelled bags and subsequently dried for 48 hours, to constant weight, in a Gallenkamp Moisture Extraction Oven at a temperature of 60°. Each sample was sorted into its constituent groups (grass, herb, shrub (excluding woody stems and twigs) and moss components), then weighed using Metter PE 360 digital scales.

Estimation of Lundy's rabbit population

During the winter sample the number of wild rabbits on the island was estimated. The method of population estimation was in the form of a standardised pellet census first used by Petterson (1996), to estimate the size of the rabbit population of Lundy Island. Some caution is needed as this technique is considered to be good at monitoring the distribution of rabbits and changes in rabbit populations, but less reliable for obtaining absolute count numbers. The rabbit population density was estimated using the following equation (1):

$$r = mc/g \dots \dots \dots (1)$$

Where:

- r = number of rabbits per hectare
- m = number of pellets per hectare
- g = number of pellets produced by a rabbit in a day
- c = decay rate of a pellet per day.

Estimation of Pellet Densities (m)

A total of 29 transects were produced, at regular intervals around the island, mainly running from the break of the slope to the centre of the plateau. The approximate positions of the transects have been provided to the National Trust. Along each transect a 'mini' belt transect was completed at regular 50m intervals for 200m, and then every 100m onto the plateau. Within each belt transect ten 0.5m x 0.5m quadrats were thrown randomly in a 10m x 1m area perpendicular to the main transect. The number of rabbit

pellets in each of the 0.25m² quadrats was recorded. The mean number of droppings per quadrat was then calculated, with a weighting applied to compensate for the variation in sampling intervals (counts separated by 100m were given twice the weighting of those located only 50m apart). This figure was then multiplied by 40,000 to give an estimate of the number of pellets in a hectare.

Determination of Pellet Production per Day

A constant figure of 360 was used as an estimate of daily pellet production. Lockley (1962) estimated pellet production in Welsh rabbits as 360 pellets per day, a rate used also by Petterson (1996).

Estimation of Decay Rate (c)

Decay and disappearance rate was defined as the proportion of pellets that degrade and disappear each day due to environmental factors such as weathering. A decay rate of 0.028 was used in the calculations, based on values obtained previously on Lundy (Petterson, 1996), though it should be noted that decay rates can vary between years because of differences in temperature and rainfall.

Estimation of Total Numbers of Rabbits on Lundy Island

An estimate of the total population of rabbits was calculated using the following equation (2):

$$n = r h \dots\dots\dots (2)$$

Where:

- n = number of rabbits on Lundy
- r = number of rabbits per hectare
- h = area of Lundy in hectares.

The total area of Lundy was taken as being 430 hectares (Wolton, 1993).

RESULTS

Exclosure biomass

In January, the control areas accessible to both rabbits and larger mammals consistently had the lowest biomass (mean ± SE = 0.92 ± 0.34 g per 0.0225m² sample, (Figures 1 and 2), while the areas with both groups excluded had the largest biomass (7.27 ± 0.67 g). Partial exclosures, where only rabbits had access, were intermediate (2.76 ± 0.74 g). Pair-wise Mann-Whitney U-Tests (all five locations combined) found significant differences between the complete exclosures and the two other types (Complete and Control: U = 3, P < 0.05; Complete and Partial: U = 24, P < 0.05), but no significant differences between controls and exclosures where rabbits alone had access (U = 72.5, P > 0.05). This probably reflects the small sample size and occasionally large variability in biomass within individual exclosures, as the partially-excluded areas nonetheless averaged around three times the biomass of the controls (Table 1). Overall, biomass reduction due to grazers was estimated to be 88%, with 62% attributable to rabbits and 26% to other stock (Table 1). The relative impact of rabbits varied between exclosure locations, being particularly noticeable at Hammers, where the controls were bare of vegetation and the partial exclosures were almost bare (Figure 1).

Table 1: Estimates of relative contributions of rabbits and larger mammals to above ground plant biomass removal in January 2004. Biomass values are means and ranges. 'Partial' exclosures allowed entry by rabbits, but not larger grazers.

Locations	Biomass (mean g/sample)			Contributions to biomass lost (%)		
	Complete exclosures	Partial exclosures	Controls	Total	Due to rabbits	Due to others
Rocket Pole	7.6	6.4	3.3	57	16	41
Hammers	6.2	0.06	0	100	99	1
St Helena's Combe	7.5	5.0	0.7	91	45	46
Halfway Wall	8.8	1.5	0.4	95	83	12
Gull Rock	6.3	0.8	0.7	89	87	2
All	7.3	2.8	0.9	88	62	26

Table 2: Estimated relative contributions of rabbits and larger mammals to biomass removal in June 2004.

Locations	Biomass (mean g/sample)			Contributions to biomass lost (%)		
	Complete exclosures	Partial exclosures	Controls	Total	Due to rabbits	Due to others
Rocket Pole	8.7	3.9	3.3	62	55	7
Hammers	10.5	4.2	0.1	99	60	40
St Helena's Combe	7.9	3.1	2.6	67	61	6
Halfway Wall	6.7	1.3	0.5	93	81	12
Gull Rock	11.6	4.9	2.5	78	58	20
All	9.1	3.5	1.8	80	62	18

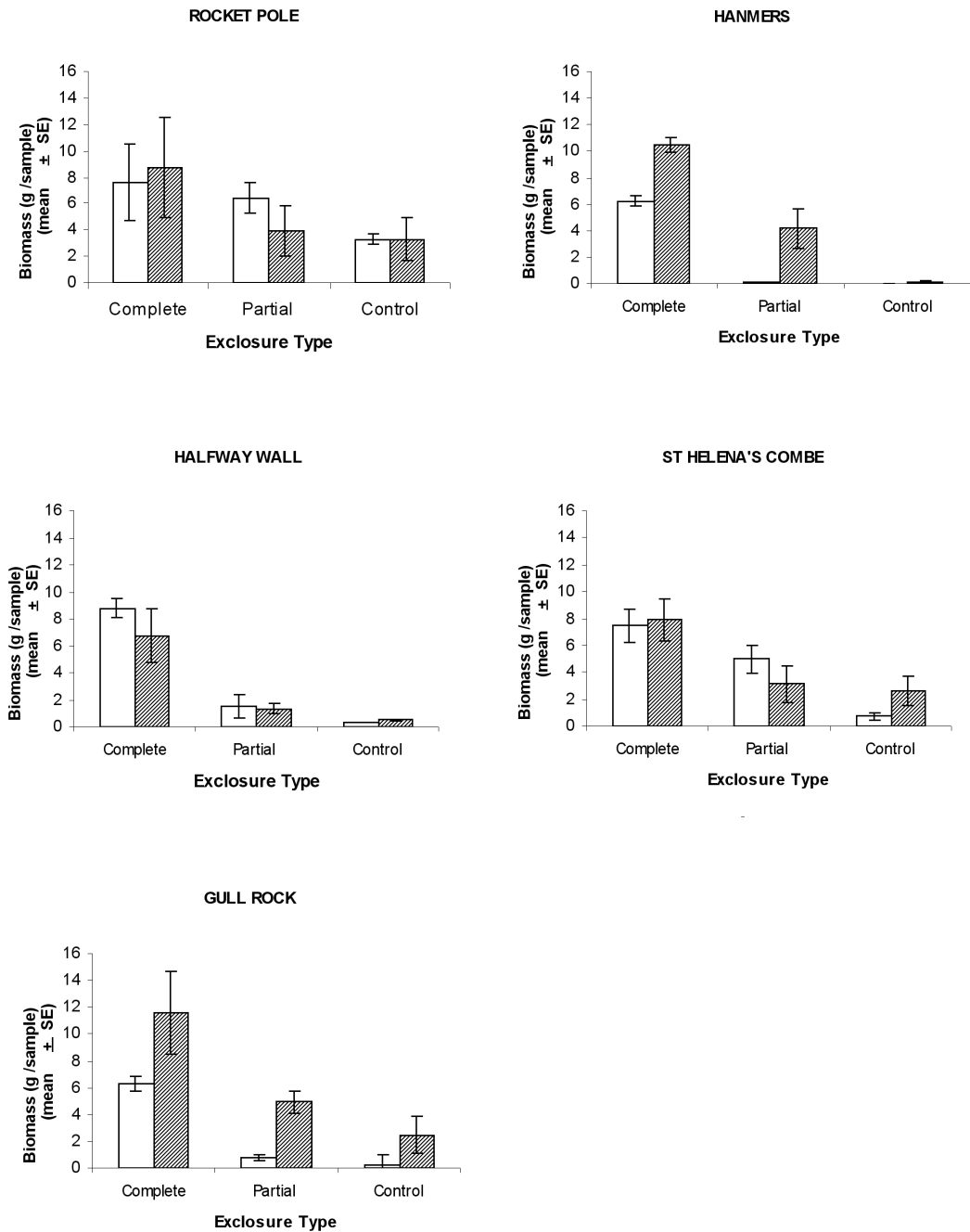


Figure 1: Above-ground biomass in controls and exclosures ('Partial' exclosures allowed rabbit access, 'Complete' exclosures prevented entry by stock and rabbits). Open bars January 2004, hatched bars June 2004.

In June, the general pattern of biomass distribution was similar to that observed in January (Figure 1). The variation in vegetative cover was slightly larger, ranging between $9.09 \pm 1.05\text{g}$ (mean \pm SE) where all grazers were excluded, $3.50 \pm 0.56\text{g}$ where rabbits alone had access and $1.80 \pm 0.53\text{g}$ in control plots. Again there was a significant difference in dry biomass between total exclosures and the areas where rabbits were present (Mann-Whitney U-Test, Complete and Control: $U = 11$, $P < 0.05$; Complete and Partial: $U = 28$, $P < 0.05$), but no significant difference in above-ground biomass between plots only grazed by rabbits and control plots ($U = 65$, $P > 0.05$). As expected, biomass overall was higher in June than January (Figure 2), but this was not the case at all the locations (Figure 1), again probably reflecting the small number of replicate samples that were taken within each exclosure.

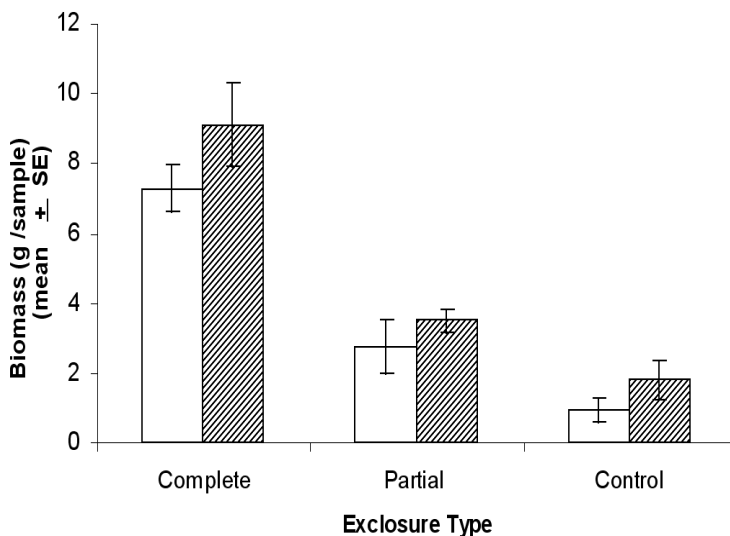


Figure 2: Above-ground plant biomass (all five areas combined). ‘Partial’ exclosures allowed rabbit access, ‘complete’ exclosures prevented entry by stock and rabbits. Open bars January 2004, hatched bars June 2004.

Composition of the vegetation

Grasses were the predominant group throughout (Figure 3). In summer mosses were not detected and the leaves of shrubs were more abundant than in the winter. All five locations were combined and the abundance of different plant groups compared between exclosure types. In winter, grasses averaged 77.7% of the total biomass in exclosures where only rabbits had access, 85.6% in the complete exclosures and 91.5% in control areas. Herbs ranged between 8.0% in complete exclosures, 11.8% in partially excluded plots and 7.7% in control areas. Mosses were never common, and were restricted to some partial exclosures.

The pattern of abundance of grasses in summer was different to that in winter. Grasses averaged 68.5% of the total biomass in exclosures where rabbits only had access, 85.3% in the complete exclosures and 69.1% in control plots. This pattern implies that rabbits were responsible for most of the grazing of grasses in the summer. Reflecting this, there was a noticeable build up of thatch in the complete exclosures, with potential negative consequences for the growth of herbs. Herb percentages ranged between 6.0% in complete exclosures, 12.1% in partial exclosures, and 2.1% in control plots.

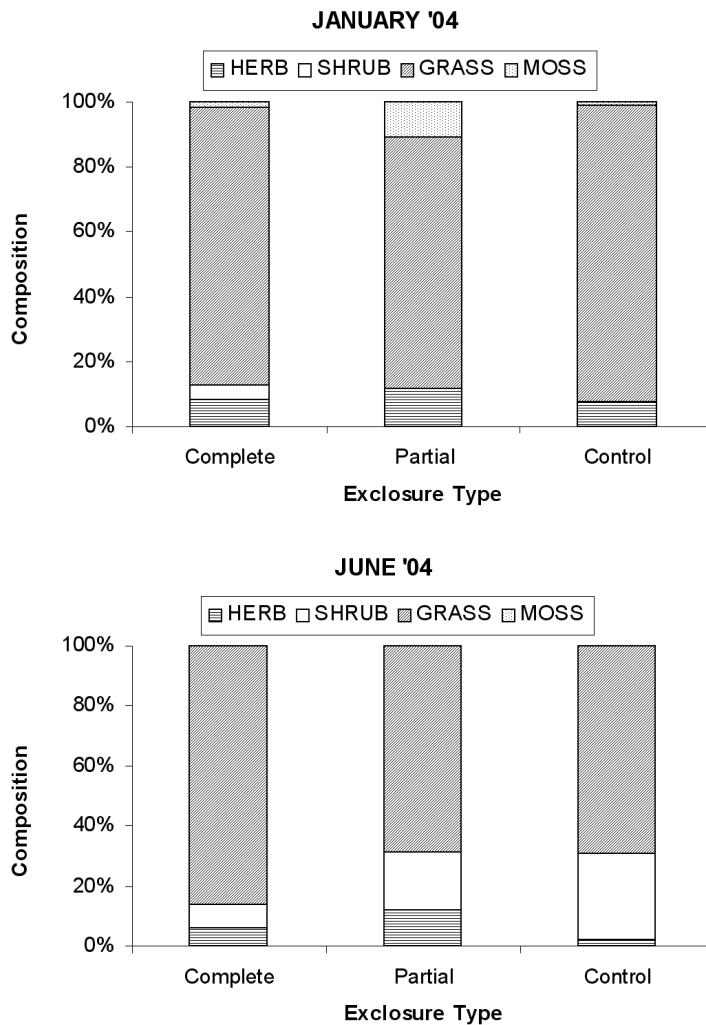


Figure 3: Percentage composition of herbs, shrubs, grasses and mosses in controls and exclosures ('partial' exclosures allowed rabbit access, 'complete' exclosures prevented entry by stock and rabbits).

Whole island extrapolations

In January, on average, the dry biomass of plants in exclosures where rabbits alone had access was 4.5g per sample greater than in controls where the rabbits were excluded. This represents a loss of 4.5g in a 0.0225m² area, equivalent to 200 grams per square metre or 2000kg per hectare. If it was assumed that the excluded areas were typical of the island as a whole, then across the whole of Lundy (with an estimated area of 430 hectares) this would represent a huge loss in standing crop of approximately 860 tonnes of vegetation. However, rabbits are not evenly distributed across the island and most of the exclosures are situated on the sidelands, where rabbits were particularly numerous. This is reflected in pellet count transects taken in January. Those that were nearest to the exclosures had an average density of 75.9 pellets per square metre, compared with an average density for the whole island of 58.8 pellets per square metre. Even when

island-wide vegetation loss is adjusted to take account of this, an estimated average of 1548 kg per hectare of vegetation had been removed, translating into 666 tonnes across the island as a whole. The estimated January 2004 biomass loss was at a time when an estimated 15,184 rabbits were present on the island (based on the pellet count method). This is equivalent to 44kg of plant biomass removed per rabbit.

In June, dry biomass in exclosures where only rabbits had access was 5.6g per sample greater than in the rabbit-proof exclosures (Table 2). This is equivalent to 248 grams per square metre or 2482 kg per hectare. After again taking into account the variation in rabbit densities, based on the January transects, the estimated vegetation loss for the island as a whole was 826 tonnes, rather higher than in winter.

DISCUSSION

Dendy *et al* (2003), concluded that in the United Kingdom grasses cope well with mild grazing pressure and that a reduction in biomass is only clearly evident at high rabbit densities. This is clearly the case on Lundy, where above-ground biomass at the sites we studied was significantly lower in rabbit-grazed areas compared with ungrazed exclosures (Plates 1A, 1B, 1C). The average reduction in biomass in areas exposed to rabbits alone was estimated to be a dramatic 62% in both winter and summer. This is comparable to studies in Australia, where high densities of rabbits can reduce plant biomass by as much as 75% (Cochrane & McDonald, 1966). Rabbit activity was clearly not uniform across the island, being concentrated along the sidelands, where most of the exclosures are situated, and relatively low on the plateau. Impacts on vegetation (and other grazers) will have been correspondingly variable across the island.

Using a standard pellet count technique, we estimated that about 15,000 rabbits were present on Lundy at the time of our winter samples, but the figure must be treated with caution, because of the assumptions implicit in the method. An underestimate of rabbit numbers may explain the high per capita vegetation removal rates, but not the large absolute amounts of vegetation removed from the plots. Our extrapolations to Lundy as a whole suggest that during winter the yield loss was 666 tonnes, or 44kg per rabbit. Assuming rabbit numbers were similar, the summer figures were 826 tonnes and 54kg respectively. The results of exclosure experiments are known to require careful interpretation, as they artificially alter the local microenvironment (Watt, 1962) and the relative growth of different species may differ under grazed and ungrazed conditions (Diaz, 2000). However, potentially the most significant factor in this study was that rabbits appeared to show a preference for the exclosure areas where they alone had access (tunnels and other obvious signs of activity appeared to be more numerous than elsewhere). This will have elevated our estimates of grazing impact as a whole, as well as inflating the relative importance of rabbits.

Notwithstanding the above caveats, rabbits are clearly likely to be having a significant impact on the island's other grazers, both domestic and feral, by removing so much vegetation. Short (1985) estimated that 16 rabbits eat as much as one sheep. Others (Mutze, 1991) put the ratio at 12 to 1. Based on Short's more conservative value, the estimated total of around 15000 rabbits on the island in January 2004 was the equivalent of over 900 sheep - considerably more than the 680 sheep on the island at the time. It has nonetheless been argued that competition between stock and rabbits may not become



Plate 1: Grazing exclosures near the Rocket Pole, May 2005
(Photos: Roger Key)

1A: Control area accessible to all

1B: Area accessible to rabbits but not stock



1C: Area where rabbits and stock are excluded. Note the contrast with the other photographs

important until food is particularly scarce, for example if there is a drought, as each species feeds in different ways and (as on Lundy) different species tend to be concentrated in different areas (Williams *et al.*, 1995).

Generally, there was more above ground biomass in June than January, reflecting faster plant growth in summer. There was a trend for a reduction in grass cover and an increase in shrub content in the exclosures where only rabbits had access in January and where rabbits only and where all grazers had access in June. This supports the theory that when swards are kept low by continual heavy grazing, the reduction in grass canopy stimulates subordinate plant growth and reduces grass yield (Bell *et al.*, 1999).

In years when they are abundant, rabbits maintain a closely cropped turf on Lundy. This may benefit plants such the rare fern *Ophioglossum azoricum* as well as other small plants that do not do well in the face of competition by grasses. One of these is the Lundy cabbage *Coincya wrightii*, which probably also benefits from the open spaces generated by rabbits through tunnelling and other activities (Compton *et al.*, 2004). At higher rabbit densities, these benefits are nonetheless likely to be outweighed by the direct effects of their grazing, particularly on highly palatable species such as Lundy cabbage. It has been noted that the impact of herbivory varies for different plant species and that grazing preferences may result in the local extinction of palatable species, lowering diversity and increasing the abundance of unpalatable species (Gillingham, 1955). Alternatively, grazing preferences for a dominant species can lower its competitive ability, providing a 'window of opportunity' for subordinate species, hence increasing diversity (Crawley, 1990). A study on Scottish grasslands (Diaz, 2000) found a strong correlation between the palatability of a plant species and their comparative abundance in grazed and ungrazed swards. Diaz found that palatability trials, offering wild rabbits plant species to eat, can prove reliable in predicting the effects of their herbivory on individual plant species. It may prove a useful predictive technique on Lundy.

This study confirms that rabbits at the densities currently present on Lundy have a significant impact on the vegetation of the island, both in terms of quantity and composition. The amount of vegetation being removed, even taking into account that the estimates may be inflated by aspects of the rabbit's behaviour and that their activity is greatest on the sidelands, also underlines the significance of rabbit grazing for the economy of the farm. Previous management proposals have stressed the importance of keeping rabbit numbers in the low hundreds (Wolton, 1993), but in practice this has only occurred during myxomatosis outbreaks (Compton *et al.*, 2004). Rabbits are clearly a major management issue on the island.

ACKNOWLEDGEMENTS

Thanks to Markus Eichhorn, Guy Smith and Kerry and Paul Fieldhouse, for their help and their company during field work. Thanks also to the warden and staff on the island for their help and to Roger Key and an anonymous referee for their valuable comments on the manuscript.

REFERENCES

- Bell, A.C., Byrne, P.M. & Watson, S. 1999. The effect of rabbit (*Oryctolagus cuniculus*) grazing damage on the growth, botanical composition and yield of rye grass re-seed. *Annals of Applied Biology* 135, 417-424.

- Bullock, D.J. & Codd, R. 2003. Lundy Island: Standardised Mammal Counts. *Report following a visit 29th April -1st May 2003*. National Trust: Unpublished report.
- Cochrane, G. R. & McDonald, N.H.E. 1966. A regeneration study in the Victorian mallee. *Victorian Naturalist* 83, 220-226.
- Compton, S.G. & Key, R.S. 2000. *Coincya wrightii* (O.E. Schulz) Stace (*Rhynchosinapis wrightii* (O.E. Schulz) Dandy ex A.R. Clapham). *Journal of Ecology* 88, 535-547.
- Compton, S.G., Key, R.S. & Key, R.J.D. 2002. Conserving our little Galapagos - Lundy, Lundy cabbage and its beetles. *British Wildlife* 13, 184-190.
- Compton, S.G., Key, R.S. & Key, R.J.D. 2004. Lundy cabbage population peaks - are they driven by rabbits and myxomatosis? *Annual Report of the Lundy Field Society 2003*, 53, 50-56.
- Crawley, M. J. 1990. Rabbit grazing, plant competition and seedling recruitment in acid grassland. *Journal of Applied Ecology* 27, 803-820.
- Dendy, J., McKillop, G., Fox, S., Western, G., & Langton, S. 2003. The development of a model to assess the effects of rabbit grazing on grass. *Annals of Applied Biology* 142, 317-322.
- Diaz, A. 2000. Can plant palatability trials be used to predict the effect of rabbit grazing on the flora of ex-arable land? *Agriculture, Ecosystems and Environment* 78, 249-259.
- Gillingham, M.E. 1955. Ecology of the Pembrokeshire islands. III. The effect of grazing on the vegetation. *Journal of Ecology* 43, 172-206.
- Hambler, D.J., Dixon, J.M. & Hale, W.H.G. 1995. Ten years in rehabilitation of spoil appearance, plant colonists and the dominant herbivore. *Environment and Conservation* 22, 323- 334.
- Key, R.S., Compton, S.G. & Key, R.J.D. 2000. Conservation Studies of the Lundy Cabbage between 1994 and 2000. *Annual Report of the Lundy Field Society 1999*, 49, 74-81.
- Linn, I. 1997. Wild Mammals of Lundy. In R.A. Irving, A.J. Schofield & C.J. Webster (eds). *Island Studies: Fifty Years of the Lundy Field Society*, 107-117. Bidford: Lundy Field Society.
- Lockley, R. M. 1962. Production of faecal pellets in the wild rabbit. *Nature* 194, 988-989.
- Mutze, G.L. 1991. Long term effects of warren ripping for rabbit control in semi-arid South Australia. *Australian Rangelands Journal* 13: 96-106.
- Petterson, D. 1996. Lundy Island Wild Rabbit (*Oryctolagus cuniculus*) Population Estimation and their Habitat Usage. Unpublished undergraduate dissertation, University of Leeds.
- Phillips, W.M. 1953. The effects of rabbit grazing on a re-seeded pasture. *Journal of the British Grassland Society* 8, 169- 181.
- Short, J. 1985. The functional response of kangaroos, sheep and rabbits in an arid grazing system. *Journal of Applied Ecology* 22: 435-447.
- Watt, A.S. 1962. The effect of excluding rabbits from grassland A (*Xerobromentum*) in Breckland, 1936-60. *Journal of Ecology* 69, 499-508.
- Williams, K. Parer, I., Coman, B., Burley, J. & Braysher, M. 1995. *Managing vertebrate pests: rabbits*. CSIRO, Canberra.
- Wolton, R. 1993. Lundy Island Site of Special Scientific Interest. *Grazing management proposals*. English Nature, Peterborough.