

ASSESSMENT OF THE THREAT OF HERBIVORY BY RABBITS, SIKA DEER, AND FERAL GOATS TO LUNDY CABBAGE (*COINCYA WRIGHTII*) THROUGH FAECAL ANALYSIS

by

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ABSTRACT

Lundy Cabbage is an endemic species which is unique in Britain in that it is the only endemic plant that is host to two endemic species of insects. This makes it an important species in terms of biodiversity and conservation. One of the main threats to Lundy Cabbage is considered to be grazing by mammalian herbivores; however, feeding on the plant by its locally-present herbivores has yet to be confirmed. By conducting analysis of the faeces of rabbits, feral goats and Sika deer we confirmed that Lundy Cabbage is a part of the diet of these herbivores.

Keywords: *Lundy Cabbage*, *endemic*, *over-grazing*, *mammalian herbivores*, *faecal analysis*

INTRODUCTION

Lundy Cabbage (*Coincya wrightii* (O.E. Schulz) Stace (Brassicaceae)) is a short-lived perennial herb endemic to Lundy (Compton & Key, 2000a), and is the only large crucifer continually present on the island. It is unique in Britain in that it is the only endemic plant which supports two endemic species of insects: the Lundy Cabbage Flea Beetle (*Psylliodes luridipennis*) and the Lundy Cabbage Weevil (*Ceutorhynchus contractus* var. *pallipes*). The Lundy Cabbage Weevil has not been formally described, but molecular data collected by Craven (2007) shows that it is a species distinct from *Ceutorhynchus contractus*. Lundy cabbage is protected under Section 8 of the 1981 Wildlife and Countryside Act (Compton & Key, 1998; Compton & Key, 2000a) and together with the Flea Beetle it is listed in the U.K. Biodiversity Action Plan (Anon., 1995), where it has an individual Species Action Plan (S.A.P). A more detailed S.A.P. for the plant was later developed by English Nature's Species Recovery Programme (Compton & Key, 1998).

The distribution of Lundy Cabbage lies on the south and south-eastern coastline of the island, where it has a current altitudinal range of 2-120m above sea level and is capable of extending about 300m inland (Compton & Key, 2000a; Compton *et al.*, 1999). It mainly occurs in areas where disturbance is frequent, be it along the sheltered bays or on the exposed rocky sea cliffs, and can therefore be considered a ruderal coloniser. Although it is mostly associated with these early successional communities, vegetation plots surveyed on the island (Compton & Key, 2000a; Compton *et al.*, 2000b;

Simensen, 2010) revealed that it does occur within a wide variety of vegetation communities within its range on the island, including more densely vegetated areas.

Standardised counts of Lundy Cabbage plants in flower have been conducted for 15 consecutive years, revealing a fluctuating population size with numbers of plants in flower ranging from 1000 to over 10,000 (Compton & Key, pers. comm.). Naturally this is of concern as a small and highly variable population size in addition to the limited geographic distribution of the species makes it more vulnerable to extinction as a result of demographic accidents and habitat modification (Gillespie & Roderick, 2002; Meyer, 2004; Pimm, 1991). Because surveys have varied in intensity, however, it is likely that the population size has been under-estimated as some of the plants grow in quite inaccessible locations (Compton & Key, 2000a). The fluctuations in population size are believed to be partly driven by grazing by rabbits (*Oryctolagus cuniculus*), whose numbers on the island vary widely in response to culling and myxomatosis outbreaks (Compton *et al.*, 2004). The distribution of Lundy Cabbage has remained relatively stable throughout (Compton & Key, 2000a).

Lundy supports several species of mammalian herbivores which may pose a threat to Lundy Cabbage through over-grazing. In addition to the farmed populations of sheep and ponies, sheep (*Ovis aries*), rabbits, feral goats and sika deer (*Cervus nippon*) have all been introduced. The population of Soay sheep is controlled by regular culling and, with the exception of Quarry Bay and the nearby sidelands, keeps mainly to the north of the island, outside the range of Lundy Cabbage. It is therefore not thought to have a major impact on the abundance of the cabbage. Furthermore, the populations of sika deer and feral goats are small and relatively stable due to frequent culling of the populations. The distribution of sika deer overlaps with the distribution of Lundy Cabbage, though it is unclear whether sika deer actually feed on the cabbage. Consequently, the level of threat they pose to the population of Lundy Cabbage is uncertain. The population of feral goats, like Soay sheep, keeps mainly to the north of the island. When goats do venture into the habitat of Lundy Cabbage, however, they can cause a large amount of damage. In 1997 Compton *et al.* (2000b) observed a trio of goats consuming 17 plants within half an hour. Rabbits were introduced to Lundy in the thirteenth century (Linn, 1997) and, due to their capability of reaching very high densities, can have severe negative impacts on the native flora (Williams *et al.*, 1995). Because rabbit numbers are concentrated along the sidelands where Lundy Cabbage occurs they are likely to greatly influence the abundance of Lundy Cabbage when at high densities. Although feeding on Lundy Cabbage by rabbits has not yet been confirmed, the circumstantial evidence is all too obvious when rabbit numbers are high.

Recent enclosure studies on Lundy assessing the effect of grazing on the vegetation and Lundy Cabbage have been performed by Compton *et al.* (2000a; 2004). These experiments suggested that rabbits and goats tend to feed on Lundy Cabbage and concluded that in areas where the level of grazing is high, reproduction of the plant is limited or non-existent. Indeed, such 'sink' populations (Pulliam, 1988) are present on the more accessible areas of the sidelands and surveys of the enclosures have shown that reproduction in these populations is only possible once grazers are excluded (Compton & Key, 2000a). However, the same survey also showed that although

Lundy Cabbage flowered briefly when herbivores were excluded, it quickly died out. This was attributed to the development of a dense sward mainly consisting of Yorkshire fog (*Holcus lanatus* L). Indeed, Lundy Cabbage is considered to perform best in disturbed areas (Compton & Key, 1998; Compton & Key, 2000a; Compton *et al.*, 1999), therefore a low or moderate level of grazing may be of benefit to the plant (Compton *et al.*, 2004).

In this study, we chose to focus on rabbits, feral goats and sika deer as Soay sheep are believed to have a minimal impact on Lundy Cabbage due to their distribution. The aim of this study was to confirm whether or not rabbits, sika deer and feral goats feed on Lundy Cabbage by conducting faecal analysis, and to assess whether there was seasonal variation in their consumption of the species. The results from this study were then tied in with knowledge from previous enclosure studies conducted on the island by Compton *et al.* (2000a; 2004), to assess the threat of herbivory by mammalian herbivores to the population of Lundy Cabbage.

METHODS

A reference collection of epidermal types of the most common plant species within the range of Lundy Cabbage was made from leaves collected in November 2008 and February 2009 on the island. Plants that are known to be unpalatable to mammalian herbivores, e.g. bracken (*Pteridium aquilinum* (L.) Kuhn) and *Rhododendron ponticum* L., were excluded from the reference collection. The leaf cuticle was peeled or scraped off using a scalpel, and the remaining fragment mounted in glycerol gelatine on a microscope slide. Using a microscope, an illustration and a description of the epidermal cells, trichomes, silica bodies, and stomata of each species were constructed. The stomatal patterns were noted, and, where possible, the density of stomata and length to breadth ratios of epidermal cells.

Faeces of rabbits, goats and sika deer were collected along seven transects across the south-eastern part of the island, running from east to west roughly perpendicular to the coast line. The length of transects varied according to the topography of the area and the distance needed for collecting a suitable amount of faeces. The distance between transects was determined by ease of access and suitability, but always between 300 and 500m. No transects were located in *Rhododendron ponticum* thickets. Faeces were collected within 1m on either side of the transect. Only fresh faeces that were not soaked or trampled were collected. Collection of faecal samples was conducted in November 2008, and February and June 2009. Samples within each transect were collected from numerous droppings whenever possible, increasing the likelihood of analysing faeces from multiple individuals. In June 2009, due to a limited availability of fresh material, goat faeces collected in two of the transects were likely to have originated from one of two individual goats, respectively.

The method for the preparation of faeces followed Bhadresa (1986; 1987). This method was described for rabbit faeces, thus, to compensate for the increased size of the faeces of sika deer and goats, the amount of distilled water, nitric acid and potassium hydroxide added for the treatment was increased by 50%. The plant fragments were mounted in glycerol gelatine on a microscope slide. Eight pellets

from rabbits, sika deer or feral goats were analysed from each transect where faeces of these species were found. Analyses were carried out separately for each sampling period.

The identification of fragments was carried out under a microscope with the aid of illustrations from the reference collection. The plant species were noted as either present or absent in each sample and no counts of each plant species within each sample were conducted. Fragments that were digested to the point where they could not be identified as either grass or herb were excluded from the results.

Vascular plant species detected in the faeces of rabbits, deer and goats were split into the following functional groups: graminoids, herbs, and shrubs. The relative proportion of each functional group was calculated for each transect. The proportions were arcsine-square root transformed and a one-way ANOVA was performed on each of the functional groups separately to test whether there were differences in their relative proportion between herbivore species. Pairwise comparisons of the proportion of each functional group consumed between herbivore species were conducted separately for each functional group using Tukey's HSD. For each herbivore, the proportion of faeces that contained Lundy Cabbage was calculated for each transect and a one-way ANOVA was conducted to test whether there were differences between herbivore species in the amount of Lundy Cabbage consumed, as well as between dates of sampling. Significance of model terms was assessed by deviance change on removal from the full model. Analyses were conducted in R 2.10.1 (R Development Core Team, 2009).

RESULTS

A total of 18 vascular plant species were identified in the faeces of the three herbivore species. The frequencies of each plant species in each of the seven transects are presented in Table 1. Lundy Cabbage was present in the faeces of all three species. Furthermore, a large number of unidentified fragments were present in all samples of all faecal types.

There were significant differences in the frequency of all three functional groups between herbivore species (Table 2). In all three herbivore species, graminoids were present in a greater proportion of faeces than were herbs and woody species (Figure 1). The greatest proportion of faeces containing graminoids was found in rabbits, while the lowest proportion was found in deer. Herbs were present in a greater proportion of faeces in deer compared to goats. Furthermore, the proportion of faeces containing woody species was lowest in rabbits. There were no significant differences in the frequency of each of the three functional groups between dates of sampling (Table 2), indicating a consistent diet across surveys.

The proportion of faeces containing Lundy Cabbage was lower throughout the survey in goats than in sika deer and rabbits (Table 1). The ANOVA, however, revealed there to be no significant differences in the proportion of faeces containing Lundy Cabbage between the three herbivore species ($F = 1.696$, $df = 2$, $P = 0.215$) or between dates of sampling ($F = 1.148$, $df = 2$, $P = 0.342$). The interaction between species and dates of sampling was insignificant ($F = 0.292$, $df = 4$, $P = 0.879$).

Table 1: The frequency of each species of vascular plant detected in the faeces of rabbits, sika deer and goats sampled in seven transects, mean \pm SE, n=7. Identification of vascular plant species follows Rose (2006).

PLANT SPECIES	RABBITS	DEER	GOATS
<i>Coincya wrightii</i>	0.17 \pm 0.05	0.21 \pm 0.05	0.11 \pm 0.05
<i>Dactylis glomerata</i>	0.01 \pm 0.01	0.10 \pm 0.06	0.02 \pm 0.02
<i>Digitalis purpurea</i>	0.02 \pm 0.02	absent	absent
<i>Festuca rubra</i>	0.77 \pm 0.04	0.71 \pm 0.05	0.72 \pm 0.04
<i>Holcus lanatus</i>	0.98 \pm 0.01	0.94 \pm 0.03	1.00 \pm 0.00
<i>Hypochaeris radicata</i>	0.17 \pm 0.06	0.08 \pm 0.05	0.06 \pm 0.02
<i>Lonicera periclymenum</i>	0.04 \pm 0.03	0.23 \pm 0.04	0.40 \pm 0.08
<i>Luzula campestris</i>	0.08 \pm 0.04	0.14 \pm 0.05	0.24 \pm 0.05
<i>Poa</i> spp.	0.52 \pm 0.07	0.31 \pm 0.04	0.21 \pm 0.02
<i>Potentilla erecta</i>	0.07 \pm 0.04	0.14 \pm 0.09	0.15 \pm 0.08
<i>Ranunculus ficaria</i>	0.21 \pm 0.06	0.17 \pm 0.05	0.23 \pm 0.07
<i>Rubus fruticosus</i>	0.02 \pm 0.01	0.02 \pm 0.01	absent
<i>Rumex acetosa</i>	0.09 \pm 0.03	0.18 \pm 0.05	0.06 \pm 0.04
<i>Rumex acetosella</i>	0.11 \pm 0.03	0.16 \pm 0.04	0.11 \pm 0.03
<i>Scrophularia scorodonia</i>	0.01 \pm 0.01	absent	absent
<i>Taraxacum</i> agg.	0.09 \pm 0.04	0.09 \pm 0.07	0.02 \pm 0.02
<i>Umbilicus rupestris</i>	0.03 \pm 0.02	0.03 \pm 0.02	0.04 \pm 0.03
<i>Viola riviniana</i>	0.07 \pm 0.02	0.16 \pm 0.04	0.13 \pm 0.05

Table 2: ANOVA testing differences in consumption of different functional groups between herbivore species and time of faeces collection. Δ D is deviance change on removal of each term from the full model. Significant effects ($P < 0.05$) in bold.

FUNCTIONAL GROUP	SPECIES		Date		SPECIES:Date	
	Δ D (df=2)	P	Δ D (df=2)	P	Δ D (df=4)	P
Graminoids	0.027	0.002	0.004	0.399	0.023	0.025
Herbs	0.047	0.003	0.014	0.173	0.032	0.102
Woody species	0.045	<0.001	0.0003	0.881	0.012	0.057

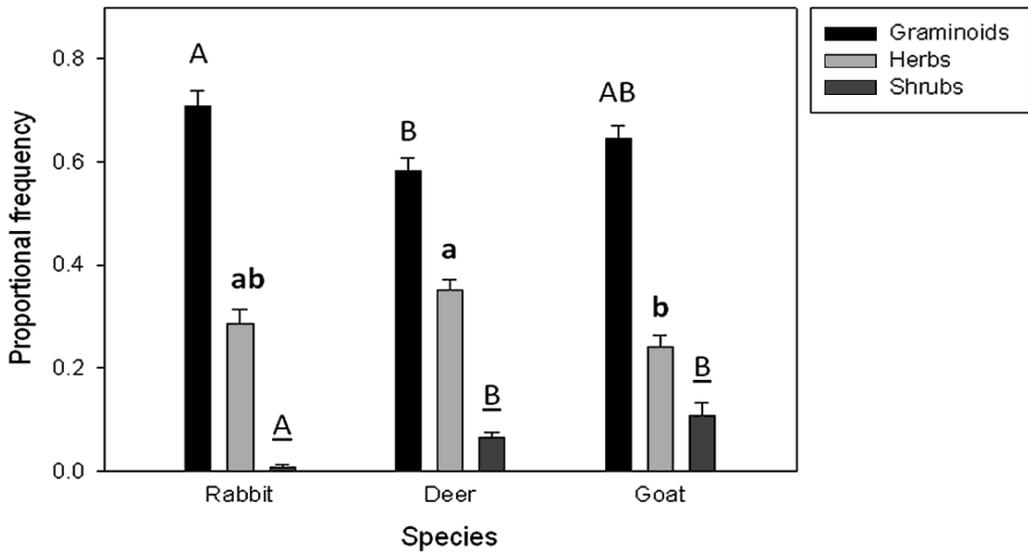


Figure 1: Proportions of functional groups detected in the faeces of rabbits, deer, and goats, mean \pm SE, n=7. Herbivore species that differ significantly in the proportion of each functional group consumed (Tukey HSD, $P < 0.05$) do not share a letter. Capital, lower case, and underlined letters are not comparable with each other.

DISCUSSION

Lundy Cabbage was identified in the faeces of feral goats, rabbits and sika deer, though the frequency was relatively low in all herbivore species. Still, the combined grazing of all mammalian herbivores is likely to have an impact on the abundance of Lundy Cabbage. Even a low density of mammalian herbivores is capable of affecting vegetation. This is particularly true with regard to goats, whose distribution mainly lies further north on the island, but have been observed to consume Lundy Cabbage at a rapid rate when venturing south into the range of the cabbage (Compton *et al.*, 2000b). Still, rabbits are likely to pose a more serious threat to Lundy Cabbage than both deer and goats, due to their capability of reaching very high densities, as well as their overlap in distribution with the cabbage. Indeed, at high densities, rabbits are capable of eliminating Lundy Cabbage locally (Compton pers. comm.). Nevertheless, Lundy Cabbage has coexisted with rabbits for centuries, and although rabbits are capable of greatly reducing the abundance of the plant at high densities, refuge is afforded by the rocky outcrops and steep cliffs that are inaccessible to most mammalian herbivores. Over-grazing by rabbits is therefore unlikely to be the sole threat to the persistence of Lundy Cabbage. Few areas are inaccessible to goats, however, and combined with the damage caused by rabbits and deer, their impact on the abundance of Lundy Cabbage could be devastating. Although it does not seem likely that mammalian herbivores are likely to graze the plant to extinction, a high level of grazing will increase the vulnerability of Lundy Cabbage to demographic

stochasticity by reducing population size. Herbivory might therefore increase the risk of extinction. Furthermore, the results of this study suggest that seasonal variation in frequency of consumption is not an important consideration for the conservation of Lundy Cabbage. However the lack of possible seasonal patterns could be due to the low frequency of Lundy Cabbage detected throughout the survey and further investigations are needed.

Graminoids were present in the majority of faeces collected from feral goats, rabbits and sika deer (Figure 1). This supports the finding by Bhadresa (1987) using faecal analysis that rabbits prefer to feed on graminoids. Deer faeces contained herbs more frequently than goats. Furthermore, goat faeces contained woody species more frequently than rabbits. Although this study provides some insights into the diet of rabbits, feral goats, and sika deer, the technique for analysis used in this study is unsatisfactory for fully determining the dietary composition of the three herbivores. One major concern is the differential digestion of species (Stewart, 1967; Strevens & Rochford, 2004). No experiment to control for these differences was carried out in this study. This was due to the following reasons: (1) the herbivores are from wild populations, (2) Lundy Cabbage is a protected species and collecting a large enough biomass to carry out a control experiment was impossible, and (3) a limited amount of time was available for the study. Moreover, the faeces of goats, rabbits and sika deer are different sizes which confound comparisons as the likelihood of finding any given species if present will differ. Another factor that might have influenced the results is the large number of fragments in the samples that were too deteriorated for positive identification, and consequently were excluded from the analysis. It is therefore likely that the relative proportions of both plant species and functional groups determined by this study are not fully representative of the actual dietary composition of the herbivores, though they are indicative of overall patterns.

CONCLUSIONS

By conducting faecal analysis, grazing on Lundy Cabbage was confirmed for rabbits, sika deer and feral goats. Even though the frequency of occurrence of Lundy Cabbage was relatively low in all three herbivore species, this result is important in identifying the major threats to Lundy Cabbage. Although it does not seem likely that mammalian herbivores are likely to graze the plant to extinction, a high level of grazing will increase the vulnerability of Lundy Cabbage to demographic stochasticity by reducing population size. Herbivory might therefore increase the risk of extinction, and in order to secure the long-term existence of Lundy Cabbage, herbivore populations should be controlled. Continued counts of Lundy Cabbage in flower will be important for early detection of a decline in population size.

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