PLANT DIVERSITY OF A LOWLAND HEATHLAND SITE ON LUNDY

by

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ABSTRACT
The total area of heathlands in the British Isles is now much reduced and fragmented due to afforestation, land-use change and atmospheric N pollution. Using field and laboratory experiments, this study aimed to describe the soil fertility and vegetation composition of a heathland site on Lundy in relation to atmospheric N pollution and management strategy. Soil fertility was higher than expected when compared with 25 heathlands on the British mainland. Species diversity was low compared with *Calluna*-dominated sites elsewhere on the British mainland. Lundy was considered a healthy heathland under the current management regime.

Keywords: *Heathland vegetation, soil fertility, atmospheric pollution, nitrogen, management*

INTRODUCTION

Heathland habitats once extended to some several million hectares in Western Europe, but now their extent has become limited over the last 20-50 years, despite conservation efforts (Bobbink *et al*., 2010). Not only has the total area of heathland been reduced, but the remaining heathland has become increasingly fragmented due to afforestation, conversion to agriculture, and urban development (Rose *et al*., 2000). Heathland communities are also subject to perturbation due to atmospheric pollution, leading to a reduced competitive ability of ericoids, or an increased sensitivity to frost or drought (Alonso & Hartley, 1998; Power *et al*., 1998). Sulphur pollution is of declining importance as atmospheric concentrations have fallen dramatically since 1990 (Matejko *et al*., 2009; NEGTAP, 2001). Atmospheric nitrogen supply, on the other hand, has declined to a much lesser extent and may have led to reduced species richness in heathland communities (Fowler *et al*., 2004; Maskell *et al*., 2010).

In order for heathland to persist it usually requires some form of management, particularly if atmospheric N deposition levels are high. This can consist of grazing, mowing, burning or sod-cutting (Heil & Aerts, 1993). Effective management will result in reduced soil nutrient concentration, an enhanced establishment or retention of desired species, such as heather (*Calluna vulgaris* (L.) Hull), and a reduction in grasses and trees, thereby halting succession to grassland or woodland. Nitrogen pollution can also increase soil fertility and promote succession, resulting in a change in competitive relationships between species (Berdense, 1985). Ineffective heathland management, on the other hand, will lead to heathland fragmentation and species loss. Species respond differently to fragmentation due to differences in dispersal capacity and persistence ability, potentially leading to a change in vegetation composition upon fragmentation (Maurer *et al.*, 2003; Quintana-Ascencio & Menges, 1996).

The flora of the island has been well documented by Hubbard and Elliston-Wright (Hubbard, 1972; 1980). Using a combination of field and laboratory studies, this research aimed to describe the soil fertility and vegetation composition of a heathland site on Lundy in relation to atmospheric nitrogen pollution and management strategy. The Lundy heathland site was compared with a range of heathlands on the British mainland to provide a national perspective.

METHODS

The lowland heathland sites were defined as areas below 300m elevation in which ground coverage of *Calluna vulgaris* was ≥ 25%. An example of the heathland on Lundy is given in Plate 1. To place the heathland on Lundy in a national perspective, data were compared with 25 other sites on the British mainland, with nitrogen deposition levels above and below that on Lundy. All 25 sites had an annual rainfall in the range 549-836mm per annum, with Lundy falling within that range (774mm). Modelled values of current N deposition at the heathland sites were obtained from 5x5km gridded data sets provided by R.I. Smith (pers. comm., CEH, Edinburgh). The data were derived using an atmospheric deposition model parameterised for moorland terrain (Smith & Fowler, 2001). The model uses a simulated rainfall field for the UK generated by the UK Meteorological Office (data from which was also available for this study), and interpolated N deposition maps derived using measurements from the UK Acid Deposition Monitoring Network (AEA Technology plc., Didcot, UK).

Plate 1: *Calluna vulgaris*-dominated lowland heathland at the north end of Lundy.
(Photo: © Stine Marie Simensen)

Soil fertility

Ten replicate soil samples were collected from a single heathland patch at the northern end of Lundy during April 2009 (SS133471). Samples were taken at random locations ≥ 10m apart. At each location a 10x10cm block of organic top soil was removed from amongst *Calluna vulgaris* bushes. The top 5cm of soil was sieved to pass 6mm and the residual debris were replaced into the ground. The soil samples, each approx. 100-200ml, were stored at *c*. 5°C. Comparable methods were used to collect soil from 25 other heathlands on the British mainland (unpublished data).

Calluna vulgaris seeds collected from Beacon Hill, Leicestershire (SK509148) during autumn 2007 were stored at *c*. 5°C. In April 2009 seeds were germinated on tap-water agar and two seedlings were placed in each soil sample and grown in individual 160ml pots in a growth room on a 14hr light (18°C)/10hr dark (12°C) programme. Opaque black beads were placed on top of the soil to prevent algal growth once the seedlings were sufficiently large. The seedlings were watered with deionised water every two days.

The *C. vulgaris* shoots were harvested after 18 weeks growth by cutting at the base. Seedlings were dried at *c.* 80°C for 24hrs and dry-mass was determined and used as an indicator of soil fertility.

Vegetation top-cover and site area

A 50x50m plot was defined in an area of heathland representative of the general vegetation composition of the heathland patch at the northern end of Lundy. Within the quadrat twenty 50x50cm quadrats were placed in a grid formation. A ten-point 50cm long pin-frame was deployed five times within each small quadrat to obtain 50 data points per sample. Top-cover was determined by lowering each pin in turn and recording the first individual that was touched by the point (Causton, 1988; Greig-Smith, 1983). A presence-absence record of all species within the larger quadrat was also collected. In all cases vascular plant, bryophyte and lichen species were recorded.

Statistical methods

SigmaPlot 11 (Systat Software Inc, California, USA) was used to perform standard statistical analyses. The relationship between nitrogen deposition and *C. vulgaris* dry-mass for all 26 sites was investigated using linear regression. Where test assumptions were not met, data were $\log_{10}$ transformed.

Simpson’s species diversity (1/D) and Simpson's diversity (1/D) index was calculated using the Species Diversity and Richness v.4.1.2 package.

RESULTS

Soil fertility

Modelled wet deposited inorganic nitrogen deposition ($NH_4^+ + NO_3^-$) for Lundy is 4.4kg ha^{-1} yr^{-1}, which when compared with 25 other heathlands on the British mainland, suggests that the Lundy heath is the third least N enriched (R.I. Smith, CEH, Edinburgh, pers. comm.). On the other hand, mean dry-mass yield of *C. vulgaris* in the bioassay was 12.8mg, which places Lundy 14th in a national perspective (Figure 1). This value is similar to heathlands on the British mainland with twice the modelled nitrogen deposition of Lundy. If these data are used as a proxy for soil fertility, then Lundy has higher soil fertility than expected when compared with 25 other heathland sites.

Vegetation composition

Six higher plant, three bryophyte and two lichen species were found in the study (Table 1). *Calluna vulgaris* exhibited 80% cover. Bare ground constituted 7% of the sample area. An example of the vegetation composition is given in Plate 2. The Simpson's diversity index value (1/D) was 1.5, placing Lundy 4th lowest in a national perspective.

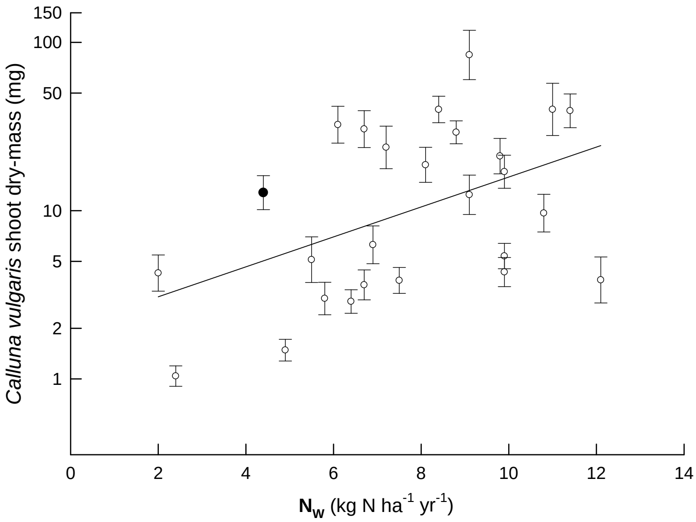

Figure 1. Relationship between shoot dry-mass for *Calluna vulgaris* and modelled wet deposited inorganic N (**N_W**) for 26 heathland sites on the British mainland. Data for Lundy are identified with a solid symbol. Plotted values are means (*n*=10) ±1 SEM.

Plate 2. An example of the *Calluna vulgaris* dominated lowland heathland at the north end of Lundy. (*Photo: © Andrew Cleave)*

Table 1: Percentage top-cover of higher plant, bryophyte and lichen species within twenty 50x50cm quadrats deployed in a $2500m^2$ area of heathland at the northern end of Lundy

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Calluna vulgaris	98	90	96	100	100	86	92	90	96	98	56	74	86	92	100	24		76	66	98
Erica tetralix							8	2												
Erica cinerea								2				6	2			8	2			
Holcus lanatus	2																			2
Blysmus compressus			4																	
Hypnum cupressiforme variant									4				4						2	
Cladonia portentosa		8									14	14	6			50	8	24	24	
Cladonia floerkeana												4					20		2	
Bare Ground		2				14		6			30	2	2	8		18	70		6	
Escaped from Animal Feed										2										

Campylopus introflexus was also found within the $2500m^2$ area but was not located within a quadrat.

DISCUSSION

Soil Fertility

Amongst the 26 heathland sites included in the study there was a positive relationship between the dry-mass of *C. vulgaris* when compared with modelled annual mean wet N deposition (Figure 1). The modelled N deposition on Lundy is 3rd lowest when compared to 25 other heathlands on the British mainland. However, Lundy scores higher than expected for the variable used as a proxy for soil fertility (Figure 1). After the 18 week bioassay period, the *C. vulgaris* mean dry-mass was 12.8 mg, which was 14th highest nationally.

Lee *et al.* (1992) found no relationship between the addition of nitrogen alone and heathland perturbation, mainly due to the ability of *C. vulgaris* to effectively outcompete other species once it is established. On the other hand, if ericoids are exposed to disturbance by trampling, overgrazing, drought, frost or heather beetle (*Lochmaea sutralis* (L.) Thompson) attack, then catastrophic death of *C. vulgaris* can occur (Morecroft *et al.*, 1994; Pitcairn *et al.*, 1995). This leads to the formation of gaps in the *C. vulgaris* canopy, allowing graminoids access to more light, and when coupled with high soil fertility, permits grasses to become dominant and prevents the regeneration of ericoids (Bobbink and Heil, 1993; Uren *et al.*, 1997; Van der Eerden *et al.*, 1991). With an increase in soil fertility, grasses such as *Molinia caerulea* (L.) Moench are able to outcompete ericoids because the former invests more biomass in leaves, resulting in greater shading of ericoids (Aerts and Berendse, 1988). This results in lower *C. vulgaris* shoot densities, and virtually complete cessation of flowering (Iason and Hester, 1993). In short, grasses respond more readily to increased nutrient availability, which will eventually lead to a replacement of ericoids with graminoids.

The management of the heathland on Lundy is limited to low-density grazing by sheep, goats and deer. However rabbit populations, when large, may have a significant effect on vegetation composition (Smith and Compton, 2008). The dominance of *Calluna vulgaris* under such a limited management regime, and despite large rabbit populations, indicates that the heathland could potentially persist without the need for any particular intervention. The low human population, low grazing densities, absence of *L. sutralis* and a relatively mild climate mean that heathland perturbation is unlikely, and offers an explanation as to why *C. vulgaris* dominated habitats persist on Lundy with the absence of any significant management despite the apparent high soil fertility relative to heathlands on the British mainland.

Vegetation composition

A Simpson's diversity index value of 1.5, places the Lundy heathland 4th in relation to the other heathlands studied. The 80% cover of *C. vulgaris*, and absence of species within the heathland patch which could potentially outcompete *C. vulgaris*, such as *Pteridium aquilinum* (L.) Kuhn or *Rhododendron ponticum* L., indicate that the habitat is currently healthy and unlikely to decline on Lundy in the near future.

The vascular plant, bryophyte and lichen diversity index value should be interpreted carefully as heathland is an inherently low diversity habitat (Usher, 1992). A *C. vulgaris* dominated heathland with low plant diversity is considered healthy and likely to persist. However, that is not the case with other groups, such as insects and spiders, where high diversity is advantageous (Usher, 1992). Three species of lichen were found in this survey. It should be noted that this did not include epiphytic or saxicolous species, and therefore actual lichen species diversity may have been higher than recorded here. The three species of bryophyte found were recorded in low abundances and had not formed extensive mats, which can hinder *C. vulgaris* regeneration (Equihua and Usher, 1993).

CONCLUSIONS

The soil fertility of the heathland habitat on Lundy is higher than expected according to the modelled annual mean N deposition of the island. However, the effect of relatively high soil fertility may be mitigated by low human population and grazing animal density, and a mild climate. These factors lead to a low potential for heathland perturbation, meaning that the *C. vulgaris* dominated heathland may be able to persist with limited management intervention.

Vascular plant, lichen and bryophyte diversity is low when compared to 25 other heathlands on the British mainland. This is primarily due to the dominance of *C. vulgaris*, and the absence of invasive plant species on the island. Providing that the heathland is not damaged, or any invasive species introduced, then the habitat should remain healthy under the current management regime.

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