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Habitat use by grass snakes and three sympatric lizard species on lowland heath managed using 'conservation grazing'.

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Running title: Heathland habitat use by reptiles

ABSTRACT

Cattle grazing is being used increasingly by landowners and statutory conservation bodies to manage heathlands in parts of mainland Europe and in the UK, where it is called 'conservation grazing'. Between 2010 and 2013, cattle were excluded from six hectares of lowland heath, in southern England, that had been subject to annual summer cattle grazing between May 1997 and autumn 2009. Changes in grass snake *Natrix natrix*, common lizard *Zootoca vivipara*, slow worm *Anguis fragilis* and sand lizard *Lacerta agilis* numbers were recorded annually in the ungrazed area and in a four hectare area of heathland adjacent to it that continued to be grazed. The number of grass snake, common lizard and slow worm sightings were significantly higher in the ungrazed heath than the grazed heath and were associated with increased habitat structure, resulting principally from increased height and cover of grasses, particularly *Molinia caerulea*. Conversely, there was no significant difference in the number of adult sand lizard sightings between the grazed and ungrazed heath though sighting frequency was inversely correlated with both grass and grass litter cover. Our results suggest that the use of cattle grazing as a management tool on lowland heath is detrimental to grass snake, slow worm and common lizard populations but may be less so to adult sand lizards. Although new born slow worms and common lizards were observed throughout the study area, significantly fewer were found in the grazed areas than the ungrazed areas. The absence of new born grass snakes and sand lizards in the grazed areas suggests that successful breeding had not occurred in these areas.

Key words: *Anguis fragilis*, *Calluna vulgaris*, cattle grazing, habitat structure, *Lacerta agilis*, *Molinia caerulea*, *Natrix natrix*, *Zootoca vivipara*.

INTRODUCTION

Following its introduction as a habitat management tool during the 1990's, in the United Kingdom (UK), the use of livestock grazing is now increasingly widespread and is the 'preferred' habitat management protocol for heathlands, where the UK's statutory body responsible for protecting England's fauna and flora (Natural England: NE) states that it is used to 'conserve wildlife and maintain biodiversity (see NE[a]). The use of 'conservation grazing', as this form of habitat management has been called is, however, controversial as its impacts on wildlife were not investigated prior to its introduction. Newton et al. (2009) concluded that more monitoring and experimental research was required to establish its effectiveness as a management technique on heathlands in north-west Europe. Indeed, there is growing evidence that it may be one of a number of factors, including forestry and agriculture, contributing to habitat change (Lindenmayer & Fischer, 2006; Böhm et al., 2013), which is recognised as a primary cause of observed declines in biodiversity generally and potentially the biggest threat to the conservation status of many taxa worldwide and to herpetofauna in particular (Sala et al., 2000; Gardner et al., 2007). This view is supported by evidence from The Netherlands and the UK where reptile populations, for which heathlands are particularly important, either disappeared or declined significantly (Strijbosch, 2002; Stumpel & van der Werf, 2012; Reading & Jofré, 2015) in areas grazed by cattle.

Livestock grazing has a direct impact on plant biomass, plant species composition and habitat structure (plant height and ground cover) that can affect the ability of a grazed habitat to support the animal communities that depend on it for food and shelter (Kie et al., 1996; Hay & Kicklighter, 2001; Reading & Jofré, 2015). This is particularly relevant to the heathlands of southern England, which have declined in area over the last 250 years due mainly to habitat fragmentation and the loss of many resultant small areas to development (Rose et al., 2000) and for which damage to their structure may reduce the ability of the remaining heathland to support wildlife. The lowland heaths of southern England are inhabited by all six native British reptile species (adder *Vipera berus*, grass snake *Natrix natrix*, smooth snake *Coronella austriaca*, common lizard *Zootoca vivipara*, sand lizard *Lacerta agilis*, slow worm *Anguis fragilis*), two of which, the sand lizard and smooth snake, are European protected species at the north-western edge of their geographical range and where the smooth snake is restricted to them (Frazer, 1983).

In 2010, cattle were excluded from part of an area of heathland where the reptiles had been studied intensively since 1997, enabling the potentially changing relationship between habitat structure and the occurrence of all six native species of British reptile to be investigated. Here we report on habitat use by grass snakes *N. natrix* and three sympatric lizard species (common lizard *Z. vivipara*, slow worm *A. fragilis* and sand lizard *L. agilis*), and how the number of sightings of each in grazed and ungrazed heathland has changed since 2010.

MATERIALS AND METHODS

The study site was a 10 ha area of lowland dry and wet heath situated within Wareham Forest, a coniferous forest in the south of England, managed by the Forestry Commission (50^{o}44′N, 2^{o}08′W). In February 2009 a small part of the study area (≈0.2 ha) was subject to a controlled burn by the Forestry Commission. In February 2010 a fence was erected that excluded cattle from approximately six hectares of the study area (hereafter referred to as the 'ungrazed' area), with the remaining four adjacent hectares, including the partially burnt area, continuing to be grazed (hereafter referred to as the 'grazed' area). A comprehensive description of the study site and its grazing regime can be found in a report of a study of smooth snakes (*C. austriaca*) that was completed at the same time and under the same conditions as this study (Reading & Jofré, 2015).

A total of 21 reptile surveys were completed annually (2010-2013), using eleven randomly placed arrays of 37 artificial refuges (407 refuges in total), between late April and late October with an inter-survey period of 7-10 days. This allowed sufficient time for reptiles observed in one survey to move within the study area thereby avoiding auto-correlation of data between successive surveys (Swihart & Slade, 1985). Within the study site there were seven refuge arrays in the six hectare ungrazed area and four in the four hectare grazed area. See Reading & Jofré (2015) for a full description of the survey methodology. The differences in body size and colouration of the two lacertid lizard species (Arnold & Burton, 1978) enabled visual identification of species, sex and differentiation between juveniles and adults, without recourse to the capture of animals. The total number of sightings of each reptile species was recorded for each array during each survey.

Vegetation surveys were completed annually in late summer between 2010 and 2013 using a 2m x 2m quadrat at each of 10 fixed locations within each of the 11 reptile refuge arrays. A detailed description of methodology is provided in Reading & Jofré (2015).

All statistical analyses were completed using Minitab v.16 (Minitab 2010). Mean values were compared using Student's t-test and linear regression analysis was used to describe the relationships between the occurrence of each reptile species and the main habitat variables. All statistical tests were considered significant at $P<0.05$.

RESULTS

Dead grasses

There were significant positive relationships between the mean depth and percent ground cover of dead *M. caerulea* (Mc), the main grass species found within the study area, and the mean height and percent cover of live Mc (DGrass depth=7.33+0.186 Mc height; r^2=25.6%; P=0.019; df=20; DGrass %cover=-4.66+0.835 Mc % cover; r^2=74.9%; P<0.001; df=47).

Grass snake and lizard associations with heathland plant species

A selection of six plant species/assemblages (see Reading & Jofré, 2015) were used to investigate grass snake and lizard occurrence within the study area and was based on their perceived ability to contribute to both cover and habitat structure (a combination of plant height and ground cover). The six species/assemblages were heather (live *C. vulgaris*, *E. cinerea*, *E. tetralix*); *U. minor*; *A. curtisii*; *M. caerulea*, dead grass (litter) and moss.

The numbers of grass snake and lizard species occurring within any array was defined as the total number of sightings of each species recorded during each year and is not equivalent to the number of individuals present. The total numbers of grass snake (Fig 1) and lizard (Figs 2-4) captures recorded in each array during each of the four years (2010-2013) were plotted against the mean height and percent cover of the six selected plant species within each array. The relationships between each reptile species and each plant species/assemblage are shown in Table 1. Overall, fewer grass snake, slow worm and common lizard sightings were recorded from the grazed arrays than the ungrazed arrays whilst the reverse was true for sand lizards (Figs 1-4).

The highest number of grass snake sightings occurred in arrays where mean heather (Cv/Ec/Et) height was approximately 30-40cm, mean dwarf gorse (Um) height exceeded approximately 17cm, mean purple moor grass (Mc) and bristle bent (Ac) heights were greater than 40cm and 20cm respectively, and grass litter depth exceeded 15cm (Fig. 1). Similarly, more grass snake sightings were recorded in arrays where heather ground cover was between 15% and 35%, Mc cover greater than approximately 60% and grass litter cover exceeded 25%. Where each vegetation category occurred at similar heights and ground covers in both grazed and ungrazed arrays fewer snakes were recorded in the grazed arrays than the ungrazed arrays. They were also more frequently observed on the wet heath than the dry heath. No grass snakes

Table 1. Regression analysis relationships between each reptile species and the six selected habitat species/assemblages. Significant *P*-values (<0.05) are shown in bold. Cv-*Calluna vulgaris*, Ec-*Erica cinerea*, Et-*Erica tetralix*, Um-*Ulex minor*, Mc-*Molinia caerulea*, Ac-*Agrostis curtisii*, DGrass-dead grass litter.

Habitat variable	Grass snake (Nn)			Slow worm (Af)			Common lizard (Zv)			Sand lizard (La)		
	P	r^2(%)	*df*	*P*	r^2(%)	*df*	*P*	r^2(%)	*df*	*P*	r^2(%)	*df*
Height												
Cv/Ec/Et	0.144	4.6	47	0.253	2.8	47	0.270	2.6	47	0.657	0.4	47
Um	**0.008**	14.5	47	**0.001**	22.3	47	**0.002**	18.2	47	0.985	0.0	47
Mc	**<0.001**	29.1	47	**<0.001**	30.0	47	**<0.001**	27.4	47	0.069	7.0	47
Ac	**0.017**	11.8	47	**<0.001**	30.5	47	**0.001**	20.4	47	**0.032**	9.6	47
DGrass	**0.006**	33.8	20	**0.020**	25.4	20	0.122	12.1	20	0.725	0.7	20
Moss	0.347	2.3	40	0.803	0.2	40	0.256	3.3	40	0.856	0.1	40
% Cover												
Cv/Ec/Et	0.377	1.7	47	0.221	3.2	47	0.340	2.0	47	**0.015**	12.2	47
Um	0.386	1.6	47	0.088	6.2	47	0.416	1.4	47	**<0.001**	24.3	47
Mc	**0.001**	23.0	47	**<0.001**	56.4	47	**<0.001**	58.7	47	0.256	2.8	47
Ac	0.302	2.3	47	0.731	0.3	47	0.308	2.3	47	0.581	0.7	47
DGrass	**0.001**	21.7	47	**<0.001**	70.5	47	**<0.001**	65.2	47	0.162	4.2	47
Moss	0.123	5.1	47	**0.002**	18.6	47	**<0.001**	29.0	47	0.947	0.0	47

were recorded from the burnt array. Although linear regression analysis showed significant (*P*<0.05) relationships between the number of grass snake observations and the height of Um, Mc, Ac, DGrass and % ground cover of Mc and DGrass no single habitat variable accounted for more than 33.8% of the observed variation (Table 1).

The highest number of slow worm sightings was recorded from ungrazed wet heath and the lowest from grazed wet heath (Fig. 2). They were also most frequently recorded in arrays where heather height was 30-35cm, Um height exceeded about 25cm, Mc and Ac heights were greater than 40cm and 20cm respectively and grass litter depth exceeded 15cm. The greatest number of slow worm sightings were also recorded in arrays where heather ground cover was between 25% and 35%, Mc cover exceeded about 20%, grass litter cover was above 30% but moss cover was lower than 10%. Where habitat variables occurred at similar heights and ground covers, in both grazed and ungrazed arrays, fewer slow worm sightings were recorded from the grazed arrays than the ungrazed arrays. No slow worms were recorded from the burnt array. Linear regression analysis showed significant (*P*<0.05) relationships between the number of slow worm sightings and the heights of Um, Mc, Ac, grass litter and % ground cover of Mc, grass litter and moss (Table 1). The habitat variables that accounted for most of the observed variability in slow worm sighting numbers were the % covers of Mc (56.4%) and grass litter (70.5%).

The highest number of common lizard sightings were from ungrazed wet heath and the fewest from grazed wet and dry heath (Fig. 3). The highest number of sightings were also recorded from arrays where heather height was 30-40cm, Mc and Ac heights were greater than approximately 40cm and 20cm respectively, grass litter depth exceeded 15cm and moss depth was below about 5cm. Similarly, common lizards were most frequently recorded in arrays where heather ground cover was between 20% and 35%, Mc cover exceeded about 50%, grass litter cover was greater than approximately 30% and moss cover was below about 10%. Where

Fig. 1. Plots of the total number of grass snake (Nn) sightings against mean plant height/depth and percent cover for each refuge array located in dry (circles) and wet (squares) heath within the burnt (▲), grazed (●, ■) and ungrazed (○, □) areas (2010-2013). Heather: *C. vulgaris* + *E. cinerea* + *E. tetralix*; Um: *U. minor*; Ac: *A. curtisii*; Mc: *M. caerulea*; DGrass: Dead grass.

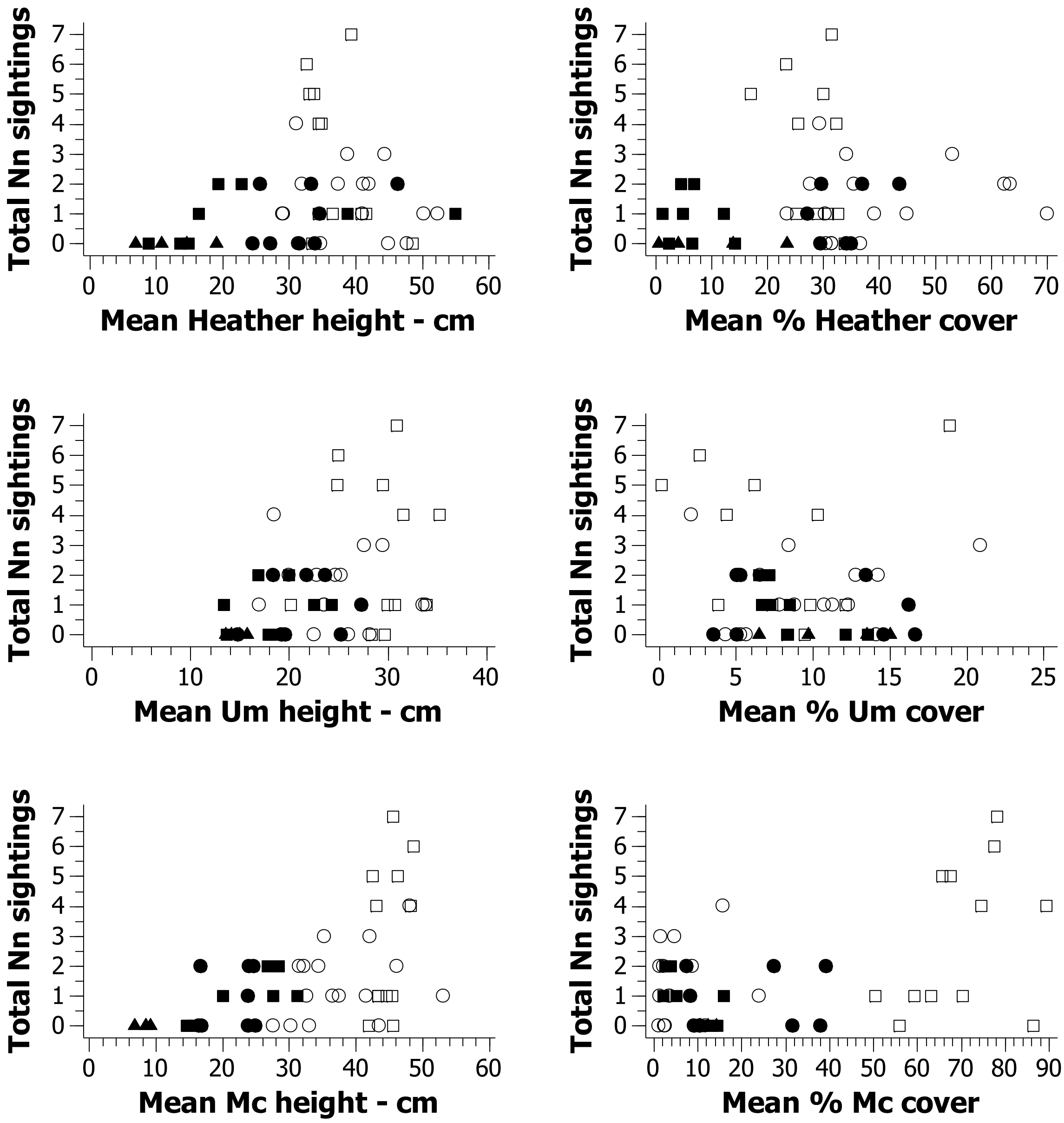


Fig. 1. Cont'd

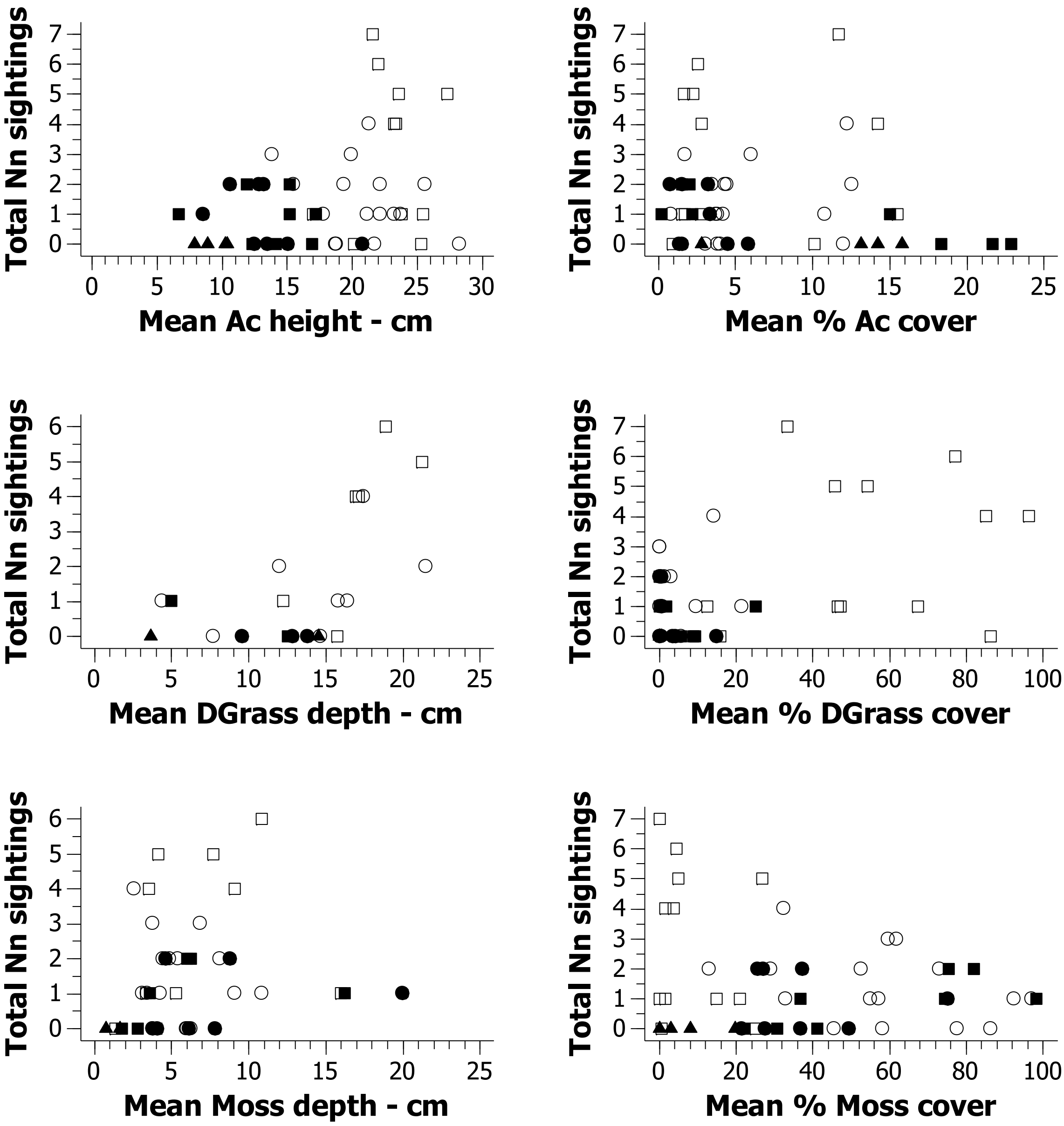
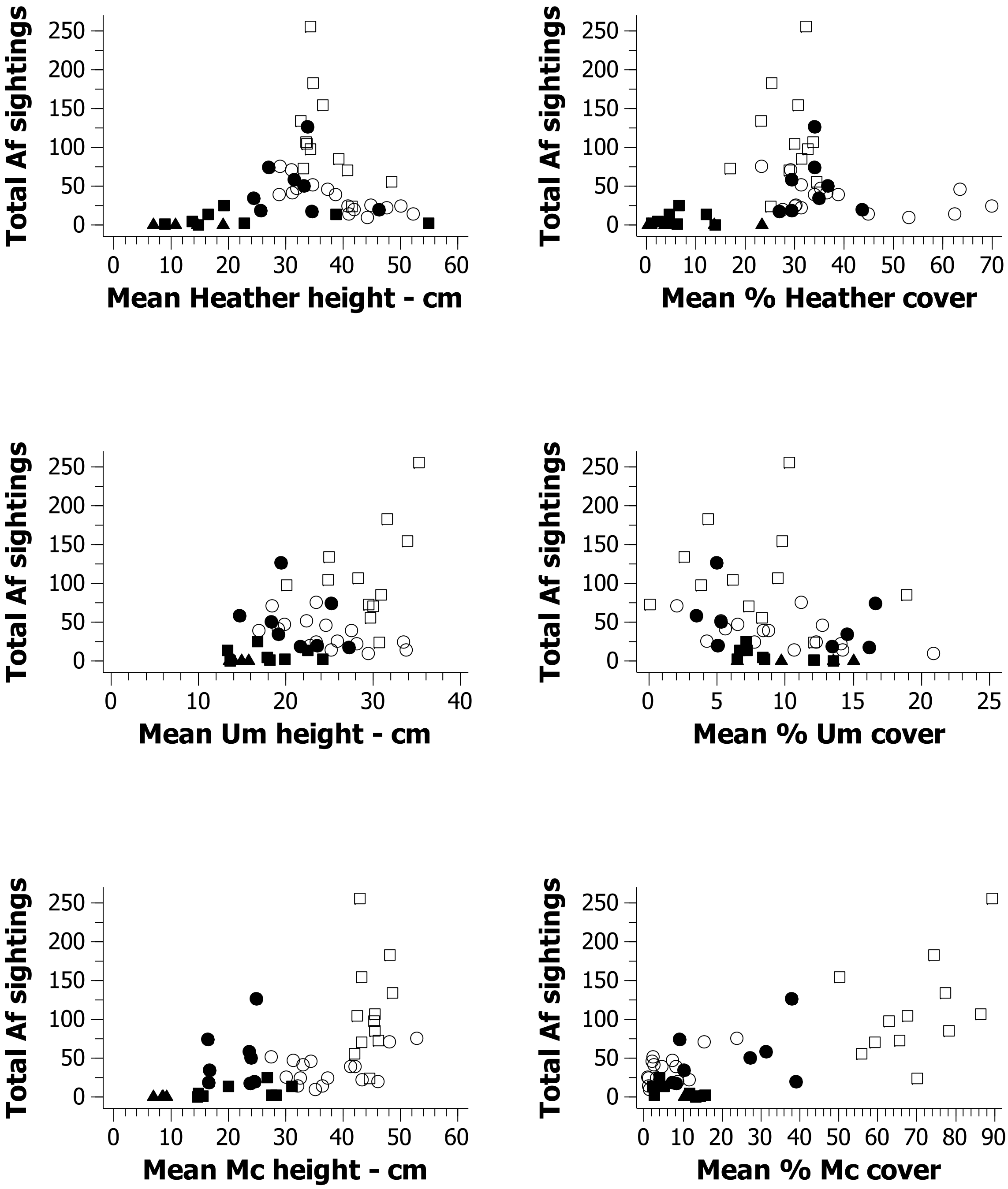

Total Nn sightings
Mean Ac height - cm
Total Nn sightings
Mean % Ac cover
Total Nn sightings
Mean DGrass depth - cm
Total Nn sightings
Mean % DGrass cover
Total Nn sightings
Mean Moss depth - cm
Total Nn sightings
Mean % Moss cover

Fig. 2. Plots of the total number of slow worm (Af) sightings against mean plant height/depth and percent cover for each refuge array located in dry (circles) and wet (squares) heath within the burnt (▲), grazed (●, ■) and ungrazed (○, □) areas (2010-2013). Heather: *C. vulgaris* + *E. cinerea* + *E. tetralix*; Um: *U. minor*; Ac: *A. curtisii*; Mc: *M. caerulea*; DGrass: Dead grass.



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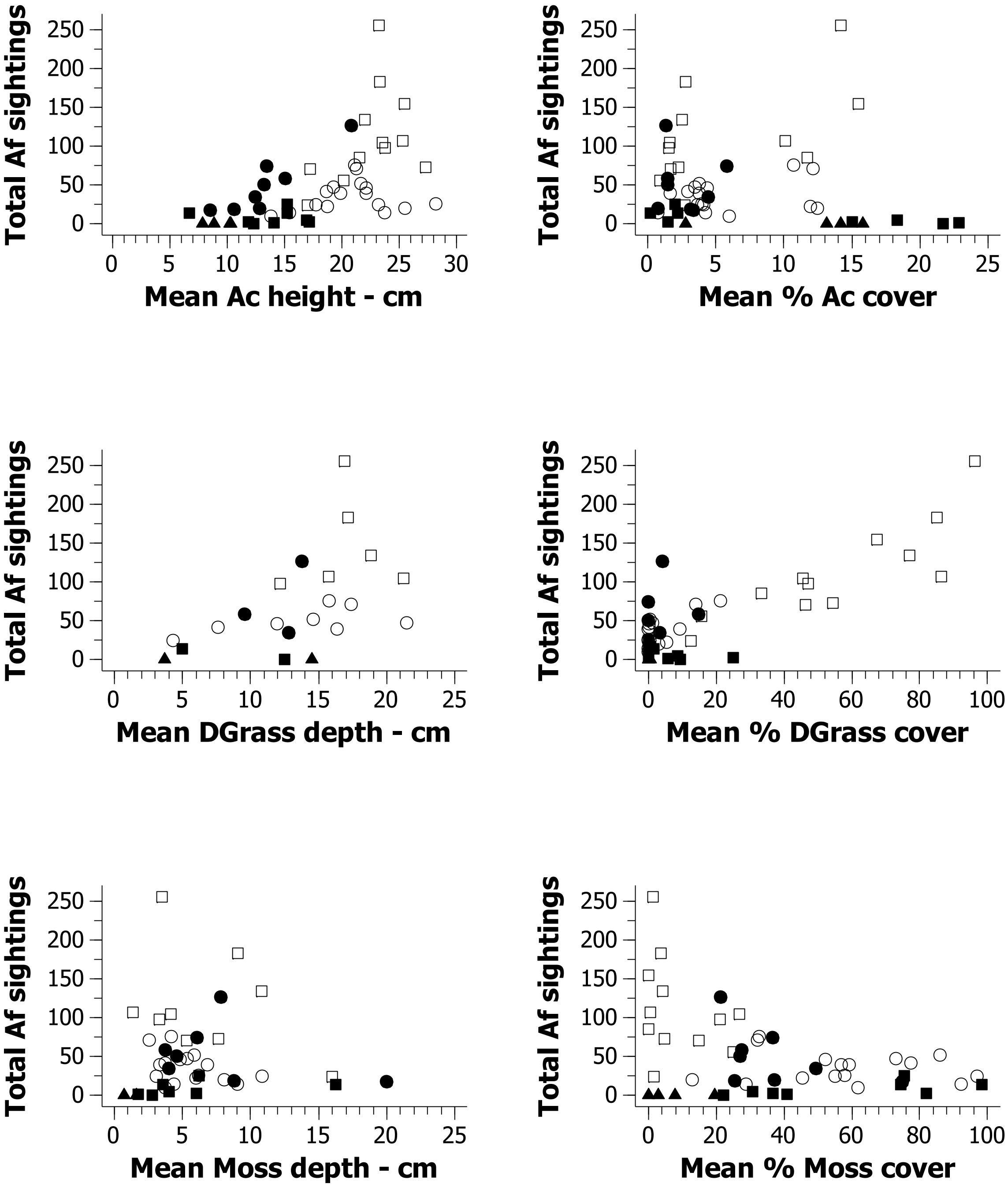

Total Af sightings
Mean Ac height - cm
Total Af sightings
Mean % Ac cover
Total Af sightings
Mean DGrass depth - cm
Total Af sightings
Mean % DGrass cover
Total Af sightings
Mean Moss depth - cm
Total Af sightings
Mean % Moss cover

Fig. 3. Plots of the total number of common lizard (Zv) sightings against mean plant height/depth and percent cover for each refuge array located in dry (circles) and wet (squares) heath within the burnt (▲), grazed (●, ■) and ungrazed (○, □) areas (2010-2013). Heather: *C. vulgaris + E. cinerea + E. tetralix*; Um: *U. minor*; Ac: *A. curtisii*; Mc: *M. caerulea*; DGrass: Dead grass.

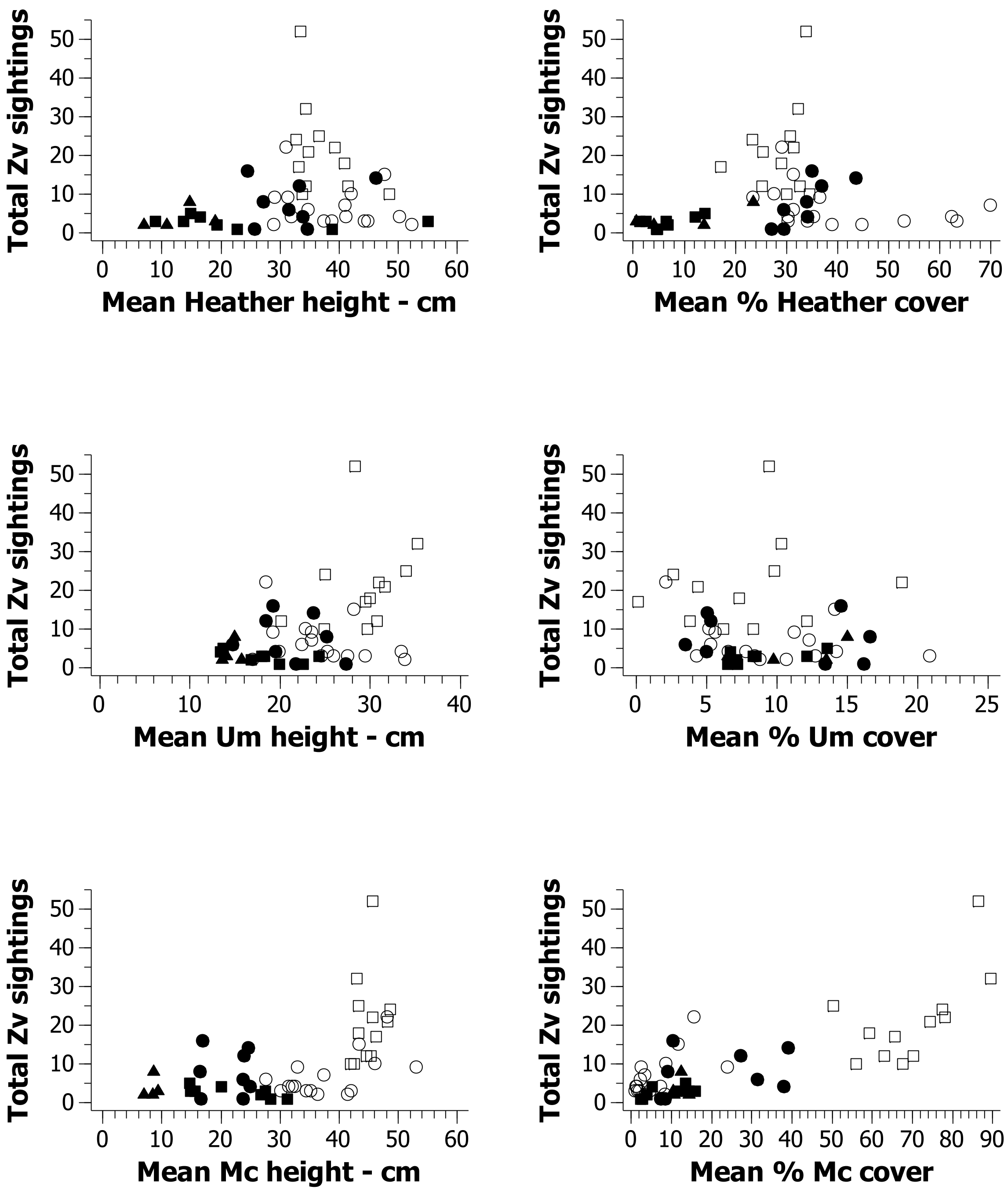


Fig. 3. Cont'd

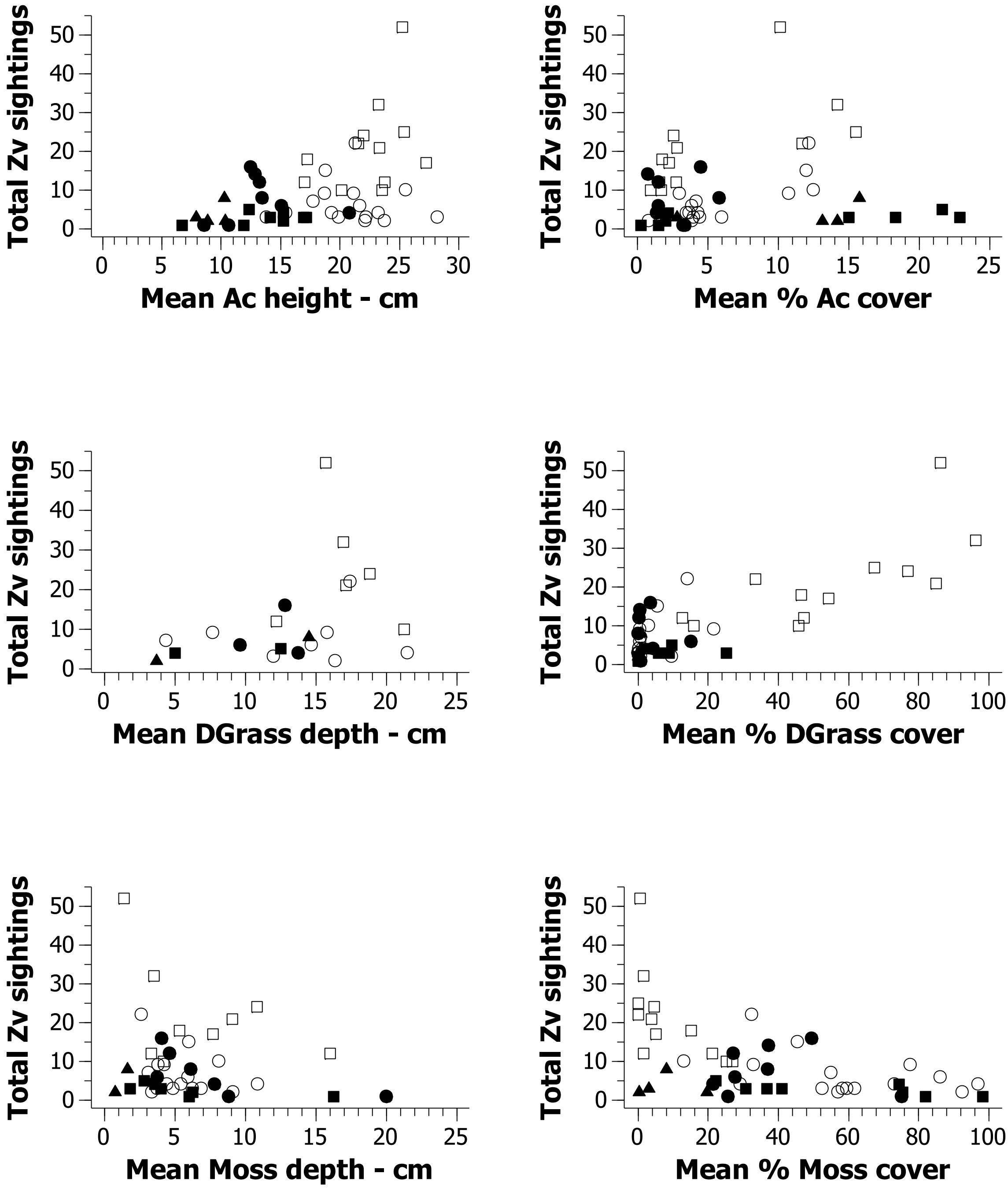

Total Zv sightings
Mean Ac height - cm
Mean % Ac cover
Mean DGrass depth - cm
Mean % DGrass cover
Mean Moss depth - cm
Mean % Moss cover

Fig. 4. Plots of the total number of sand lizard (La) sightings against mean plant height/depth and percent cover for each refuge array located in dry (circles) and wet (squares) heath within the burnt (▲), grazed (●, ■) and ungrazed (○, □) areas (2010-2013). Heather: *C. vulgaris* + *E. cinerea* + *E. tetralix*; Um: *U. minor*; Ac: *A. curtisii*; Mc: *M. caerulea*; DGrass: Dead grass.

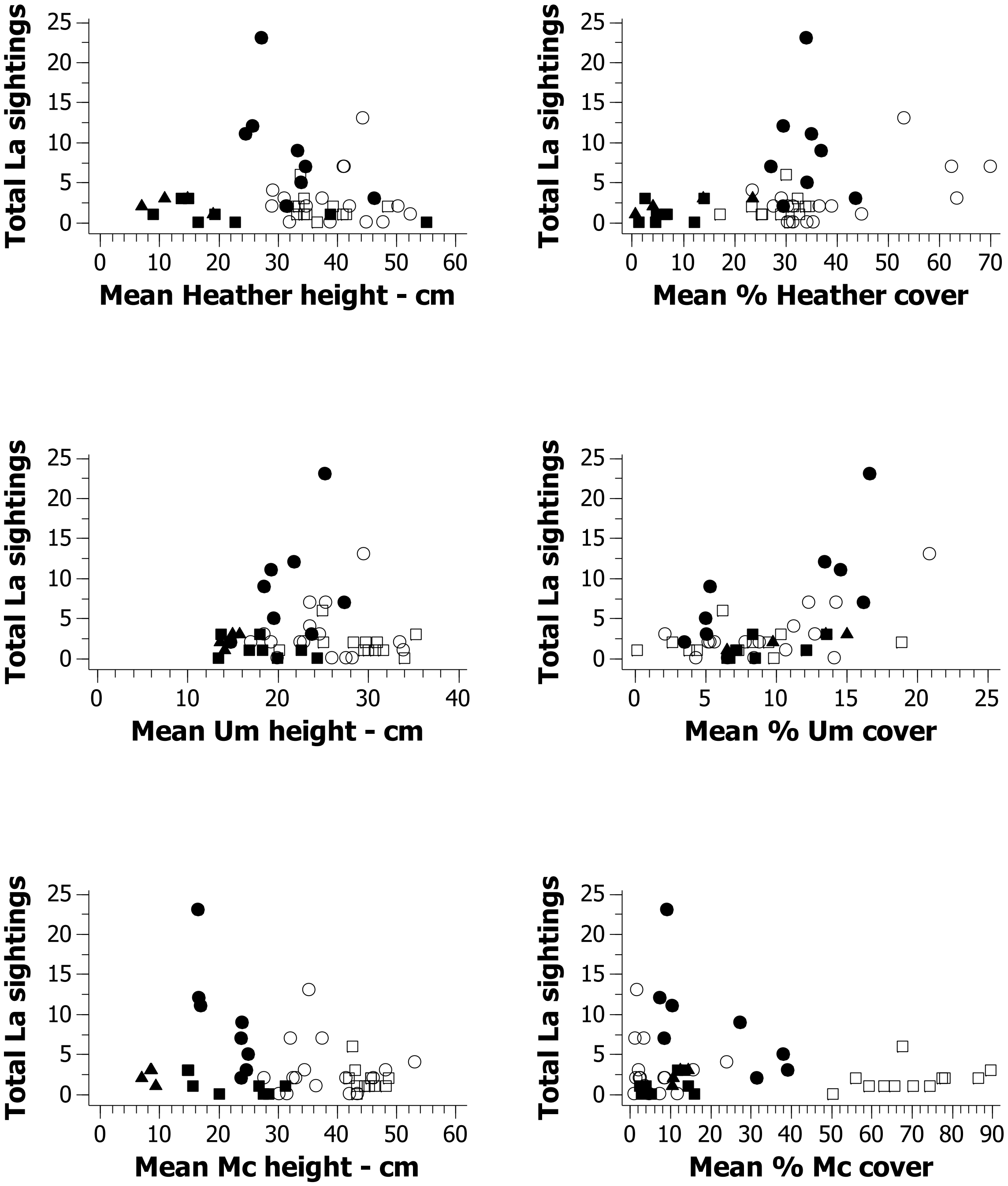
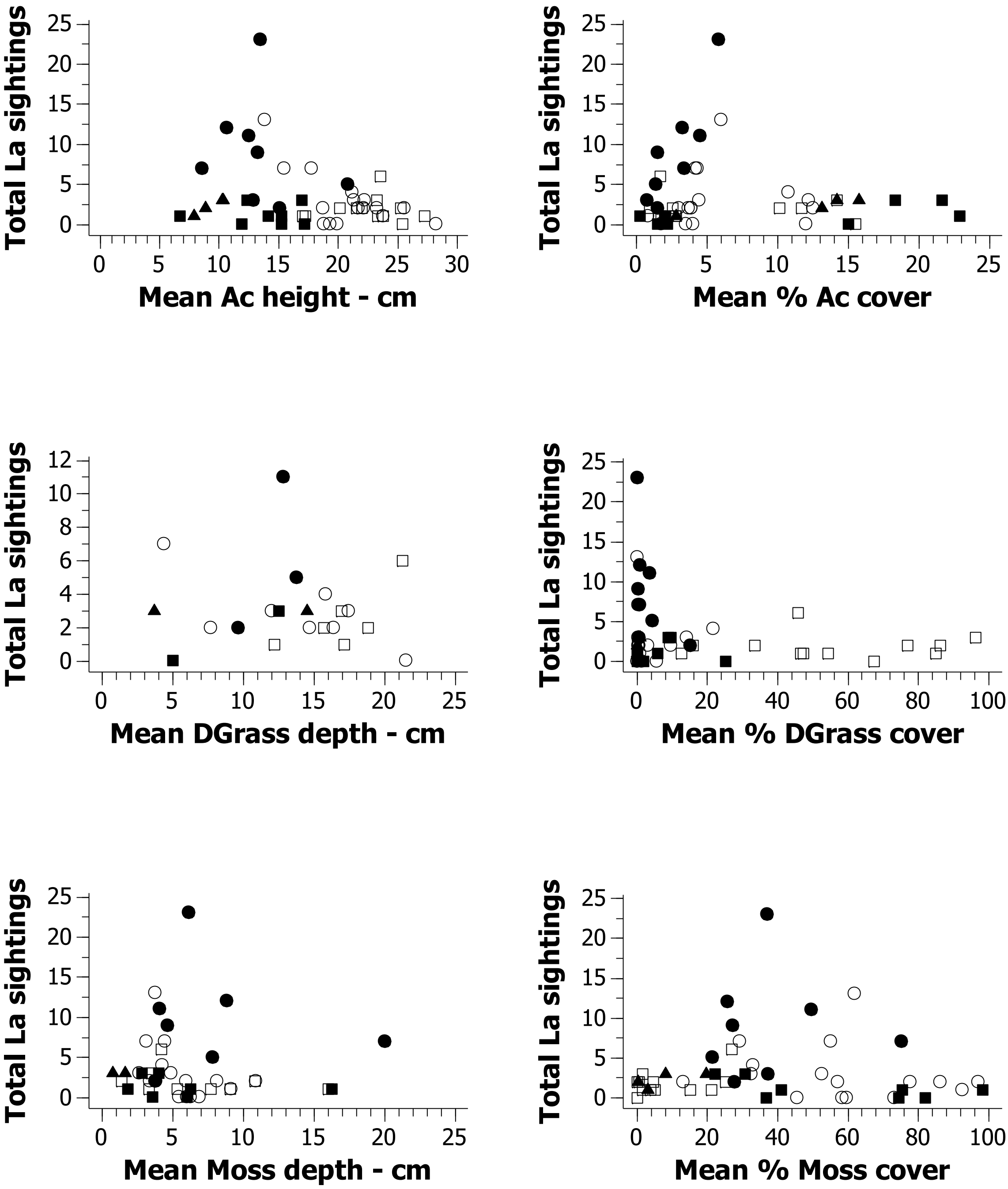


Fig. 4. Cont'd


Total La sightings
Mean Ac height - cm
Total La sightings
Mean % Ac cover
Total La sightings
Mean DGrass depth - cm
Total La sightings
Mean % DGrass cover
Total La sightings
Mean Moss depth - cm
Total La sightings
Mean % Moss cover

each habitat variable occurred at similar heights and ground covers in both grazed and ungrazed arrays, fewer common lizard sightings were recorded from the grazed arrays than the ungrazed arrays. Linear regression analysis of the frequency of common lizard sightings against each of the six selected habitat variables showed significant relationships with the heights of Um, Mc, Ac and ground cover by Mc, grass litter and moss. The most significant relationships that explained most of the observed variability in the number of common lizard sightings were ground cover by Mc (58.7%) and grass litter (65.2%).

In contrast to the grass snake, slow worm and common lizard, the highest number of sand lizard sightings were recorded from grazed dry heath and the fewest from grazed wet heath or ungrazed wet and dry heath (Fig. 4). The highest number of sightings were in arrays where heather and Um heights were approximately 25cm and Mc and Ac heights were below about 35cm and 15cm respectively. The highest frequency of sand lizard captures were also from arrays where heather ground cover was between 30% and 40%, Um cover above 10-15%, Mc and Ac cover both below about 15% and moss cover below approximately 10%. Linear regression analysis showed that the number of sand lizard sightings was relatively poorly predicted by any of the six selected habitat variables though ground cover by Um did account for 24.3% of the observed variation in the number of sightings.

Evidence of reptiles breeding in grazed and ungrazed arrays

The mean number of adult (>1 year old) and new-born grass snakes, slow worms, common lizards and sand lizards recorded in grazed and ungrazed arrays is shown in Table 2. Although adult grass snakes were captured in both grazed and ungrazed arrays significantly more (P=0.012) were found in the ungrazed arrays whilst no new-born snakes were found in the grazed arrays and just one in the ungrazed arrays.

Table 2. Mean number of adult and new born grass snakes *N. natrix*, slow worms *A. fragilis*, common lizards *Z. vivipara* and sand lizards *L. agilis* found per array in grazed and ungrazed heathland (2010-2013). Significant *p*-values (<0.05) are shown in *italic*.

Species			Mean	SD	*n*	*t*	*P*	df
N. natrix	Adults	Ungrazed	2.04	2.009	28	-2.64	**0.012**	40
		Grazed	0.87	0.885	16			
	New born	Ungrazed	0.04	0.189	28	-	-	-
		Grazed	0	-	16			
A. fragilis	Adults	Ungrazed	64.21	55.889	28	-2.77	**0.008**	41
		Grazed	26.75	33.777	16			
	New born	Ungrazed	3.18	2.957	28	-2.51	**0.016**	41
		Grazed	1.50	1.460	16			
Z. vivipara	Adults	Ungrazed	11.82	9.918	28	-2.61	**0.013**	41
		Grazed	6.00	4.830	16			
	New born	Ungrazed	0.93	1.631	28	-2.28	**0.029**	32
		Grazed	0.19	0.403	16			
L. agilis	Adults	Ungrazed	2.46	2.822	28	1.99	0.062	18
		Grazed	5.62	5.976	16			
	New born	Ungrazed	0.04	0.189	28	-	-	-
		Grazed	0	-	16			

Adult slow worms and adult common lizards both occurred in grazed and ungrazed arrays with significantly more sightings recorded from the ungrazed arrays (*P*=0.008 and *P*= 0.013 respectively). Similarly, new-born slow worms and common lizards were recorded from both grazed and ungrazed arrays with significantly more of both species observed in the ungrazed arrays than the grazed arrays (*P*=0.016 and *P*= 0.029 respectively).

Only adult sand lizards were recorded in grazed and ungrazed arrays though the numbers occurring in each were not significantly different (*P*=0.062). As with the grass snake, no new-born sand lizards were found in any of the grazed arrays whilst a single individual was found in an ungrazed array.

DISCUSSION

Here we report the relationships between *N. natrix*, *A. fragilis*, *Z. vivipara* and *L. agilis* occurrence and attributes of habitat structure in an area of lowland heath, between 2010 and 2013, that had been grazed annually by cattle for 13 years (1997-2009) before the cessation of grazing from part of it in 2010. This report complements a previous study of the relationship between smooth snakes *C. austriaca* and habitat structure in the same area (Reading & Jofré, 2015). Our data agree with the findings of two previous studies of reptiles inhabiting heathland in The Netherlands where either fewer reptiles were found in grazed heathland than ungrazed heathland (Strijbosch, 2002; Stumpel & van der Werf, 2012), or they totally disappeared from grazed areas e.g. smooth snake *C. austriaca*, common lizard *Z. vivipara* and slow worm *A. fragilis* (Strijbosch, 2002).

The observed differences in the occurrence of the four reptile species between the grazed and ungrazed areas were related to differences in habitat structure (plant height and percent ground cover) between these areas that were recorded over the same period. These differences were most apparent in the height and ground cover of purple moor grass *M. caerulea* and bristle bent *A. curtisii* and the height of dwarf gorse *U. minor*. In the grazed area, the height and ground cover of both grass species were less than half that in the ungrazed area, and the height of dwarf gorse approximately 70% that in the ungrazed area. Although the grasses (particularly *M. caerulea*) had been cropped by cattle the reason for the reduced height of dwarf gorse in the grazed area was unclear though this may also have been grazed.

With the exception of the sand lizard, which was observed more frequently in the grazed areas, where grass height was relatively short, the highest number of sightings of grass snakes, slow worms and common lizards, were associated with tall grass and grass litter (dead grass) which were both virtually absent from the grazed areas. This finding agrees with previous studies which have demonstrated a clear association between common lizards and areas with a high cover of relatively tall *M. caerulea* (Strijbosch, 1988; Edgar et al., 2010; Stumpel & van der Werf, 2012). Also, with the exception of the sand lizard, which had a significant positive relationship with the percent cover of dwarf gorse, the other three species showed no significant association with dwarf gorse cover though they did with its height.

Heathers, particularly *C. vulgaris*, are the dominant plant species associated with lowland heath in the UK and more sightings of all four reptile species were associated with heather that was 25-35cm tall with a ground cover of approximately 30%. With the exception of a weak relationship between heather cover and sand lizard occurrence, no significant relationships between either its height or percent cover and the occurrence of grass snakes, slow worms or common lizards were found. This is in contrast to the smooth snake *C. austriaca* which had strong positive relationships with both heather height and cover in the same study area (Reading & Jofré, 2015). Although cattle are known to graze *C. vulgaris* (Putman et al., 1987) their main source of food on southern lowland heaths in the UK are grasses, particularly *M. caerulea* which, along with heather, is important in providing a significant part of the habitat structure. Our results indicate that cattle grazing has resulted in a degradation of the heathland habitat structure, thereby reducing its carrying capacity with respect to grass snakes, slow worms and common lizards, with sand lizards appearing to be less adversely affected.

Along with habitat degradation, disturbance may pose a significant threat to the survival of local reptile populations as has been demonstrated for smooth snakes *C. austriaca* in the southern Iberian Peninsula (Santos *et al.*, 2009) and in southern England (Reading & Jofré, 2015). This possibility is further supported by our finding that where the height and/or ground cover of heathland plants were similar in both grazed and ungrazed arrays the numbers of grass snake, slow worm and common lizard sightings were usually lower in the grazed arrays. The reverse was, however, true for sand lizards with more sightings of adults recorded in grazed arrays than ungrazed arrays.

Despite the number of sand lizard sightings being higher in the grazed arrays, compared to the ungrazed arrays, no evidence was found that they were able to successfully breed in these areas. A possible explanation is that sand lizards lay their eggs in relatively shallow burrows that are excavated in areas of exposed sandy soil (Corbett, 1990; Edgar et al., 2010) which is more common in grazed than ungrazed habitat. However, these areas of bare ground also tend to be favoured by cattle as resting areas and are therefore exposed to trampling damage which may be sufficiently intense and widespread to destroy sand lizard egg burrows.

Although the cattle stocking densities used in the study area between 2010-2013 were consistent with those recommended by Lake et al. (2001) the total number of cows used to manage habitat by 'conservation grazing' is based on the size of the area to be managed and assumes that cattle will be evenly dispersed over all of it. A combination of cattle herding behaviour and their avoidance of some areas will result in overgrazing in those areas that they frequent (Reading & Jofré, 2015).

Given the impact of cattle grazing on heathland reptiles that this study has highlighted it would be prudent to define, more precisely, what is meant by 'conservation grazing' and what this form of habitat management is actually trying to conserve. In the UK, Natural England states that its policy of using grazing on heathland is designed to 'conserve wildlife and maintain biodiversity' (see NE[a]) despite numerous studies, worldwide, demonstrating that with the exception of a few species that are adapted to early successional stages (Kie et al., 1996; Buckley, Beebee & Schmidt, 2013), grazing is usually damaging to species that require a habitat with high structural complexity (Lindenmayer & Fischer, 2006; Jofré & Reading, 2012; Reading & Jofré, 2015). The problem concerning the use of 'conservation grazing' is that every species subject to this form of habitat management will have its own unique set of habitat requirements and that a policy that uses grazing as a panacea for the conservation of all species is clearly absurd. Regrettably, the growing body of scientific evidence showing that grazing is harmful to many species of conservation concern has yet to be acknowledged by Natural England and be incorporated into their habitat management guidelines.

There is, therefore, an increasingly urgent need for influential conservation bodies to tailor conservation policy, based on sound ecological research, to the specific habitat requirements of species of concern. It is possible that within any given habitat there may be more than one species of conservation interest with each requiring a different management protocol. In such instances care should be taken not to conserve one species at the expense of another. It is also important that the areas managed for each target species should be sufficiently large to support sustainable populations. Finally, there is an ongoing need for detailed ecological research into the specific habitat requirements of many species, not just those that are under threat, before the implementation of untested and untargeted conservation management protocols. It is essential that the initiation of such measures should be followed by detailed monitoring to determine their real, as opposed to anticipated, impact on both the target species and other species present within the habitat (Bullock & Pakeman, 1997; Newton et al., 2009; Böhm et al., 2013; Reading & Jofré, 2015).

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