Amphibian and Reptile Conservation

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An assessment of the impact of conservation grazing on reptile populations

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NATURAL ENGLAND

amphibian and reptile conservation

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EXECUTIVE SUMMARY

- As a result of concerns that the increasing use of livestock grazing to manage natural habitats may have potentially damaging effects on reptile populations in the UK, Natural England (NE) and Amphibian and Reptile Conservation (ARC) commissioned this review of the available information on the impact of grazing on reptiles and natural habitats, with particular reference to those where reptile populations occur.
- The results of studies investigating the relationship between grazing and reptile populations in countries which have experienced losses in reptile biodiversity, driven by habitat change, potentially resulting from grazing by domestic livestock were accessed.
- The single most important, and incontrovertible, conclusion of this review is that, in sites where reptile conservation is the primary objective, grazing by domestic livestock, particularly cattle and ponies, is not, and should not be considered to be, an appropriate form of habitat management as it will ultimately result in their eradication rather than their conservation.
- Lowland heathland is the premier reptile habitat in Britain and the only one supporting all six species; over 95% of sand lizards occur on lowland heathland and smooth snakes are found nowhere else.
- Grazing in any habitat results in a simplified structure in terms of vegetation height and reduced ground cover, and one that is unable to support such a high diversity of animal species as one that is not grazed and has a more complex structure.
- As a result of adding nitrogen (dung) to nutrient deficient habitats (acid grasslands and heathlands) and losing the litter layer (all habitats), that sequesters nitrogen, grazing accelerates the rate of succession to woodland, rather than slowing it down.
- Cattle do not prevent the encroachment of pine and birch trees on lowland heathland.
- Plant species diversity is increased in sites managed by grazing, and grazing is critical for the maintenance of species rich (plants) grasslands.
- This review has highlighted the lack of specific research, in the UK, linking the effect of grazing on natural habitats, and its subsequent impact on reptile populations.
- Two potential areas have been selected where field experiments, investigating the effects of grazing on reptile habitats and reptile populations, might be feasible over the next 5-10 years.
- Experimental designs have been prepared, and costed, that will allow the impact of grazing on reptile habitats and reptile populations in different habitat types to be evaluated.

- The use of grazing to manage and ‘conserve’ natural habitats in the UK appears to be governed by a ‘one size fits all’ mentality in which the specific habitat requirements of different animal groups are ignored resulting in habitat mis-management and the conservation of nothing in particular, other than dogma.
- The management of lowland heathlands in the UK, through the use of ‘conservation grazing’, amounts to little more than large scale ‘habitat gardening’ in which the primary objective appears to be the achievement of an aesthetically pleasing landscape, driven by low financial cost and the welfare of the grazing livestock, rather than concerns about habitat and wildlife conservation.

1. INTRODUCTION

There is general consensus that habitat change is a proximate cause for global biodiversity loss and has become the single biggest threat to the conservation status of many taxonomic groups (Sala et al., 2000). In particular, there is now worldwide recognition that habitat change is the primary cause of reptile and amphibian population declines (Gardener et al., 2007). However, the consequences of changes to habitat structure (fragmentation, logging, fire, native regeneration and grazing) have not been studied sufficiently well, if at all, to provide an understanding of the impact of such changes on conservation target species.

Extensive grazing of 'natural habitats' by domestic livestock, e.g. cattle, horses/ponies, sheep and goats, has been used in the British Isles for centuries (Tubbs, 1991, 1997). However, its use as a conservation management tool was only introduced into the UK in the early 1990's when Gimingham (1992) proposed that 'controlled grazing' might be a feasible, and potentially sustainable, means of managing transitional habitats, such as heathlands. The idea of using grazing as a 'natural' (to mimic natural processes), and 'traditional' (to replicate traditional agricultural practices), form of habitat management, was not only perceived to lack many of the disadvantages and dangers associated with other forms of habitat management, such as burning, mowing and cutting trees and shrubs, but was also seen as a relatively inexpensive option from an economic perspective (Gimingham, 1992; Grayson, 2000; Lake et al., 2001; Stumpel, 2004).

However, the biggest problem associated with the use of any management technique is its potential to cause harm to the habitats and target species being managed (Corbett, 1998; Edgar & Bird, 2006; Edgar, Foster & Baker, 2010). Knowledge about, and an understanding of, how habitats and populations of target species of conservation interest are likely to respond, in both the short and long term, to a particular form of management e.g. grazing or burning, is essential if these habitats and target species are to be conserved effectively. In general, the manner in which a species is likely to respond to habitat changes, resulting from management practices, depends to a large extent on how it utilises, and is adapted to, different aspects of its preferred habitat.

When grazing is used as a habitat management technique, it may, if appropriately managed, improve the habitat for a target species that is dependent on early successional stage plant communities (Kie et al., 1996) and the availability of bare ground. Two well-known examples of this are the use of specialised grazing management to maintain the habitat of the Natterjack toad (Denton, et. al., 1995; Oates et al., 1998) and the Large Blue butterfly (Thomas, 1991). However, species, such as the sand lizard (*L. agilis*), that are dependent on a highly structured habitat may be negatively affected as a result of using grazing to manage their habitat (Corbett, 1998; Strijbosch, 2002; Stumpel, 2004; Edgar & Bird, 2005).

The reintroduction of grazing as a habitat management technique has attracted increasing interest over recent years and is being increasingly used as a management tool on heathland sites to encourage diversity in both plant species composition and habitat structure (Bullock & Pakeman, 1997; Lake et al., 2001; Lake, 2002; Newton et al., 2009). However, reliable information about the impact of grazing on natural reptile populations is missing in the UK with most of the available information being anecdotal and statements, in reports, extolling the potential benefits of grazing for maintaining reptile habitats are unsubstantiated (Edgar et al., 2010).

Concerns about the increasing use of livestock grazing on sites in the UK where reptiles are currently relatively abundant has prompted this review, by the ARC (Amphibian and Reptile Conservation) of the impact of 'conservation grazing' on reptiles in the UK. The approach taken here will be to review the available scientific literature on:

1. The general effects of livestock grazing on habitats.
2. The habitat requirements of British reptiles.
3. The mechanisms by which livestock grazing impacts on reptile populations.

Given the recognised lack of detailed knowledge about how 'conservation grazing' affects reptile populations in the UK a programme of field research will be outlined with the aim of starting to fill this gap in our knowledge.

2. THE EFFECTS OF GRAZING ON HABITATS AND THEIR COMMUNITIES

Livestock grazing has a direct negative affect on plant biomass, as a result of grazers eating it, and an indirect affect on seed dispersal, nutrient regeneration, and plant biodiversity (Hay & Kicklighter, 2001). However, the ecological effects of grazing are not only restricted to the obvious response of the vegetation (Van Wieren 1998). Grazers may show active selection for, or against, particular plant species (Fleischner, 1994) and plant species may exhibit differential vulnerability to being grazed (Szaro, 1989), both of which may have cascading effects on other processes, often leading to substantial reductions in ecological function (Eldridge & Whitford, 2009).

The relationship between grazing and wildlife habitat is, therefore, not simple but complex. Grazing affects wildlife habitat by modifying plant biomass, species composition, and some structural components of the vegetation, such as height and cover (Kie et al., 1996), which may be important resources for the animal communities inhabiting them by providing food and shelter. Changes in these habitat attributes may also play an important role in the survival of particular species and overall species diversity within habitats. In general, those habitats with a relatively complex structure (plant species diversity, plant volume and density) support more diverse animal communities, than those with a simple structure, due to the provision of a greater range of available niches that can be exploited (Pianka, 1966).

The effects of grazing on different habitat types may vary and have been treated individually:

2.1 *Areas adjacent to fresh water*

Although there are no reported studies on the effects of grazing on habitats adjacent to fresh water, it is known that cattle and ponies tend to concentrate their feeding activity on various types of improved grassland and on streamside lawns (Putman et al., 1987). A number of publications reviewed by Fleischner (1994) and Belsky et al. (1999) found general negative effects on both the habitats and the wildlife communities associated with them, including those of amphibians and reptiles, as a result of trampling, dunging, and a decline of the structural diversity of the plant communities (reduced height and cover), which resulted in the loss of the prey base and the loss of cover that provided protection from predators.

In Argentina, for example, larval survivorship of an endangered toad, *Bufo achalensis*, occurring in upland grasslands was negatively affected as a direct result of trampling and stream bank erosion by free ranging cattle. The transition habitat, used by juvenile toads, was also transformed from tall tussock grassland to short turf resulting in a loss of cover during their migration from the streams to the rocky outcrops where they lived as adults (Jofré et al., 2007).

2.2 *Grassland*

Grazers are considered crucial to the maintenance of species-rich grasslands (Ball, 1974; Bakker, 1985; Olff & Ritchie, 1998). Without them there is an accumulation of plant litter that sequesters nutrients, physically limits vegetative growth, and interferes with seedling establishment (Hay & Kicklighter, 2001).

Information on the effect of conservation grazing on chalk grasslands is mainly found in reports. Unfortunately, many of them are more focused on economic outcomes and animal welfare than on monitoring the effects of grazing on the vegetation itself. For example, the results of monitoring vegetation changes as a consequence of restoration-grazing regimes, by cattle and sheep, on limestone grassland of high nature conservation value around Morecambe Bay, in north-west England, were inconclusive due to their short duration and the patchy distribution of effort during the study (Grayson, 2000). Although the appraisal of the impact of grazing was both subjective and anecdotal the general opinion was that the swards became more open, dead plant material decreased and structural variation increased. Grazing also helped to control the spread of scrub, and trampling seemed to create gaps and pathways within dense bracken that was thought to benefit the Hill-brown fritillary butterfly.

Within one year of introducing hardy ponies, in 1993, to Langdon Cliffs SSSI, Dover, Kent, the chalk grassland, which was dominated by Tor-grass (*Brachypodium pinnatum*), was transformed into sward. In general, all the reports by Oates (1998) concluded that grazing is effective at creating swards and that a mixed sheep, cattle and pony regime is better than sheep alone for providing 'a more structurally varied' sward and removing rank vegetation.

The effects of cattle and sheep grazing on nutrient poor, acidic grassland have been studied experimentally in Denmark (Buttenschon & Buttenschon, 1982). Sheep concentrated their grazing on the preferred swards, and exerted very close grazing on these, whilst cattle tended to spread their grazing and seldom grazed as closely as sheep.

The upland grasslands in Scotland have been grazed continuously for many years (Bullock & Pakeman, 1997; Pollock, 2003). The seasonal effects of the presence, or absence, of sheep grazing under different grazing intensities, on upland plant diversity and vegetation structure, showed that the general effects of all year round sheep grazing on swards were a reduction of tussock structure and an increase in plant diversity. Light grazing regimes, during the summer, increased the amount of dead vegetation material (which is good for insects), whereas heavy grazing prevented tussock build-up and increased pressure on dwarf shrubs (Grant et al., 1996). Heavy grazing increased plant diversity by opening gaps in the sward and allowing seeds to reach the ground. Pollock (2003) concluded that all year round grazing by sheep, at moderate levels, would be adequate to maintain species-rich upland grasslands and prevent increases in dwarf shrubs and trees.

2.3 *Sand dunes*

Sandscale Haws SSSI, Burrow in Furness, Cumbria is currently grazed by sheep and cattle. The dune habitats are diverse, have retained short sward grassland with a diverse flora, largely free of scrub, which is ideal for the Natterjack toad. However, cattle tend become faithful to feeding sites, confining their foraging to relatively small areas, resulting in localised under-grazed areas, litter accumulation, an increase in soil organic matter and the loss of plant species, particularly in slacks (Oates, 1998).

Conservation grazing by sheep, used in the Murloug Dunes in Ireland, showed a beneficial impact, significantly reducing dense stands of bramble, opening up bracken litter and reducing grass height. However, monitoring showed that sheep grazing had an adverse impact on the heathers, particularly during late winter (Oates, 1998). When ponies were introduced after removing the sheep casual monitoring and stock checking revealed that the ponies tackled many of the problem species, such as European gorse (*Ulex europaeus*), bracken (*Pteridium aquilinum*), thistles (*Cirsium sp.*) and sea buckthorn (*Hippophae rhamnoides*). Continued heather monitoring showed 'negligible damage'.

2.4 *Lowland heathland*

Present management methods for lowland heathland are directed towards arresting the process of succession from heathland to woodland in "order to maintain the structure and composition of dwarf shrub communities" (Newton et al., 2009). While a large majority of practitioners believe that grazing is an effective management option for lowland heath, evidence for a number of negative impacts on habitat attributes has been recorded (Corbett, 1998; Newton et al., 2009).

Although lowland heathlands have been the focus of many studies (Hill, 1985; Putman et al., 1987; 1989), there is relatively little research regarding the impact of grazing on the vegetation. However, the effects of cattle and sheep grazing on nutrient poor heathland was studied experimentally in Denmark by Buttenschon & Buttenschon (1982) where they showed that the uptake of *Calluna vulgaris* by sheep was continuous whereas by cattle it was extremely seasonal (July-August).

In addition, the effects of different management methods used in five different lowland heath areas, in a wide geographical distribution across southern England, were studied by Bullock & Pakeman (1997). Although the effect of grazing was examined at five different sites, un-grazed control areas were only used at two sites: Ashdown Forest and Cavenham Heath. A comparison between the effects of grazing on the vegetation structure and plant diversity on both grazed and un-grazed areas of these two sites is shown in Table 1.

Table 1. Effects of grazing by domestic animals in two lowland heath sites, information taken from Bullock & Pakeman (1997). Only significantly different differences were considered.

Categories	Ashdown		Cavenham		Effect of grazing
	Un-grazed	Grazed	Un-grazed	Grazed	
Scrub layer	-	-	-	-	
Dwarf shrub/ herb layer height	↑	↓	↑	↓	decreased
Bryophyte/ lichen layer	-	-	-	-	
Litter depth	↑	↓	-	-	decreased
Bare ground	-	-	↓	↑	increased
Plant species diversity	-	-	-	-	

Grazing significantly reduced the height of the dwarf shrub layer and the litter depth in both sites, and significantly increased the bare ground cover at Cavenham. There were no significant effects on either the scrub layer or the bryophyte/lichen layer.

Similar patterns were obtained when comparing the effects of slight and heavy grazing on the percentage of bare ground cover, on the height of the dwarf shrub/herb layer in the Aylesbeare sites, and on the dwarf shrub/herb layer height and litter depth in the New Forest sites. In the latter, however, the effects were stronger, probably due to its long term grazing history.

The impact of cattle and pony grazing on heathland was also investigated in detail by Lake (2002) in four lowland heath nature reserves in southern England: Arne RSPB Reserve, Hartland Moor NNR, Godlingston Heath and Stoborough Heath RSPB Reserve. The aim of this research was to investigate the use of livestock as a management tool, particularly on heath where successional processes had led to a decline in species diversity. A summary of the results of this study are:

2.5 *Use of Habitat*

- All livestock groups showed non-random behaviour and used particular habitat types while avoiding others.
- Cattle selected habitats with a high cover of fine grasses and young heather *Calluna vulgaris* over habitat supporting woody species.
- Young *Calluna vulgaris* plants were positively selected.
- Dry heath, characterised by old leggy *Calluna vulgaris*, was selected in autumn for resting, although largely avoided for the rest of the season.
- Cattle reduced their use of wet heath and valley mires during winter. This change was generally compensated for by an increase in the use of acid grassland, restoration heath (young plants), or dry heath. When the availability of acid grassland areas was limited the use of dry heath habitats increased.
- The use of woodland by cattle varied in different sites, increasing in one but decreasing in another.
- The use of restoration heath (new plants) by New Forest ponies peaked during winter, whereas Exmoor ponies made little use of it.

2.6 *Use of space*

- *Resting places*: Growing dry heath, mature dry heath, woods and managed scrub/wood were selected over wet habitats.

- *Moving*: Tracks, roads and dry heath were used predominantly for moving. Livestock generally moved along small paths when moving across dry heath, except when foraging on dwarf gorse when they moved through (trampled) the vegetation.
- *Dunging*: In general this was in proportion to habitat use though there was a tendency for increased dunging around the resting areas, possibly resulting in a transfer of nutrients and plant species between foraging and resting habitats.

2.7 *Diet*

- Cattle positively selected grasses over other species. *Calluna vulgaris* was positively selected on dry heath where young shoots were available. Scrub species were occasionally eaten but never positively selected for. With the exception of dwarf gorse (*Ulex minor*), which was positively selected for during autumn, there was little seasonal variation in species selection within habitats.

2.8 *Differences of impact between ponies and cattle*

- Ponies spent considerably more time foraging than cattle and therefore removed a greater biomass.
- Cattle are heavier than ponies; therefore the impact through trampling is expected to be greater.
- Cattle spent more time lying down and so, due to their greater body mass, are likely to cause more vegetation damage.
- New Forest ponies were less selective than cattle and Exmoor ponies and made most use of habitats other than acid grassland.
- Cattle made more use of dry heath and ate more *Calluna vulgaris* than ponies, when on dry heath.

In the UK, perhaps the most complete analysis of the effects of heavy grazing, by domestic herbivores, upon the dynamics of the community as a whole comes from a series of detailed studies on the ecology of the New Forest (Van Wieren, 1998). Reduced diversity and the overall abundance of small mammals (wood mice, bank voles and shrews), resulting from the loss of their habitat and, in part, their food supply, in grassland, woodland and heathland communities of the forest were demonstrated to be the direct result of sustained heavy grazing pressure over many years (Hill, 1985). This, in turn, was shown to have had an effect on the foraging behaviour, diet, population density and breeding success of a diverse array of predators, such as foxes, badgers, buzzards, kestrels and tawny owls (Putman, 1989; Tubbs, 1997; Van Wieren, 1998). It is also likely to have had an impact on adders and smooth snakes, both of which include small mammals in their diet.

Lowland heathland is an example of a nutrient deficient successional habitat in which grazing has been used as a means of slowing down its succession to woodland. However, grazing has been shown to accelerate the succession of lowland heath to woodland as a direct result of the addition of nitrogen from the dung deposited by the grazers (Mitchell et al., 2000; Bokdam, 2002; Strijbosch, 2002). Grazing also removes the litter layer, that sequesters nitrogen, making more available for plant growth (Hay & Kicklighter, 2001) and hence also accelerating succession. In addition cattle do not prevent the encroachment of pine and birch trees (Bokdam & Gleichman, 2000; Bokham, 2002).

3. SUMMARY OF MAJOR EFFECTS OF GRAZING ON HABITATS

The major effects of grazing, by domestic livestock, are essentially the same irrespective of the habitat type being grazed. They are:

- Grazing removes plant biomass.
- Grazing breaks down the structure of the habitat by reducing plant height, ground cover and the litter layer resulting in a simpler overall structure.
- Grazing increases the area of bare soil.
- Grazing increases the rate of succession to woodland in nutrient poor habitats (acid grasslands and heathlands) as a direct result of nitrogen added via dung from the grazers.
- Grazing results in higher plant species diversity, particularly on grasslands.
- Grazing results in a simpler habitat structure that supports a less diverse animal community than a habitat with a more complex structure.

4. THE KNOWN EFFECTS OF GRAZING ON REPTILE POPULATIONS

Although scientific literature reporting the results of studies on the effects of grazing on reptile populations are absent for the six species of British reptiles, such information is available for countries where livestock grazing has been the most widespread land management practice since late 1800's e.g. The United States of North America, Mexico, Argentina and Australia. Reviews about the impacts of grazing on entire ecosystems, including reptiles, though not focusing on them, have been done by Fleischer (1994) and Belsky et al. (1999). Publications where the effects of grazing and burning were studied together have also been included in the review presented here.

The results of this review show that, although the impact of grazing on reptiles vary, the overall effects were common to most of the studies. In general, grazing resulted in a simplification of the vegetation structure, particularly in height and cover, and a loss, or reduction, of the litter layer as a consequence of active biomass removal. Grazing and trampling led to an overall decline in reptile population abundance, changes in reptile species composition, and reduced reptile diversity in the majority of the habitat types where it was studied.

In this review the impacts of grazing on reptile's populations have been classified as positive, negative or neutral, and are shown below by country and affected habitat type.

4.1 *POSITIVE impacts of grazing on reptiles*

United Stated of America (USA)

Sedge meadows fed by ground water in the north east of the USA. Low intensity grazing by cattle had a positive impact on the maintenance of the bog turtle (*Glyptemys muhlenbergii*) microhabitat, reducing the cover of invasive plant species, which had invaded the area due to nutrient enrichment from manure and agricultural runoff (Tesauro & Ehrenfeld, 2007).

4.2 *NEGATIVE impacts of grazing on reptiles*

The Netherlands

- Heathland grazed by cattle. Common lizard (*Zootoca vivipara*) populations were 3-5 times higher in un-grazed areas compared to grazed areas (Strijbosch, 2002).
- Heathland nature reserves grazed by cattle. After grazing was introduced to arrest succession, sand lizard (*Lacerta agilis*) populations declined and common lizards, slow worms (*Anguis fragilis*) and smooth snakes (*Coronella austriaca*) were eradicated due to the probable reduction of prey species resulting from reduced vegetation cover. Although habitat macro-diversity was maintained by grazing, the micro-diversity disappeared (Strijbosch, 2002).

United Stated of America (USA)

- Streams and riparian habitats grazed by cattle: reviews by Fleischer (1994) and Belsky et al. (1999).
- Desert grassland grazed by livestock. Cattle trampled young desert tortoises (*Gopherus agassizy*), damaged burrows and shrubs used for shelter and removed critical forage (Berry, 1978; Campbell, 1988).

- Heavily grazed chaparral, desert grassland, mixed riparian scrub and cotton-wood willow vegetative communities. The abundance of the 20 lizard species were compared between the five habitat types, defined by their plant communities, under lightly grazed and heavily grazed regimes. Lizard abundance and diversity were 4-5 times higher on un-grazed sites in four of the five vegetation cover types. No difference was found between the two grazing regimes (Jones, 1981).
- Streams and riparian habitats grazed by cattle. Grazing along the edges of water sources reduced the vegetative cover used by the garter snake (*Thamnophis elegans vagrans*) for foraging and to escape from predators. The abundance of the garter snake was five times higher in un-grazed areas compared to grazed areas (Szaro et al., 1985).
- Mojave desert grassland grazed by sheep. Lizards: 5 species. The abundance of 5 species of lizard was two times higher and their biomass four times higher on un-grazed sites compared to grazed sites. Lizard diversity was greater in un-grazed sites. (Busack & Bury, 1974).
- Desertified arid grassland grazed by cattle. The abundance of the Bunch-grass lizard (*Sceloporus scalaris slevini*), which is extremely vulnerable to predation, was 10 times greater in an area protected from cattle grazing for 20 years compared to a grazed area in the same vicinity. The results were attributed to the destruction of bunchgrass tussocks which were used by the lizards as refuges against predation while foraging (Bock et al., 1990)
- Desertified arid grassland restored by suppressing cattle access. Eight species of lizard: In un-grazed areas, total lizard diversity and the abundance of two species increased. In grazed areas the abundance of one species increased but there was also an increase in tail-break frequency suggesting higher predation pressure. The removal of livestock and subsequent recovery of perennial grass cover resulted in a sharp increase in total lizard abundance (Castellano & Valone, 2006).
- Mountain ranges in the western Great Basin grazed by feral horses. Reptiles present: 9 lizard species and 5 snake species. There was greater lizard species richness in un-grazed areas than grazed areas and total reptile abundance was 2 times higher for 7 species. Only 7 snakes were observed, 6 occurring in the un-grazed areas (Beever & Brussard, 2004).
- Chaparral grazed by cattle. Rotational grazing and winter burning, implemented for conservation, resulted in reduced survival of the threatened Texas horned lizard (*Phyronosoma cornutum*) (Helgren et al., 2010).

Mexico

- Tropical deciduous forest grazed by cattle. The abundance of four, out of five lizard species, was 3-7 times (4 times on average) lower in the grazed area than in the un-grazed area. The differences were attributed to changes in the vegetation structure, particularly through the reduction of the ground cover and the height of the grasses and forbs (Romero-Schmidt et al., 1994).
- Xerophyte scrub grazed by cattle. Reptiles present: 3 lizard species. In grazed areas the abundance of one species not affected and the abundance of one species was 2 times higher. In un-grazed areas the abundance of one species was 2.5 times higher than in grazed areas (Romero-Schmidt & Ortega-Rubio, 1999).

Argentina

- Chaco forest in the west of Argentina after 25 years of restoration, based on grazing suppression. Reptiles present: 18 snake species and 14 lizard species. Overall snake and lizard diversity was un-affected. In un-grazed areas the abundance of 2 species of snake and 2 species of lizard increased. In grazed areas the abundance of one species of snake and 3 species of lizard increased (Leynaud & Bucher, 2005).
- Arid Chaco semi-deciduous woodland following restoration after being grazed by cattle and goats. Reptiles present: 10 lizard species. Compared the effects of grazing regimes on reptiles. In the un-grazed, restored areas there was higher species richness, a higher diversity index and a higher relative abundance value. Four species were more abundant in un-grazed areas whereas 2 species were more abundant in grazed areas (Pelegrin & Bucher, 2012).

Australia

- Tropical savannah woodland (western Australia) grazed by cattle. Reptiles present: 18 lizard species. The abundance of 5 species declined in grazed sites. The abundance of one skink species was reduced by both burning and grazing (Kutt & Woinarsky, 2007).
- Arid grassland under different intensities of cattle grazing. Reptiles present: 38 lizard species. The diversity, and the number of captures of geckos and skinks, was reduced on heavily grazed sites. Agamid lizard captures increased in heavily grazed areas (Read & Cunningham, (2010).

4.3 *NEUTRAL impacts of grazing on reptiles*

Australia

- Chenopod grassland grazed by cattle. Reptiles present: 4 snake species, 2 blind snake species, 27 lizard species. Although the grass cover decreased significantly as the result of biomass removal by cattle, the abundance of only one lizard species changed significantly (increased) in the grazed area one year after the cattle were removed. No changes were observed in experiments involving different grazing intensities. The results were attributed to the short duration (24 days in total) of the grazing impact (Read, 2002).

The impact of grazing on the plant communities where changes in reptile populations and communities were observed were:

- Increased cover of low-growing vegetation, reduced height of tall-growing exotics and invasive vegetation (Tesauro & Ehrenfeld, 2007).
- Reduced vegetation structure: height and cover, and an increase in the amount of bare ground (Busack & Bury, 1974; Jones, 1981; Szaro et al., 1985; Bock et al., 1990; Fleischer, 1994; Romero-Schmidt et al., 1994; Belsky et al., 1999; Romero-Schmidt & Ortega-Rubio, 1999; Read, 2002; Beever & Brussard, 2004; Read & Cunningham, 2010).
- Increased ground cover and vegetation complexity in restored habitats (Castellano & Valone, 2006).
- Decreased total ground cover, an increase in the amount of bare ground and a decrease in foliage cover. Combined burning and grazing also increased the cover of forbs (Kutt & Woinarski, 2007).
- Reduced litter depth; reduced grassland height and vegetation ground cover, reduced shrub cover. Significantly reduced plant community richness (Leynaud & Bucher, 2005; Pelegrin & Bucher, 2012).
- Changes in vegetation cover: increased forb cover and woody canopy cover (Helgren et al., 2010).

5. THE HABITATS WHERE BRITISH REPTILES ARE FOUND

The habitats where the six native British reptile species occur must first be identified before the potential impact of grazing on these habitats, and on the reptile populations occurring in them, can be investigated. In order to identify the full range of habitat types used by native British reptiles, particularly the common species (adder, grass snake, common lizard and slow worm), which are more widely dispersed than the two rare species (smooth snake and sand lizard), data collected between 03/07/1708 and 31/12/2001 by the Biological Records Centre (BRC) were used (records since 01/01/2002 were not available).

Unfortunately, a high proportion of the total BRC records do not have a habitat type assigned to them and therefore only those records which gave the habitat type where each species was captured, or seen, could be used. The number of records and the number providing habitat data for snakes and lizards are shown in Table 2 and Table 3 respectively. The records, with known habitats for snakes and lizards, are presented separately in Tables 4 and 5 respectively.

Table 2. Proportion (%) of the BRC snake records with assigned habitat types.

Species	Total number of records	Assigned habitat
Smooth snake	163	1 (0.61 %)
Grass snake	2,645	842 (31.83 %)
Adder	3,221	1,096 (34.03 %)

Table 3. Proportion (%) of the BRC lizard records with assigned habitat type.

Lizard species	Total number of records	Assigned habitat
Sand lizard	431	12 (2.78 %)
Common lizard	3,517	1,516 (43.10 %)
Slow worms	2,826	845 (29.9 %)

Table 4. Number (and %) of smooth snake (Ca), grass snake (Nn) and adder (Vb) records in each habitat type. Data courtesy of the Biological Records Centre (BRC).

BRC Habitat designation	Habitat Code	Ca		Nn		Vb	
		N	%	N	%	N	%
Airfield	2	-	-	3	0.4	-	-
Allotments	3	-	-	1	0.1	-	-
Ants nest	8	-	-	-	-	-	-
Arable land/farmland	3	-	-	10	1.2	4	0.4
Canal	1	-	-	5	0.6	-	-
Canal-side	1	-	-	5	0.6	-	-
Caravan site	2	-	-	-	-	-	-
Chalk grassland/downland	2	-	-	7	0.8	23	2.1
Chalk or gravel pit	6	-	-	39	4.6	5	0.5
Chicken hatchery/henhouse	8	-	-	1	0.1	-	-
Churchyard	2	-	-	2	0.2	1	0.1

Table 4 (cont'd). Number (and %) of smooth snake (Ca), grass snake (Nn) and adder (Vb) records in each habitat type. Data courtesy of the BRC.

BRC Habitat designation	Habitat Code	Ca		Nn		Vb	
		N	%	N	%	N	%
Cliff top	2	-	-	1	0.1	9	0.8
Compost heap	4	-	-	8	1.0	-	-
Conifer plantation	7	-	-	31	3.7	51	4.7
Copse	5	-	-	3	0.4	3	0.3
Deciduous wood	5	-	-	27	3.2	20	1.8
Dewpond	1	-	-	1	0.1	-	-
Ditch/dyke	1	-	-	31	3.7	2	0.2
Farm buildings	8	-	-	-	-	-	-
Farmyard	8	-	-	1	0.1	-	-
Football pitch/playing field	2	-	-	2	0.2	-	-
Garden	3	-	-	66	7.8	9	0.8
Garden pond	1	-	-	4	0.5	-	-
Golf course	2	-	-	4	0.5	2	0.2
Grass bank	2	-	-	10	1.2	7	0.6
Hay/straw stack	4	-	-	1	0.1	-	-
Hedgerow	5	-	-	16	1.9	8	0.8
Hill pasture	2	-	-	2	0.2	-	-
Inside house	8	-	-	-	-	-	-
In sea	8	-	-	3	0.4	-	-
Lake	1	-	-	7	0.8	-	-
Limestone grassland	2	-	-	-	-	2	0.2
Manure heap	4	-	-	6	0.7	-	-
Marsh	1	-	-	33	3.9	18	1.6
Meadow/pasture	2	-	-	17	2.0	5	0.5
Mixed/unspecified woodland	5	-	-	148	17.6	281	25.6
Moorland/heathland	7	1	100	95	11.3	430	39.2
On road	8	-	-	38	4.5	13	1.2
Orchard	5	-	-	4	0.5	2	0.2
Parkland	2	-	-	6	0.7	2	0.2
Pond	1	-	-	28	3.3	1	0.1
Quarry	6	-	-	6	0.7	5	0.5
Railway track/embankment	5	-	-	23	2.7	38	3.5
Reed bed	1	-	-	3	0.4	2	0.2
Reservoir	1	-	-	-	-	1	0.1
River	1	-	-	6	0.7	-	-
Road verge/lay-by	2	-	-	12	1.4	17	1.6
Rough grass/grass moor	2	-	-	22	2.6	27	2.5
Rubbish dump	8	-	-	-	-	-	-
Sand dunes	2	-	-	2	0.2	25	2.3
Sawdust heap	4	-	-	1	0.1		
Scrub	5	-	-	52	6.2	41	3.7
Sea shore	2	-	-	3	0.4	24	2.2
Sea wall	2	-	-	1	0.1	-	-
Sewage farm	2	-	-	1	0.1	-	-
Stone wall	6	-	-	1	0.1	7	0.6
Stream	1	-	-	4	0.5	-	-
Stream/river side	1	-	-	23	2.7	5	0.5
Under tin etc	8	-	-	6	0.7	5	0.5
Water meadows	1	-	-	10	1.2	1	0.1

Table 5. Number (and %) of sand lizard (La), common lizard (Zv) and slow-worm (Af) records in each habitat type. Data courtesy of the Biological Records Centre (BRC).

BRC Habitat designation	Habitat Code	La		Zv		Af	
		N	%	N	%	N	%
Airfield	2	-	-	-	-	-	-
Allotments	3	-	-	2	0.1	4	0.5
Ants nest	8	-	-	3	0.2	1	0.1
Arable land/farmland	3	-	-	11	0.7	4	0.5
Canal	1	-	-	-	-	-	-
Canal-side	1	-	-	3	0.2	-	-
Caravan site	2	-	-	1	0.1	-	-
Chalk grassland/downland	2	-	-	26	1.7	12	1.4
Chalk or gravel pit	6	-	-	40	2.6	12	1.4
Chicken hatchery/henhouse	8	-	-	-	-	-	-
Churchyard	2	-	-	4	0.3	16	1.9
Cliff top	2	-	-	9	0.6	9	1.1
Compost heap	4	-	-	-	-	9	1.1
Conifer plantation	7	-	-	21	1.4	11	1.3
Copse	5	-	-	-	-	-	-
Deciduous wood	5	-	-	18	1.2	11	1.3
Dewpond	1	-	-	-	-	-	-
Ditch/dyke	1	-	-	4	0.3	4	0.5
Farm buildings	8	-	-	2	0.1	1	0.1
Farmyard	8	-	-	-	-	-	-
Football pitch/playing field	2	-	-	-	-	2	0.2
Garden	3	-	-	54	3.6	115	13.6
Garden pond	1	-	-	2	0.1	3	0.4
Golf course	2	-	-	1	0.1	2	0.2
Grass bank	2	-	-	11	0.7	19	2.2
Hay/straw stack	4	-	-	-	-	1	0.1
Hedgerow	5	-	-	43	2.8	23	2.7
Hill pasture	2	-	-	-	-	-	-
Inside house	8	-	-	-	-	2	0.2
In sea	8	-	-	-	-	-	-
Lake	1	-	-	1	0.1	-	-
Limestone grassland	2	-	-	1	0.1	-	-
Manure heap	4	-	-	-	-	1	0.1
Marsh	1	-	-	6	0.4	7	0.8
Meadow/pasture	2	-	-	3	0.2	6	0.7
Mixed/unspecified woodland	5	-	-	184	12.1	150	17.8
Moorland/heathland	7	8	66.7	620	40.9	109	12.9
On road	8	-	-	9	0.6	13	1.5
Orchard	5	-	-	1	0.1	6	0.7
Parkland	2	-	-	4	0.3	4	0.5
Pond	1	-	-	1	0.1	-	-
Quarry	6	-	-	18	1.2	8	0.9
Railway track/embankment	5	-	-	55	3.6	49	5.8
Reed bed	1	-	-	-	-	1	0.1
Reservoir	1	-	-	1	0.1	-	-
River	1	-	-	-	-	-	-
Road verge/lay-by	2	-	-	56	3.7	17	2.0
Rough grass/grass moor	2	-	-	35	2.3	38	4.5
Rubbish dump	8	-	-	2	0.1	1	0.1
Sand dunes	2	3	25.0	96	6.3	12	1.4

Table 5 (cont'd). Number (and %) of sand lizard (La), common lizard (Zv) and slow-worm (Af) records in each habitat type. Data courtesy of the Biological Records Centre (BRC).

BRC Habitat designation	Habitat Code	La		Zv		Af	
		N	%	N	%	N	%
Sawdust heap	4	-	-	-	-	-	-
Scrub	5	1	8.3	98	6.5	73	8.6
Sea shore	2	-	-	19	1.3	3	0.4
Sea wall	2	-	-	2	0.1	-	-
Sewage farm	2	-	-	-	-	1	0.1
Stone wall	6	-	-	30	2.0	14	1.7
Stream	1	-	-	1	0.1	1	0.1
Stream/river side	1	-	-	9	0.6	6	0.7
Under tin etc	8	-	-	7	0.5	58	6.9
Water meadows	1	-	-	1	0.1	5	0.6

The number of categories ('habitat types') found in the records was too many to be useful in an analysis of habitat preference (60 for snakes and 61 for lizards). As many effectively overlapped, these data were simplified by clustering them into eight broad habitat categories (Table 6).

Table 6. The percentage occurrence of reptiles in each of 8 broad categories of habitat. See previous tables of BRC records to see which habitats were combined into the codes shown here. Smooth snake (Ca), Grass snake (Nn), Adder (Vb), Sand lizard (La), Common lizard (Zv), Slow-worm (Af). The total number of habitat records for each species are shown in parenthesis. Based on data provided by the Biological Records Centre (BRC).

Code	Broad habitat description	Ca (1) %	Nn (842) %	Vb (1,096) %	La (12) %	Zv (1,516) %	Af (845) %
1	Associated with/adjacent to fresh water	-	19.0	2.7	-	2.0	3.3
2	Grassland of various types	-	11.3	13.1	25.0	17.7	16.7
3	Land associated with cultivation	-	9.1	1.2	-	4.4	14.6
4	Rotting/stacked plants/plant remains	-	1.9	-	-	-	1.2
5	Woodland and scrub	-	32.4	35.9	8.3	26.3	36.9
6	Rocky areas of various types	-	5.5	1.6	-	5.8	4.0
7	Heathland/moorland/conifer plantations	100.0	15.0	43.9	66.7	42.3	14.2
8	Other	-	5.8	1.6	-	1.5	9.1

The relatively few records of smooth snakes and sand lizards on heathland, where they are known they occur, along with the other four endemic British reptile species, can be explained by both, the secretive nature of these reptiles, and the fact that unless a planned survey is carried out, surveyors tend to look only where they expect to find reptiles, thereby overlooking and/or ignoring other areas.

6. SPECIES SPECIFIC HABITAT REQUIREMENTS OF BRITISH REPTILES

6.1 *SMOOTH SNAKE* (Coronella austriaca)

6.1.1 *Habitat preferences*

The smooth snake is the UK's rarest snake, being confined to the lowland heathlands of Dorset, Hampshire and Surrey (Spellerberg & Phelps, 1977; Pernetta, 2009). Other habitats used by this species are: woodland margins, wet heath, and bogs adjacent to heaths, and commercial pine plantations within lowland heathlands (Goddard, 1981; Gent, 1988; Reading, 2004; Pernetta, 2009; Jofré, 2011).

Although smooth snake habitat use has not been studied in depth in the UK, their general qualitative habitat requirements are known (Spellerberg & Phelps, 1977; Goddard, 1981; Gent, 1988; Pernetta, 2009; Jofré, 2011). The habitat types 'favoured' by this snake have been described following the criterion that 'higher densities indicate more favourable habitats', the same criteria has also been applied for the other native reptile habitats.

There are three factors common to all habitats used by the smooth snake, both in Europe and the UK: the presence of a substratum in which the snakes can burrow, a dense ground cover layer where they can hide, and an upper stratum, which may provide shelter during extreme high summer temperatures, as well as preventing extreme low temperatures during the winter. (Spellerberg & Phelps, 1977).

The optimum habitat of this snake consists of gentle, and well drained, south or south-east facing slopes, with some low density woodland amongst a mixed grassland-tall mature heathland community that is interspersed with small patches of bare ground (Spellerberg & Phelps, 1977). Within this landscape, this species favours deep stands of mature heather, usually older than 20 years (in some instances 30 to 40 years old), with deep basal pads of bryophytes and lichens within the heather bushes (Braithwaite et al,. 1989). Within the lowland heaths forming part of Wareham Forest, Dorset, the smooth snake has been extensively studied in an east–west orientated mature heathland site that si dominated by mature heather *Calluna vulgaris*, with numerous small patches of open sandy ground sometimes covered by moss, and with areas of Purple moor grass (*Molinia caerulea*), scattered gorse (*Ulex europaeus* and *Ulex minor*), and the occasional small (<3 m high) conifer *Pinus sylvestris* (Reading, 2004). This site was surrounded by commercial conifer plantations.

In an on-going study in Wareham Forest (2009-present), funded by the Forestry Commission, investigating how commercial pine plantations of different ages and structure, are used by all six species of native British reptile, plantations were grouped into four broad age categories: Sites A: planted between 1930 and 1966; Sites B: planted between 1975 and 1987; Sites C: planted between 1994 and 2001, and Sites D: planted between 2003 and 2006 (Jofré, 2011). Within a managed forest regime, like this, the suitable habitat for some reptile species is transient, lasting only as long as the time taken for the trees to reach a sufficient height and tree canopy cover, to reduce incident ground light levels to a point where ground cover vegetation dies back. The duration of this period depends on the rate of growth of the trees and their density.

Smooth snakes colonise the new plantations once the heather/ground vegetation cover has grown back. However, the arrival of smooth snakes in new plantations appears not to be only determined by the availability of suitable habitat but also by the close proximity to sites, with a high number of snakes, which can act as 'source' populations.

Evidence of smooth snake breeding has been found in 7-10 year-old plantations with a well-developed ground cover (approximately 80%) dominated by tall (>50cm height) *Calluna vulgaris* (65 %), and smaller proportions of *Erica cinerea* (approximately 10 %) and *Molinia caerulea* (<5 %). Smooth snake were largely absent from plantations greater than 20 years old (Figure 1).

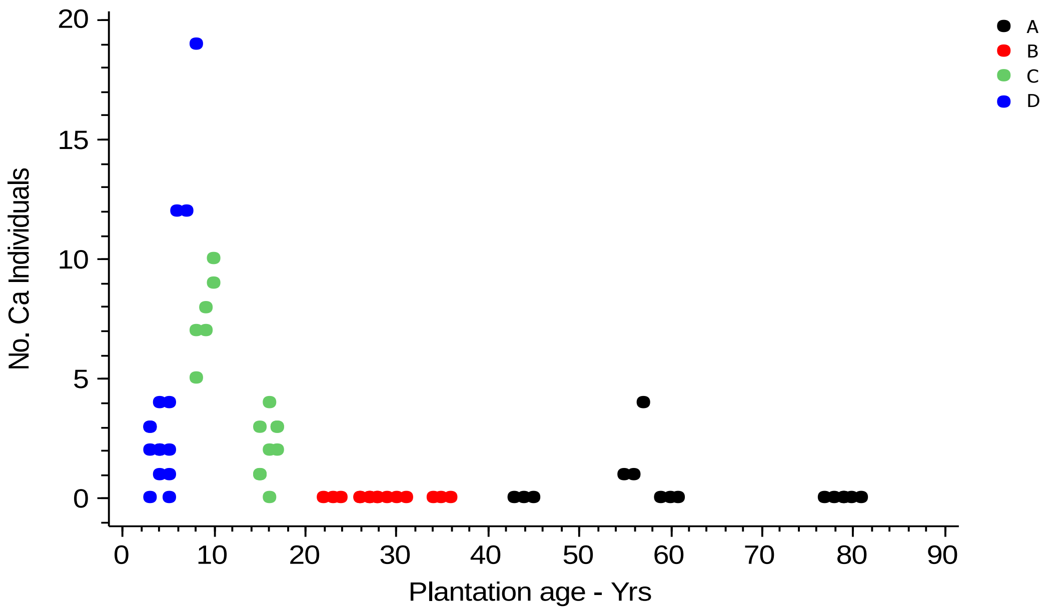

Figure 1. Total number of individual smooth snakes captured in plantations of different ages (A, B, C, D) between 2009 and 2011.Courtesy of the Forestry Commission.

The relationship between plantation age and the mean tree height, in the plantations where the reptiles were surveyed, is shown in Figure 2.

6.1.2 *Diet*

The composition of the diet of the smooth snake in Britain has been studied using faeces and regurgitated material (Spellerberg & Phelps, 1977; Goddard, 1984). Smooth snakes feed mainly on small mammals (rodents and shrews), particularly nestling individuals; and on reptiles (common lizards, sand lizards and slow worms). Some insects, such as beetles and crickets, may also occasionally be form part of their diet. In the absence of information relating to prey selection or preference on small mammal or lizards, the smooth snake can be considered to be an opportunistic predator, feeding without preference on both types of prey in according to their availability. The diet composition of this snake has also been analysed in the Mediterranean (Rugiero et al., 1995) where it also includes some invertebrates (orthopterans and oligochaetes) and juvenile smooth snakes and adders.

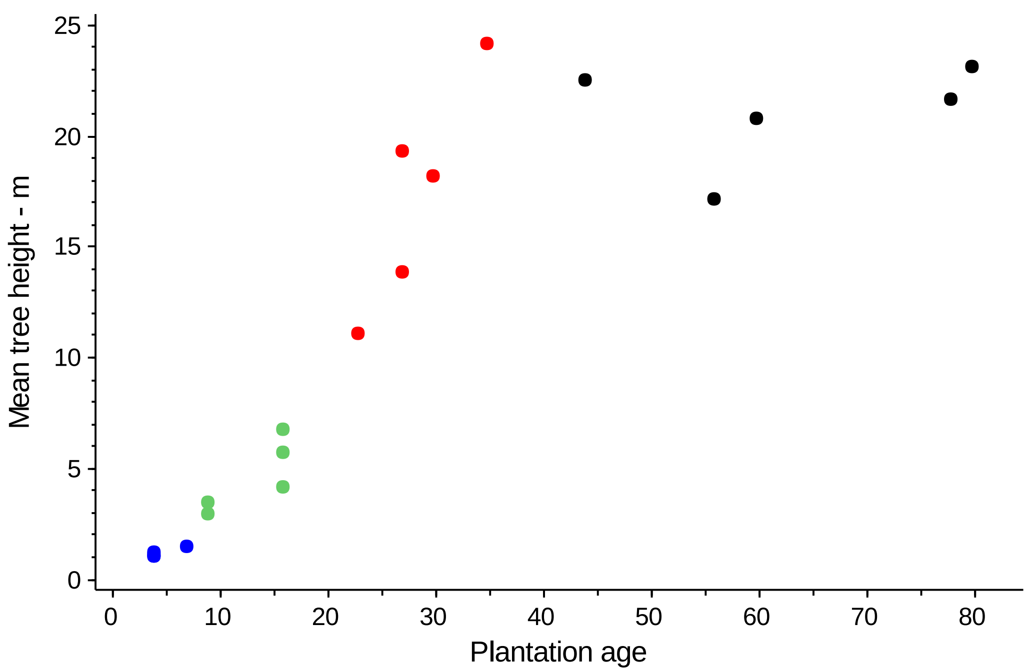

Figure 2. Relationship between plantation age and mean tree height in various pine plantations in Wareham Forest. Courtesy of the Forestry Commission.

6.1.3 *Movements*

Studies of movement behaviour of the smooth snake suggests that this species is relatively sedentary and has only a limited potential for dispersal and colonising new areas (Spellerberg & Phelp, 1977; Goddard 1981). Smooth snakes have low median daily movement rates of 13.30m/day (Gent & Spellerberg, 1993) and a mean home range size for adult males and females of 1.850ha (0.537-3.879ha), and 0.871ha (0.325-0.619ha) respectively, (Reading in preparation). In addition, smooth snakes do not appear to have different summer and winter ranges (Phelps, 1978). Sites where they occur therefore provide all their requirements e.g. for feeding, thermoregulating, shelter and protection (Gent & Spellerberg, 1993).

6.2 *GRASS SNAKE* (Natrix natrix)

6.2.1 *Habitat preferences*

The grass snake is one of the most widespread species of snake in Europe, ranging from northern Africa to Scandinavia and across Europe east to Lake Baikal (Beebee & Griffiths, 2000). In Britain, this snake is widely distributed in England and Wales but is absent from Scotland. They occur in a wide range of habitats, usually close to ponds (disused water quarry pits, or clay pits), lakes and river banks, and open woodlands (Smith, 1964) where their main prey (amphibians) occurs. They are also found along the edges of paths and banks covered with dense ground vegetation, including stinging nettles (*Urtica dioica*), bramble (*Rubus fruticosus*) and hawthorn (*Crataegus monogyna*) (Reading & Davies, 1996; Gregory & Isaac, 2004). Common attributes of habitats preferred by the grass snake are a combination of basking site availability and close proximity to relatively dense vegetation that offers potential protection from predators. These habitat requirements are found at the interface between different types of vegetation. For example, in an agricultural landscape in southern England, the grass snake occurred along the deciduous woodland/pasture field interface, the deciduous woodland/pond interface as well as in field and garden hedges and banks (Reading & Jofré, 2009). Grass snakes avoid open spaces with little or no cover (Brown, 1991; Reading & Jofré, 2009). Grass snakes use field boundaries as corridors to access different parts of the landscape (Madsen, 1984; Brown, 1991; Reading & Jofré, 2009) that have been modified and fragmented as a result of human activities.

In the Wareham Forest reptile habitat preference study, grass snakes colonised the new pine plantations once the heather/ground vegetation cover had grown back, a little sooner (1-2 years) than smooth snakes, possibly due to their greater vagility compared to the more sedentary smooth snake. Grass snakes used all plantations, including open old plantations whose ground cover comprised *Molinia caerulea* or *Calluna vulgaris*. Evidence of grass snake breeding was found in plantations near to ponds and ditches. The number of individual grass snakes captured in pine plantations of different ages is shown in Figure 3.

6.2.2 *Diet*

Grass snakes feed mainly upon amphibians, particularly anurans (frogs and toads). The anuran species found in their diet varies geographically and is assumed to be related to their availability in a particular area (Gregory & Isaac, 2004; Reading & Davies, 1996). Grass snakes are also known to feed on, small mammals (rodents and shrews), fish and birds (Gregory & Isaac, 2004; Reading & Davies, 1996).

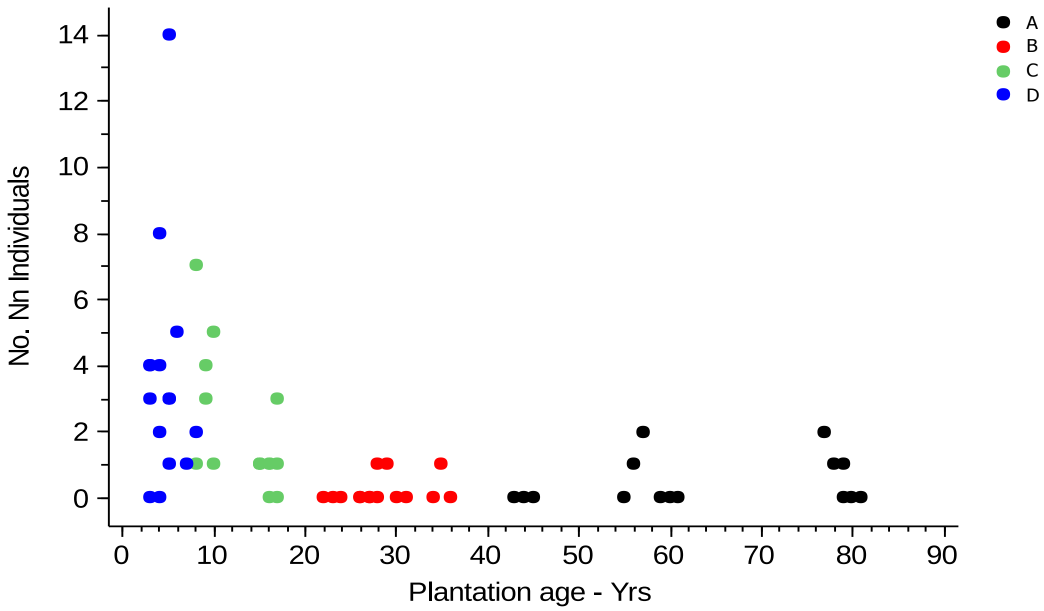

Figure 3. Total number of individual grass snakes captured in plantations of different ages (A, B, C, D) between 2009 and 2011.Courtesy of the Forestry Commission.

6.2.3 *Movements*

Grass snakes are a very mobile species capable of moving in excess of 100m/day and generally occupy large home ranges of 0.18-9.41 ha (Madsen, 1984; Reading & Jofré, 2009).

6.3 *ADDER* (Vipera berus)

6.3.1 *Habitat preferences*

The Adder is the most widespread snake in the UK, occurring in England, Scotland and Wales. Its favoured habitats include sandy heathland, open moorland, grassland with a dense sward and low scrub, including acid and chalk grassland, clearings and rides in deciduous or coniferous woodland. They are also found in coastal dune systems and cliffs. Dry open, sunny areas and slopes, suitable for basking, which are adjacent to dense ground vegetation cover appear to be essential. Crevices in banks, piled material and root systems on south facing slopes are used as hibernation sites (Prestt, 1971). During the summer months they often frequent wetter areas alongside, or adjacent to, river banks, lakes, bogs and mires (Smith, 1964; Edgar et al., 2010).

6.3.2 *Diet*

Adders feed primarily on small mammals such as voles, shrews, and mice, as well as small lizards and ground nestling birds (Prestt, 1971).

6.3.3 *Movements*

Adders make seasonal migrations between summer areas where they feed on small mammals and winter areas where they hibernate (Prestt, 1971).

6.4 *SAND LIZARD* (Lacerta agilis)

6.4.1 *Habitat preferences*

This species is confined to two habitats types in Britain: lowland heathlands, where over 95% of the national population occur, and sand dune ridges (House & Spellerberg, 1983; Edgar, Foster & Baker, 2010).

Sand lizards occur in areas of dry heathland with high levels of structural diversity. These areas usually consist of open ground and heather stands of different ages in areas with local topographical variation, usually on warm south facing slopes such as banks and ridges (House & Spellerberg, 1983; Fearnley, 2009). The presence of shrubs, up to 100cm tall, dense scrub e.g. *Ulex* species, and patches of structured grasses like *Molinia* are also important structural components of the habitat of this lizard (House & Spellerberg, 1983).

In addition, Sand lizards can also occur in sub-optimal habitat types such as wet heath or bog, rough grassland, scrub, mineral working, hedgerows, railway embankments, roadside verges and urban gardens bordering heathland (Fearnley, 2009). In commercial conifer plantations, sand lizards are early colonisers of new pine plantations following the felling of the mature trees and the subsequent planting of new trees on bare ground (Jofré, 2011). They are largely absent from conifer plantations greater than 10 years old. Open un-planted spaces, newly planted areas and ride verges also appear to provide suitable habitats for this species (Dent & Spellerberg, 1988).

In the Wareham Forest reptile habitat preference study the total number of sand lizard sightings in pine plantations of different ages is shown Figure 4. Adult sand lizards were observed during courtship in relatively newly planted plantations, with areas of bare ground and where the main ground cover vegetation, where present, consisted of a mosaic of *Agrostis curtisii*, *Calluna vulgaris*, *Erica cinerea* and scattered gorse (*Ulex sp*) and broom (*Cytisus scoparius*) bushes. Courtship was also observed in an open plantation with a good ground cover of tall *Calluna vulgaris*.

6.4.2 *Diet*

Sand lizards forage both on the ground and within the scrub canopy. Their diet consists mainly of insects, spiders, opiliones and crustacean (Nicholson, 1980). This group of invertebrates, are generally associated with heathland habitats with a high level of structural diversity: bare ground, rabbit disturbance, mature flowering heather, dung and patches of scrub (Fearnley, 2009), and are particularly abundant in the ‘interface areas’ of heathland with other habitat types eg. heathland /grassland (Fearnley, 2009).

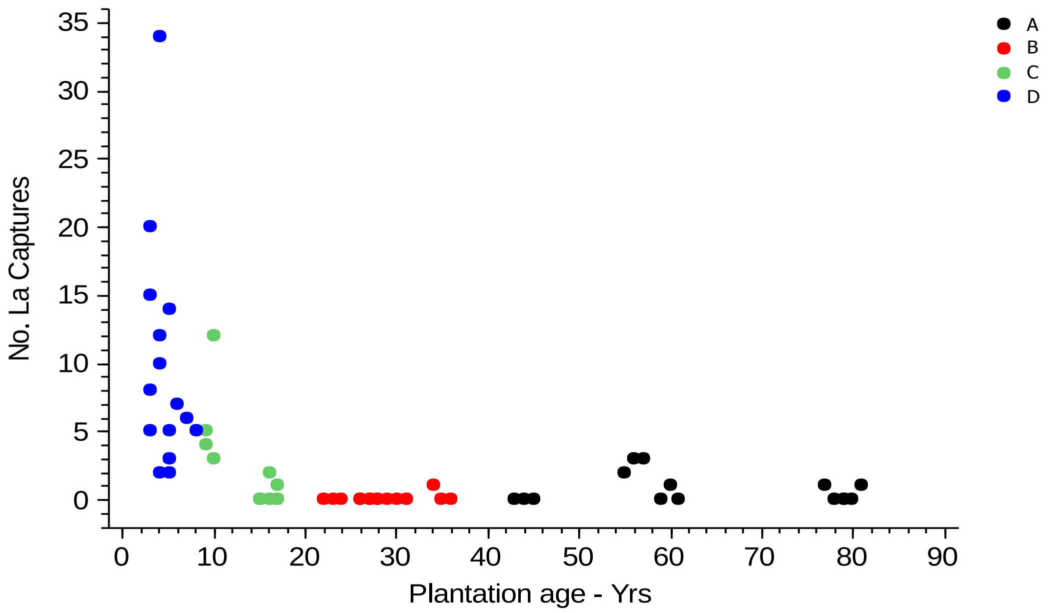

Figure 4. The total number of sand lizard sightings recorded in plantations of different ages (A, B, C, D) between 2009 and 2011. Courtesy of the Forestry Commission.

6.4.3 *Reproduction*

In June females excavate burrows in sandy substratum where they lay their eggs. The areas selected for egg laying by females usually receive large amount of sunlight (Beebee & Griffiths, 2000).

6.5 *COMMON LIZARD* (Zootoca vivipara)

6.5.1 Habitat preferences

Common Lizards are widely distributed throughout the UK and although they are commonly associated with rough grass, can be found in a wide range of habitats types. The habitat preferences of the common lizard have been studied in heathland in the The Netherlands, along a succession from inland dune to closed oak-birch forest. This species colonises areas at an early successional stage that is dominated by young, open dry heathland vegetation. The high population densities observed in the transitional stages, from mature heathland to mature heathland with dispersed pioneer shrubs, all characterised by a rich vegetation structure with a strong spatial heterogeneity, suggest that it is their optimum habitat (Strijbosch, 1999). A subsequent population decline was observed following an invasion of the site by pioneer oak and birch trees. The population finally disappeared once a relatively open oak-birch forest was established and dominated the area.

In the Wareham Forest reptile habitat preference study common lizards colonised newly planted sites at an early successional stage dominated by low heather and patches of grass. Total number of common lizard sightings, in the Wareham Forest pine plantations of different ages, between 2009 and 2011 are shown in Figure 5. As with sand lizards, common lizards were largely absent from conifer plantations greater than 10 years old.

Adults and new born were observed in newly planted plantations where the main ground cover vegetation consisted of a mosaic of *Molinia caerulea*, *Calluna vulgaris* and scattered gorse bushes (*Ulex sp*). Evidence of common lizard breeding was also found in old plantations where the ground cover consisted almost completely in *M. caerulea*.

6.5.2 *Diet*

Common lizards feed mainly on arthropods. Although common lizards may be considered to be generalist predators, their diet generally reflecting the abundance of prey species in their environment (Avery, 1966; Diaz, 1995), they do tend to select soft prey such as spiders (*Aranae*) and flies (*Diptera*), avoiding tougher prey such beetles (Roig-Fernandez, 1997).

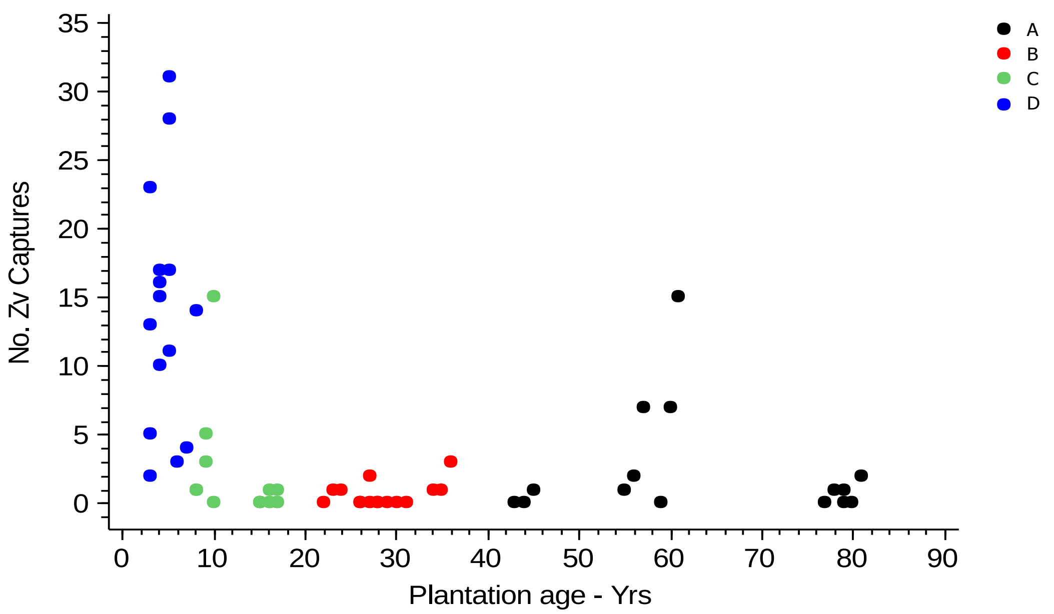

Figure 5. The total number of common lizard sightings recorded in plantations of different ages between 2009 and 2011. Courtesy of the Forestry Commission.

6.5.3 *Reproduction*

In Britain, adult females reproduce annually and require a sheltered humid microhabitat in which to give birth (Edgar, Foster & Baker, 2010).

6.6 *SLOW WORM* (Anguis fragilis)

6.6.1 *Habitat preferences*

The slow worm occurs in herbaceous microhabitats with a high vegetation cover, and is often found under flat stones and logs. Slow worms are morphologically and physiologically adapted to a semi-subterranean life. Because of their secretive, semi-fossorial habits, few studies on their ecology have been made (Cabido et al., 2004). Slow worms probably spend much of their life under ground or in thick herbage at the surface (Beebee & Griffiths, 2000).

In the Wareham Forest reptile habitat preference study slow worms colonised the newly planted areas following the felling of the mature trees and the subsequent planting of new trees on bare ground. Though this species was the most widely dispersed within the forest, occurring in plantations of all ages, they appear to favour some of the oldest plantations, particularly those with an open aspect and a dense ground cover of Purple Moor grass (*M. caerulea*). New-born slow worms were found in all plantations, independent of the ground cover.

Slow worms hibernate underground in burrows, in loose soil and in dense vegetation.

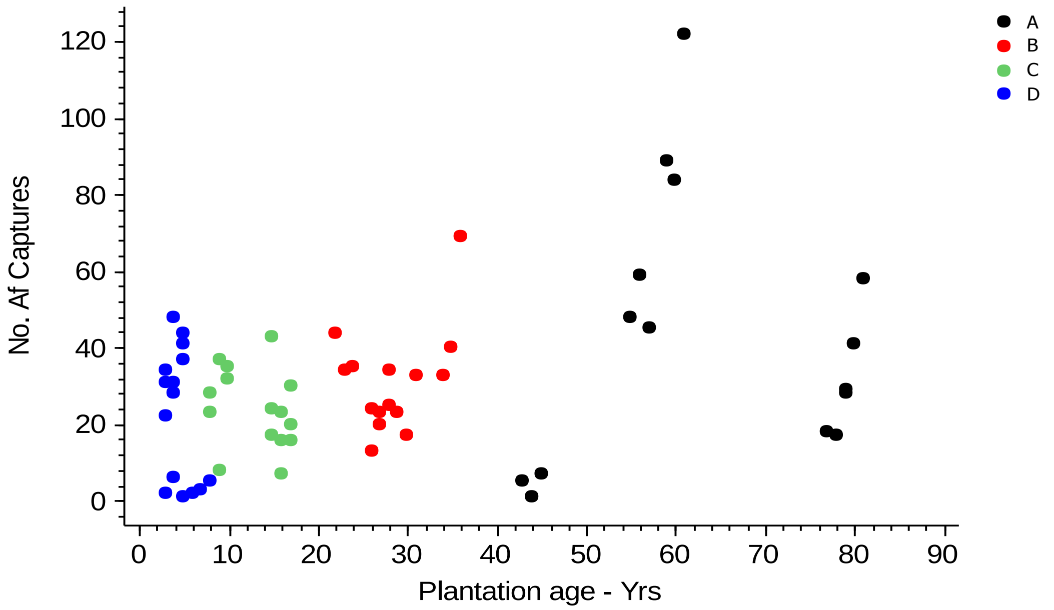

Figure 6. The total number of slow worm sightings recorded in plantations of different ages between 2009 and 2011. Courtesy of the Forestry Commission.

6.6.2 *Diet*

Soft-bodied invertebrates, particularly slugs and worms are the favoured prey though it is likely that on heathlands, where they are commonly found within ants nest, they also feed on ant larvae and pupae.

7. SUMMARY OF THE CRITICAL HABITAT REQUIREMENTS OF UK REPTILES

Irrespective of which species of native British reptile is being considered they all have broadly similar requirements within the habitats in which they occur. These attributes, which appear to be critical for the persistence and survival of all six reptile species are the presence of a relatively rich vegetation structure that includes at least three different 'layers':

1. a suitable substratum in which to burrow,
2. a dense ground vegetation cover (e.g. moss and/or lichen) to provide cover,
3. an upper vegetation layer that provides shelter against extremes of temperature during the summer and winter.

Within lowland heathlands, a habitat used by all six species of reptile in the UK, these requirements are met within deep, mature stands of heather (*Calluna vulgaris*) that also includes open areas for basking, open sandy areas for egg laying (in the case of the sand lizard) and areas of dense grass tussocks (e.g. *M. caerulea*) that provides spatial and structural heterogeneity, an attribute particularly important for the three lizard species. Each of the six reptile species also requires the availability of suitable prey species (small mammals, lizards and invertebrates).

Grasslands, woodlands, farmland, and coastal dunes and cliffs, also need to provide these characteristics, which are often met by the presence of hedgerows and ditches, areas of dense undergrowth, coarse grass, bramble and scrub species.

8. PROPOSED EXPERIMENTAL DESIGN TO INVESTIGATE THE EFFECTS OF GRAZING ON REPTILES

Although there is much published information in the scientific press, and reports to various conservation bodies on the effects of grazing on different habitat types and the potential effect on the reptile species they support there have been, to date, no reports of studies specifically designed to investigate the link between the impact of grazing on a particular habitat and how subsequent habitat changes impact on reptile populations. There are only anecdotal reports that, following the introduction of grazing to a site, the reptile sightings declined and although it is quite likely that grazing caused the changes in reptile population densities sound data to support this is lacking. There is, therefore, a clear need for some well-designed 'scientific' studies aimed at investigating precisely how grazing affects reptile populations.

Unfortunately it is rather unlikely that a thorough set of field studies will ever be done in the UK due to both its cost, particularly given the present condition of the UK economy, and the availability of sufficient areas of suitable land on which to conduct them. A compounding factor is also the amount of time required to complete such a thorough study.

For a thorough study the following variables would need to be included, along with replicates of each experiment to provide statistical robustness, and controls:

- ***Habitat type***: Lowland heathland, acid and chalk grassland, riparian habitats.
- ***Grazer type***: Cattle, horses/ponies and sheep (and possibly goats).
- ***Grazing intensity***: Low, medium and high densities.
- ***Area of each habitat type***: each experimental area would need to be large enough to support a sufficient number of the selected grazers, at appropriate densities, over a sufficient length of time (minimum 6 months /year).

8.1 I*n an ideal world (funding, land area and time not restricted)*

Given the above set of variables, sufficiently large areas of each habitat would be required to provide as much habitat uniformity between replicate and control areas so that variations in the effect of grazing, and in carrying capacity for reptiles, due simply to habitat variability could be minimised thereby reducing the number of replicates required.

Mean stocking densities currently used on lowland heaths for conservation management are 0.19 cows (>2 years old) per hectare (ranges: 0.01-0.5/ha (Lake et al., 2001). At this mean density a minimum area of approximately 5 hectares (grazed by one cow) would be required for each experiment. For a single horse the area would be 1.5-2.0 times larger (7.5-10.0 ha) and for a single ewe/goat approximately 0.5 ha. Given that grazers are herd/flock animals, and animal welfare concerns must be a consideration, then larger study areas would be required, depending on the number of cows/grazers used.

Equivalent areas of similar habitat would be required for each study area replicate and for each control area. Thus, using 5 cows, a study area of 25 ha would be required plus 25 ha as a control giving a total of 50 ha which, if replicated 5 times, gives a total area of 250 ha. A similar area of habitat would be required for each of the grazing intensities used in the study. Each of the study, and control areas, would also need to be fenced.

Ideally each of the study and control areas should be surveyed for reptiles and plants for 3-5 years before grazing is introduced and then for up to 5 years once grazing commences with all reptiles individually identified, as far a possible, using photographs (lizards) and pit-tags (snakes) so that movements between grazed and un-grazed areas could be monitored.

8.2 *In a realistic world (funding, land area and time restricted)*

8.2.1 *Study area selection*

Assuming funding, availability of suitable study areas and time are restricted then it would be sensible to select study areas in habitats that are used by most/all of the UK's native reptile species, particularly the species of high conservation concern (sand lizard and smooth snake), and ones that are most susceptible to damage resulting from livestock grazing. It would then be sensible to select areas where the reptiles have already been, or are currently being, studied so that much of the baseline data required, before grazing is introduced, is already available.

The habitat used by all six reptile species that is most at risk is, therefore, lowland heathland (including acid grassland) in the south of England. The largest continuous areas of this habitat are found in the New Forest and the heaths of Dorset. However, the reptile populations occurring in New Forest have not been studied intensively over recent years and are, due to the long-term grazing that has occurred in the New Forest for many years, present at relatively low densities where are found. This effectively narrows the choice of potential study sites to those found in Dorset.

In March 2012, funding was obtained by the Dorset Area of Outstanding Natural Beauty partnership (AONB) under the government's NIA Programme (Nature Improvement Areas) to restore habitats within the Isle of Purbeck. Part of the proposal includes the introduction of cattle grazing to large blocks of heathland at Arne, Hartland Moor and Rempstone Forest, commencing in 2015 after a programme of public consultation. These areas may provide potential study sites for investigating the impact of grazing on reptiles.

An additional area is Wareham Forest where the reptiles inhabiting one area of mature heathland have been continuously studied for up to 20 years (1992-present) and there is already an experiment in place investigating the impact of grazing on this population. There is also a research programme underway, funded by the Forestry Commission, that is investigating how reptiles utilise the changing habitats of the forest, resulting from its management for timber, from newly planted conifer plantations to mature plantations. The majority of sites in this study are in areas not currently being grazed by cattle but where grazing is scheduled to start in 1-2 years.

8.2.2 *Proposed programme of research and monitoring*

The abundance and species diversity of the reptiles occurring at the selected study sites should be determined for 5 years prior to the introduction of grazing. This length of time is necessary to ensure that all the reptiles using a particular site can be recorded and, where possible, individually marked/recognised, so that any movements following the start of grazing can be determined. In Wareham Forest this data is already available for some locations.

To enable comparisons to be made between different sites/areas within the forest the same surveying methods should be used. In Wareham forest all the sites currently being studied (>20) use hexagonal arrays of artificial refuges (tins) and so this method should also be used in any additional sites (control areas). Between 15-20 reptile surveys (approximately weekly but weather dependent) are required throughout the spring and summer months (mid/late April to mid October). In addition, annual vegetation surveys at each of the sites would be required so that changes in the habitat structure and plant species composition could be determined.

Reptile and vegetation surveys should be continued for 5 years following the introduction of grazing as the impacts of grazing are unlikely to be immediately apparent but are likely to be cumulative over time.

Since British reptiles are all predatory it would be interesting to also investigate the impact of grazing on small mammals (an important prey for adders and smooth snakes) and invertebrates (prey for the lizards). Surveys for both small mammals and invertebrates should also be done for 5 years, before and after, the introduction of grazing to a site.

8.2.3 *Estimated cost*

1 x herpetologist (full time for 30 weeks): 30 x 37hr x £20/hr	£	22,200.00
(all reptile surveys, vegetation surveys, data analysis & annual report)		
2 people (herpetologist + assistant): 3 weeks x 37hr x £20/hr (x 2)	£	4,440.00
Laying out refuge arrays during the winter prior to the start of surveys	£	????

Equipment

Refuges (tins): dependent on number of sites: one-off cost	£	3,000.00
Pit tags for individually marking snakes (lizards?): one-off purchase	£	1,600.00
Fencing: to exclude grazers from control sites: one-off prior to start	£	????
Mileage costs: to and from study sites: 45p/mile (public mileage rate)		
For a person living in/close to Wareham:		
130 days x 12 miles x £0.45 (surveys): annually:	£	702.00
15 days x 12 miles x £0.45 (setting up refuge arrays): at start:	£	81.00
15 days x 12 miles x £0.45 (removing refuge arrays): at end:	£	81.00

Annual totals (approximate costs only)

1st Year:	Personnel:	£	26,640.00
	Equipment/mileage: (excluding the cost of fencing)	£	5,383.00
2nd Year:	Personnel:	£	22,220.00
	Mileage:	£	702.00
3rd Year:	Personnel:	£	22,220.00
	Mileage:	£	702.00

4th Year:	Personnel:	£ 22,220.00
	Mileage:	£ 702.00
5th Year:	Personnel:	£ 26,640.00
	Mileage:	£ 783.00
TOTAL FOR 5-YEAR STUDY:		**£128,212.00**

These costs ONLY include work on the reptiles and vegetation for the 5 years after grazing commences as they assume that full use will be made of already existing data if Wareham Forest is selected as the site for the research project. The cost of fencing has not been included and there will be some additional costs for setting up additional 'control' areas, should they be required. If totally new sites are selected for the study of grazing on reptiles then the figures above (for 5 years) can be effectively doubled. There may also be a cost associated with gaining access to data already collected by the Forestry Commission and CEH at the various study sites in Wareham Forest.

If small mammals and invertebrates are to be surveyed then considerable additional costs (personnel, equipment and travel) will be involved but these are difficult to estimate and so have not been included.

9. DISCUSSION

In a detailed search of the available literature (both peer-reviewed scientific research papers and 'grey' literature) about the specific effects of livestock grazing on reptiles, and British reptiles in particular, it became apparent that the perceived view that almost nothing was known on this subject was not correct, with respect to reptiles worldwide, but was largely true in the case of British reptiles. Indeed, in Britain there are no peer-reviewed reports of scientific studies specifically aimed at investigating the impact of livestock grazing on reptile populations.

Studies carried out in the USA, Australia, Argentina and Mexico almost all showed that livestock grazing had a serious negative affect on both lizard and snake populations. The principal cause of the observed declines in these populations, where grazing had occurred, was damage to the structure of the habitat in which the reptiles were living, which not only affected them directly, by reducing the availability of suitable ground cover, but also indirectly by negatively affecting the prey upon which the reptiles depended. Irrespective of the habitat type being grazed the effects were all similar resulting in a more open and less complex vegetation structure that was able to support a less diverse animal community (Pianka, 1966). It also resulted in a more open and 'patchy' habitat with little or no litter layer, an attribute of importance for many reptiles as it provides both shelter and protection from extremes of temperature.

In the UK, the habitat attributes that are known to be important for native British reptile species were, as in the rest of the world, where studies have been done, precisely those that grazing, particularly by cattle and ponies/horses, destroyed, and it is therefore extremely likely that the deleterious affects of grazing, on reptile populations found in other parts of the world, will also apply in the UK.

Although there is no scientific literature about the effects of grazing on British reptiles there have been a number of studies on the effects of livestock grazing on many of the habitats in the UK where reptiles are known to occur, particularly grasslands and lowland heathlands. It is therefore not correct to assume that nothing is known about the effects of livestock grazing on reptile habitats. What is missing is a confirmed link between changes in habitat and changes in reptile abundance and diversity resulting from grazing. This is the gap that now needs to be plugged by field research.

Although livestock grazing has been present for a long time in some parts of the UK e.g. The New Forest, Exmoor, Dartmoor, and the uplands of Scotland, the use of grazing to manage habitats specifically for the purposes of conservation is relatively new, being first proposed in the mid 1990's (Gimingham, 1992). Unfortunately grazing has been mis-used by many managers and some conservation bodies, who have ignored the advice of researchers about grazing protocols (Newton et al., 2009) and appear to assume that grazing represents a 'one size fits all' policy for managing wild habitats. It doesn't.

Grazing often results in an increase in plant diversity at sites where it is used, and is known to be critical for the maintenance of species rich grasslands (Ball, 1974; Bakker, 1985; Olff & Ritchie, 1998), but this does not automatically benefit the animal communities within them. In the New Forest, where cattle and ponies have grazed freely for hundreds of years (Hill, 1985) the heathlands are maintained at a very early successional stage that provides fodder for the grazers but has simultaneously virtually eradicated reptiles. Loss of habitat and food supply, resulting from sustained heavy grazing pressure over many years in the New Forest has also resulted in a reduction in the diversity and overall abundance of small mammals which, in turn, has affected the foraging behaviour of many predators (Hill, 1985; Putman, 1989; Tubbs, 1997; Van Wieren, 1998) and is likely to have also affected the adder and smooth snake which also prey upon small mammals (Prestt, 1971; Goddard, 1984).

Grazing is also known to have eliminated reptiles from chalk grassland (Offer et al., 2003) and severe overgrazing on upland moorlands, although not as a result of 'conservation' management, has eradicated adders and common lizards from extensive areas of the country where they would be expected to occur at high densities (Offer et al., 2003).

Part of the rationale that is often used to justify the use of ‘conservation grazing’, particularly on heathland sites, is that it prevents the encroachment of pine and birch trees, and slows down the progression to woodland by taking the heathland back to an earlier successional stage. Unfortunately, this has been shown to be a fallacy. Cattle do not prevent the encroachment of pine and birch trees (Bokham, 2002; Bokdam & Gleichman, 2000) and in nutrient impoverished habitats, such as acid grasslands and lowland heathlands, the removal and/or reduction of the litter layer, that sequesters nitrogen, and the deposition of nitrogen in the dung of the grazers have been shown to have the opposite effect and accelerate the progression to woodland (Bokdam, 2002; Strijbosch, 2002).

Although there is information describing the susceptibility of reptiles to the large-scale management of heathland, using cattle to promote the regeneration of heather, before it reaches the older, mature stages, and that this does not benefit reptiles (Gimingham, 1992; Offer el al., 2003; Edgar et al., 2010), this tends to be conveniently ‘ignored’ by site managers.

The best management approach for reptile species in lowland heathland, was explicitly pointed out by Gimingham (1992) in which he states that ‘Management should maximise the amount of mature heather, which may mean having to take special measures to control invading species, such as trees’. However, since mature heather is often more fragile than younger stands, trampling needs to be kept to a minimum, and access to heathland must be strictly controlled, “pine pulls” should not be permitted and intervals of at least three years (and preferably five years) should be left between management events’. Thus, any management practice that reduces the amount of mature heather on heathland should be avoided.

Given that the available evidence indicates that the management of ‘natural habitats’, using of livestock grazing, appears to be generally harmful for many of the animal communities present within them, though it may be beneficial for plant species diversity, then it seems likely that its use is being driven by concerns other than those related to conservation. Livestock grazing, such as that found in the New Forest, also results in an aesthetically pleasing, and relatively uniform landscape, that is attractive to visitors but has more in common with large scale ‘habitat gardening’ than habitat management for conservation purposes. Livestock grazing is also cheaper management tool, financially, than using manpower, and it is therefore not unreasonable to suggest that this is the main driver for its use, though this is unlikely to be admitted to by those organisations promoting it.

We believe that if grazing continues to be used as a management tool, then the statutory conservation bodies will need to make some potentially difficult decisions in the relatively near future about what, precisely, a particular habitat is to be managed for. This precise point was stated by Webb et al. (2010) in their report for Natural England on the need to integrate the needs of priority species with management practice. If the aims of management are to increase plant diversity then livestock grazing may be a suitable option but if reptile conservation is the primary objective then livestock grazing is clearly totally inappropriate and should be avoided at all costs.

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