Amphibian and Reptile Conservation
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An assessment of the impact of controlled burning on reptile populations

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EXECUTIVE SUMMARY

- As a result of concerns about the use of controlled burning to manage lowland heathlands, and the perceived lack of substantiated evidence about its impact on reptile populations in the UK, the ARC authorised this review of the available information.
- The results of studies in which the impact of burning on reptile populations was investigated, worldwide, were assessed for their applicability to the situation occurring in the UK.
- Given the known habitat requirements of the six native species of reptile occurring on lowland heathland, in the UK, the clear conclusion of this review is that fire destroys reptile habitat and is likely to result in significant mortality to the animals present in burnt areas.
- The effects of fire on reptiles are both direct (burning animals) and indirect (destroying their habitat).
- Reptiles surviving the direct effects of a fire, by seeking refuge underground, will be exposed to increased predation due to the loss of habitat cover as they emerge from their refugia.
- Reptiles escaping to adjacent areas of potentially suitable habitat may also experience increased mortality if these areas are already at carrying capacity for reptiles (which is likely).
- The current law relating to the burning of lowland heathlands provides guidelines about the frequency of burning but sets the recommended overall target height of the regenerated heathland too low (30cm) to provide the necessary habitat structure required to support reptiles.
- The controlled burning of heathland is aimed more at providing new plant growth that is suitable as food for domestic grazing animals, also used to manage heathland, than managing it for wildlife.
- The use of controlled burning to manage heathland appears to be governed, as with grazing, by a ‘one size fits all’ approach to ‘conservation’ rather than one that should be tailored to the specific requirements of the animal species whose conservation is/are of concern in a particular area.
- Controlled burning is not an appropriate management tool for lowland heathlands where reptile conservation is a primary concern.

1. INTRODUCTION

Conservation management of *Calluna* heathlands is a critical issue that has been intensively studied (Hobbs & Gimingham, 1987) and, throughout Europe, a range of different management regimes, including prescribed burning, grazing at different stocking rates, and mechanical cutting have been proposed for maintaining them (Whittacker & Gimingham, 1962; Hobbs & Gimingham, 1984a; Hester et. al., 1991; Pakeman et al., 2003; Niemeyer et al., 2005; Britton & Fisher, 2007; Ascoli et al., 2009). Fire, either naturally occurring or intentionally used, has for millennia, had a major ecological impact on many of the world's plant communities, shaping and maintaining ecosystems and ecosystem processes (Velle et al., 2012).

Controlled burning has traditionally been used as a management tool in the UK to increase pasture value and herbivore production in heathlands (Webb, 1998) and remains a common practice in much of the uplands, for the management of *Calluna* moorlands for agricultural purposes, which represent a significant financial and cultural resource through their use for grouse shooting (Hobbs & Gimingham, 1987).

In the New Forest, Commoners have ancient rights to graze their domestic animals (Tubbs, 1997) and use burning management to stimulate the regeneration of old gorse and to produce fresh heather (*Calluna vulgaris*) and purple moor-grass (*Molinia caerulea*) for grazing their stock (Tubbs, 1991). Controlled burning has also been used on nature reserves as a management tool for conservation purposes (Corbett, 1998).

On southern lowland heaths, burning tends to be restricted to mature and degenerate stands, resulting in the death of most of the plants with its subsequent regeneration depending on seedling establishment, which is slow (Gimingham, 1992). In these areas management fires are limited, in any one year, to relatively small patches, representing only a small proportion of the total area. With the exception of the Breckland, where the interval between burning is 6-10 years, the usual interval between fires, on any one patch of heathland, is between 20-30 years, giving a reasonable period of time for the re-establishment of heathland flora and fauna (Gimingham, 1992). Fires may also help to perpetuate acid-tolerant heath vegetation by removing the litter layer and maintaining the low nutrient condition, which is an important characteristic of lowland heathland (Tubbs, 1991; Gimingham, 1992).

The importance of lowland heathland for British reptiles has long been recognised (Spellerberg, 1975; Smith, 1964). Favourable habitats for all the six native species exist in lowland heath and woodland areas, yet the decline of heathlands in the south of England has been immense (Spellerberg, 1975). Between 1759 and 1996 the total area has declined by more than 80%, from 40,000ha to 7,373ha with the remaining area being considerably fragmented (Rose et al., 2000).

The habitat requirements of the six native British reptile species, all of which occur on lowland heathland, are met within deep, mature stands of heather (*Calluna vulgaris*) that also includes open areas for basking, open sandy areas for egg lying (in the case of the sand lizard), and areas of dense grass tussocks (e.g. *Molinia caerulea*) and a litter/moss and lichen layer that provides spatial and structural heterogeneity, an attribute particularly important for the three species of lizard. Each of the six reptile species also requires the availability of suitable prey species (e.g. small mammals and lizards for snakes and invertebrates for lizards).

The past 50 years have seen a steep, and accelerating, decline in the abundance and distribution of some reptile species associated with lowland heathland in Britain, e.g. the sand lizard (*Lacerta agilis*), following the widespread loss, and fragmentation, of habitat, principally due to afforestation, urbanisation, agricultural reclamation and mineral extraction (Moore, 1962; Prestt el. al., 1974; Tamarind, 1975; Corbett & Tamarind, 1979). Degradation of much of the remaining habitats had been caused by both the encroachment of pine, from pine plantations, by fire induced encroachment of birch and bracken (Corbett & Tamarind, 1979) and grazing, that destroys the complex habitat structure required by reptiles (Jofré & Reading, 2012).

Controlled burning is considered an important tool for wildlife management as it affects the amount, and type, of food and cover by modifying habitat structure (Leopold, 1933; Komareck, 1963; Wade & Lunsford, 1989; Hunter, 1990; Cain et al., 1998). For example, it is used to alter succession by killing or reducing the size of trees and shrubs and enhancing frequency, biomass and diversity of herbaceous vegetation (Cain et al., 1998). However, specific knowledge about how individual species respond to fire regimes is essential for ecologically sustainable management (Driscoll et al., 2010).

Although controlled burning is only one of the management techniques, along with grazing, cutting, mowing, spraying etc., used to maintain heathland habitats in the UK, only the use of controlled burning will be addressed in this report.

2. THE LAW CONCERNING CONTROLLED BURNING OF HEATHLANDS IN ENGLAND

The Heather and Grass etc. Burning (England) Regulations (2007) and the Heather and Grass Burning Code (2007 version) govern the burning of heather, grass, bracken, gorse and vaccinium (a range of shrub species including bilberry and blueberry) in both the uplands and lowlands of England. The Regulations state that:

- Burning may only take place in the burning season, unless under licence from Natural England. Burning must be conducted safely, with care for people, property, the environment and natural resources.
- In upland areas the burning season is from 1st October in one year to 15th April in the following year, both dates inclusive. In all other lands, including lowland heath, the period runs from 1st November in one year to 31st March in the following year.
- The burning of any specified vegetation on any land between sunset and sunrise is illegal.

There are a number of prohibitions within this law that can only be carried out under licence from Natural England. The two that may potentially be of most relevance to reptile conservation on lowland heath are:

- burn, in a single burn, an area of more than 10 hectares of specified vegetation.
- in connection with the burning of specified vegetation, leave soil smouldering for more than 48 hours.

The Code was produced by Defra, in collaboration with Natural England, in consultation with many organizations. However, no specialist reptile conservation organisations appear to have been consulted. This Code is voluntary and outlines good practice on planning and providing information on where, and how, to burn. Additional information is provided about 'sensitive areas' where there should be a strong presumption against burning as burning these may permanently damage the environmental interest of the land and may be unlawful. In special circumstances sensitive areas can be burned but only under licence from Natural England.

Areas of mature/degenerate heather, which have not been burned for many decades, are included under 'sensitive areas' in the Code, because they are likely to be particularly rich in plants and insects. Although reptiles also favour this type of habitat they have not been specifically mentioned and have apparently not been taken into consideration!

The Heather and Grass Burning Code provides a general guide on how to burn heathland and states:

- Aim to burn dry heath when it is about 30 cm (12 inches) tall.
- Allow some patches of heather (and other heathland vegetation) to grow to over 40 cm (16 inches) to increase structural diversity and provide havens for wildlife.
- Anywhere in a Site of Special Scientific Interest (SSSI), where burning has been notified as an 'operation likely to damage', burning may only be conducted in line with a consent issued by Natural England.

Specific mention is made about:

- Lowland, coastal and maritime heathland where the advice is that great care must be taken to avoid damage to fire-sensitive species and their habitats e.g. lizards and snakes.

The implications of these Regulations and Codes for site managers, who intend using fire as a management tool, are that they may potentially be committing an offence, particularly if the sand lizard and smooth snake (European Protected Species), occur within the sites that are intended to be burnt. The Wildlife and Countryside Act 1981 (as amended), and The Conservation of Habitats and Species Regulations 2010, also make it unlawful, except under licence from Natural England, to conduct any activity which disturbs or destroys protected animals, plants and habitats. This applies throughout the year, regardless of the burning season.

3. THE ECOLOGICAL IMPACT OF FIRE

Burning is considered to be a reliable and effective means of managing heathland if it is carefully controlled, according to well-known principles of good practice, and heather usually regenerates quickly following a well-controlled fire. Burning is also relatively cheap, compared with other management practices, and is carried out in areas where access for machinery is restricted (Gimingham, 1992). Fires can, however, have significant detrimental impacts on the habitat including:

- The destruction and long-term exclusion of fire sensitive species and low colonising rate species.
- The removal of cover for ground dwelling wildlife (e.g. reptiles and small mammals) and ground nesting birds.
- The reduction of habitat structure, species diversity, and vegetation composition if carried out too frequently. In particular frequent burning weakens *Calluna*. This, in conjunction with high grazing pressures, has probably contributed to the loss of *Calluna* cover and its replacement by grasses such as purple moor grass (*Molinia caerulea)* over much of the uplands (Tucker, 2003).
- *Calluna* plants that are burnt when they are mature usually die.
- The post-fire establishment of invasive species such as bracken (*Pteridium aquilinum*).

Additionally, there is concern that controlled burning, when used too extensively or in inappropriate areas, has a negative impact on reptile habitats, threatening the survival of some species e.g. sand lizard (*Lacerta agilis*), (Edgar & Bird, 2005; 2006).

Understanding the ecological impact of fire on reptile populations involves an appreciation of the following aspects:

- Plant species life history characteristics
- Post-fire succession of both plants and animals
- The role of abiotic factors other than fire

3.1 *Plant species life history traits*

In fire adapted vegetation types two categories of plants are recognised:

- Fire tolerant plants also known as 're-sprouters': these tolerate fire and are generally able to re-grow from shoots after the fire.
- Fire sensitive plants known as 'non-re-sprouters': these die when their leaves are burnt or scorched and rely on seed regeneration to maintain their presence in the plant community.

After fire, *Calluna vulgaris*, the dominant species in lowland heathland may regenerate, either vegetatively or from seed depending on it age when burnt (Calvo et al., 2002; Velle et al., 2012).

3.2 *Post-fire succession: Plants*

The ericaceous heathlands in north-west Europe are habitats in which fire is a dominant ecological factor with post-fire succession depending on the precise composition of the plant community and, if present, the density of grazers (Allen et al., 1996).

The burning of wet heath, composed mainly of heather (*Calluna vulgaris*), cross-leaved heath (*Erica tetralix*) and purple moor-grass (*Molinia caerulea*) on slowly permeable soils, is followed by the dominance of purple moor-grass for 1-3 years followed by the re-establishment, first of the cross-leaved-heath and then of heather. The rate at which the plant community re-establishes, and in particular, the rate at which the heather reassumes dominance, depends on whether the burnt areas are grazed and, if so, the intensity of the grazing (Tubbs 1991).

The burning of dry heath, where the community is mainly comprised of heather, bell heather (*Erica cinerea*) and bristle bent (*Agrostis curtisii*), regenerates slowly, and a high percentage of bare ground, resulting from burning, can persist for 4-6 years (Tubbs, 1991).

In the years after a fire, plant communities change in structure, dominance and above ground composition.

3.3 *Post-fire succession: Reptiles*

General patterns of how the fauna responds during post-fire succession have been widely explored in small vertebrates (Anderson, 1991; Fox et al., 2003; Friend & Wayne, 2003). There is agreement that reptile communities, like small mammals (Driscoll & Henderson, 2008), follow a predictable sequence based on the recovery of the vegetation structure following a fire (Mushinsky, 1985, 1992; Greenberg et al., 1994; Taylor & Fox, 2001a,b; Letnic et al., 2004) and is known as the 'habitat accommodation model of succession' (Fox 1982).

Caughley (1985) described a detailed habitat accommodation model, for reptiles, using a chronological sequence in mallee eucalyptus woodlands (Australia) and identified three different reptile succession trajectories, following fire, which were defined by their life history/ecological traits (Figure 1).

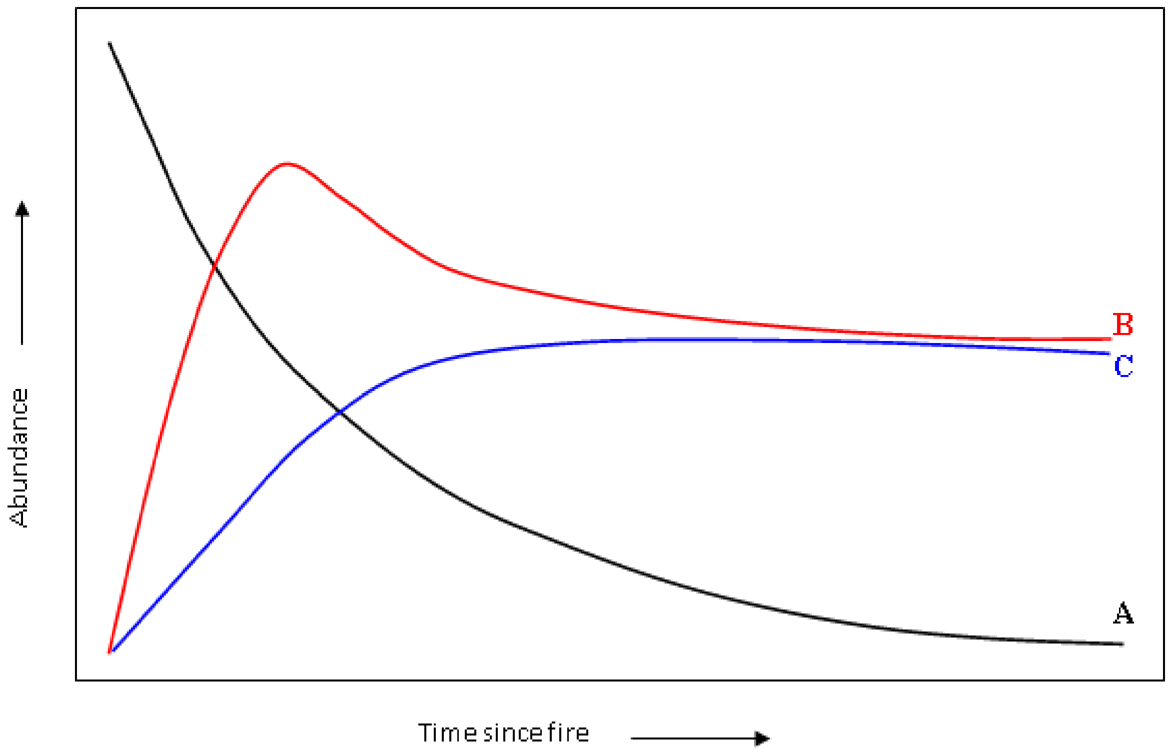


Figure 1. Reptile succession trajectories after fire. Modified from Driscoll & Henderson, 2008.

The three trajectories are:

A - Burrowing species, that forage in open areas and use bare ground for territorial displays, are most abundant in recently burned sites and then decline. These early successional species can tolerate relatively high environmental temperatures.

B - *Triodia* spp. specialist species, that shelter in *Triodia* clumps/tussocky grass, decline after the fire and then recover over approximately six years as the tussocks re-grow (*Triodia* is a large genus of hummock-forming grass endemic to Australia).

C - Leaf litter specialists that decline after the fire and recover slowly, over approximately 25 years due to the slow accumulation of litter following a fire. These late successional species are less tolerant to high environmental temperatures, use the shade of the vegetation for thermo-regulation and are poor burrowers (Letnic et.al., 2004)

Although fire successional models provide a framework for predicting reptile fire responses, and warrant ongoing development and testing, a deeper understanding of the mechanisms underlying responses to fire is needed in order to predict the outcome of fire regimes and fire mosaics (Driscoll & Henderson, 2008).

3.4 *The role of abiotic factors other than fire*

Abiotic factors, such as the characteristics of soil (e.g. permeability, fertility), rainfall regimes, temperature regimes, and the topography all determine the distribution and abundance of plant and animal species (Townsend et al., 2003) and may affect the results of controlled burning. For example, soils tend to be deeper and richer in gullies, and moisture is retained better than on slopes resulting in vegetation that is likely to be more mesophytic (moisture-loving plants), and with a higher canopy cover. The patchwork of vegetation that results from the interaction of fire with other abiotic factors has implications for biodiversity conservation.

In addition, fire affects soil temperature, as a result of changes in its chemistry and its increased exposure to solar energy, its nutrient level and its moisture content (Marcos et al., 2009), all of which may affect its short-term ability to support re-colonising plants.

4. THE IMPACT OF FIRE ON LOWLAND HEATHLAND

4.1 *The effects of burning on reptile habitat*

Despite the lack of scientific research in the UK into the effects that controlled burning, to manage lowland heathland, has on the reptile populations, there is information (reports) that refers to the devastating effects of burning management, wildfires and arson, on the native reptile populations (Tubbs, 1991; Corbett & Tamarind, 1979; Moulton & Corbett, 1999). The damaging effects on reptile habitats, when fire is used too extensively, or in inappropriate areas, are also known. For example the loss of the sand lizard, from the New Forest, is thought to be the result of over-enthusiastic controlled burning (Tubbs, 1976; Edgar & Bird, 2005).

There is growing concern that inappropriate burning management is having a detrimental impact on all the British reptiles, but particularly on the sand lizard (*Lacerta agilis*) (Edgar & Stumpel, 2004; Fearnley, 2009, Edgar et al., 2010). Inappropriate cutting and burning has not only caused local extinctions of sand lizards in the past, but may also be limiting the migration of introduced sand lizard populations into adjacent heathland areas (Moulton & Corbett, 2003).

However, this concern is not new. Thirty three years ago (Corbett & Tamarind, 1979) stated that New Forest heaths had become unsuitable for sand lizards as a result of the management regimes that were based on regular burning, in the mistaken belief that the burning of dry heath improved the grazing for cattle and ponies (Tubbs, 1974). In reality, according to Tubbs (1991), there is little profit to the grazers from burning this kind of vegetation and it is disastrous for reptiles, like the smooth snake and sand lizard, for which mature dry heath is prime habitat.

Perhaps, ironically, some nature conservation management measures can also be detrimental to reptiles, or the habitat features on which they depend. For example, some methods employed for re-establishing botanical diversity, such as grazing, mowing or burning of heathland or grassland, may have an adverse effect on reptiles (Corbett, 1998).

Burning, as a management method, or through accidents or arson, has been pointed out as probably the most significant threat to heathland sites supporting rare reptiles (Edgar et al., 2010). Loss of habitat structure, due to unsympathetic management, and especially inappropriate burning, grazing and scrub clearance, are now considered a threat to the survival of those reptile species which depend on mature heath (Corbett & Tamarind, 1979; Corbett, 1998; Moulton & Corbett, 1999; Moulton & Corbett, 2003; Edgar & Stumpel, 2004; Fearnley, 2009, Edgar et al., 2010).

5. THE IMPACT OF CONTROLLED BURNING ON REPTILES

5.1 *The direct effects of fire*

Spring and summer fires, either accidental or due to arson, are likely to be more harmful as the reptiles will have to confront the impacts directly rather than having several months e.g. over winter to ameliorate habitat conditions (Friend, 1993). However, it is currently accepted that when managed burning is carried out during late autumn and winter, as required by law, its adverse direct effects on the fauna are minimised. Despite this, controlled burning should still be exercised with caution where reptiles are present (Gimingham, 1992). It is assumed that larger animals (e.g. mammals) are able to disperse and escape a fire whilst small and less mobile vertebrates, such as amphibians and reptiles, are thought likely to experience relatively high rates of direct mortality from fires (Lyon et al., 1978). Hibernating vertebrates, using burrows, may also survive fire given that the presence of moss, litter and upper soil layers may provide some degree of insulation/protection from fire. Burning carried out in winter (January) when the subsoil is moist, also usually results in little, or no, damage to the litter layer (Stumpel, 2004) and thus, during a fire, the rise of temperature only a few centimetres below the surface is likely to be negligible (Gimingham, 1992).

Unfortunately, no records of reptile mortality, resulting from the use of controlled burning, have been kept in the UK, and so the impact of its use, on reptiles, remains uncertain. The lack of rigorous records, reporting the direct effects of fire on herpetofauna mortality, has been highlighted in America where most of the literature reporting post-fire mortality consisted of anecdotal reports that, although consistent, where of little value without a frame of reference by which to measure it (Russell et al., (1999).

Research carried out in American deciduous forests has shown that snake species associated with moist, cool microclimates, or leaf litter, were significantly less abundant in burned stands compared to those that were not burned (MacLeod & Gates, 1998). Similar results were obtained in Australian (savanna woodland and open forest), where the abundance of litter lizards and litter snakes decreased significantly as a result of fire, whereas other snakes present at the same sites were not affected (Andersen et al., 2005). This suggests that burning is likely to have a greater impact on those species associated with litter, moss or other surface cover (Spellerberg, 1975) possibly because these animals may attempt to bury or hide in the litter instead of trying to escape a fire.

A study that tested three different annual fire regimes on the survival of Australian reptiles found that the abundance of terrestrial lizards and snakes, associated with litter, decreased when fire was used in late winter/early spring compared to fires in late autumn/early winter fires and treatments where fire was not used (Andersen et al., 2005). This difference suggests that reptiles are more able to escape fire before, or at the beginning of hibernation, than at the end of hibernation and the beginning of their activity period.

In the UK, although allowed by law, it would be advisable to avoid using controlled burning during mid-February to March in areas where reptiles are known to be present, as it is possible that some individuals/species could be emerging from hibernation, depending on weather conditions. This is particularly true for common lizards, slow worms and adders, and possibly grass snakes, which can be active as early as February or March when the weather is mild.

Any factors which affect the ability of individuals to escape fire will consequently increase their mortality. For example, a study on a population of diamond back rattle snakes (*Crotalus adamantenus*), found that only individuals that were in the process of shedding their skin died, as the consequence of prescribed fire, suggesting that ecdysis may have affected their sensory perception and consequently their ability to detect and disperse away from approaching fires (Means & Campbell, 1981).

Although direct mortality, due to burning, is thought to be low (Means & Campbell, 1981; Russell et al., 1999; Engstrom, 2010), baseline pre-fire estimates of reptile abundance are essential in order to assess its real impact. In a review of the effects of prescribed fires on herpetofauna, in the United States, Russell et al. (1999) found that fire-induced mortality of most species was in the order of 10 or fewer individuals burn in any of the habitats sampled. However, most of the studies failed to provide pre-fire estimates of abundance and therefore the real impact that fire-induced mortality inflicted on the population dynamics of these species was unclear, since it was un-known if 10 individuals represented all, or just a small proportion, of the population.

It is also important to consider that post-fire mortality is also likely to occur once the fire has removed the vegetation, used as protective cover by reptiles, thereby increasing their exposure to predators (e.g.) birds of prey, either immediately after the fire (Corbett & Tamarind, 1979; Friend, 1993) or when they emerge from hibernation.

With respect to the reptiles which escape a fire, they will need to find an ‘empty’ un-burnt patch of suitable habitat. This may be difficult given that some species, e.g. the smooth snake, may occur at densities at, or close to, the carrying capacity of the habitat in which they occur (Goddard, 1983). Conversely, the expected post-fire reptile succession will only be possible if source populations are located in adjacent areas.

5.2 *The indirect effects of fire*

More typically, the effects of fire on reptiles are indirect and manifested through habitat modification, changes in the food supply (invertebrates and small mammals), or changes in the abundance of competitors. Although the magnitude of the long-term impact of burning on reptiles remains unknown it will depend on the size of the areas burnt, the resilience of the vegetation to fire, the speed of its recovery and its capacity to recolonize the burnt areas.

Research on the effects of fire on herpetofauna has progressed steadily in the last 20 years, especially in the USA and Australia (Masterson et al., 2008), where it has been shown that they will mainly vary according to: fire size (Letnic et al., 2004), fire intensity (Hailey, 2000), season (Hailey, 2000), fire frequency (Cunningham et al., 2002; Mushinsky, 1992; Letnic et al., 2004; Woinarsky et al., 2004), location (Driscoll & Herderson, 2008) and the ecology/natural history of the species concerned (Cunningham et al., 2002).

The effect of fire on reptile populations depends on many variables that makes any comparison between experimental information gathered under different conditions difficult and/or meaningless. However, comparisons between the ecology of different species can be made to establish valid analogies, or to determine differences, between the reptile faunas present within different habitats.

In a 5-year experiment in Kapalga, Australia, the impact of controlled fire on complete communities was assessed and showed that the savanna biota was remarkably resilient to fire, even high intensity fire, and demonstrated a high degree of adaptation to a regime of natural fire (Andersen et al., 2005). The abundance of most invertebrate groups remained unaffected by different fire treatments, as was the abundance of most vertebrate species, and no effect was detected on the floristic composition of the grass-layer. However, riparian vegetation and associated stream biota, including mammals, were a notable exception to this general resilience (Andersen et al., 2005). They also observed that the occurrence of fire, independent of its intensity, was the major factor influencing fire sensitive species. These results raised concerns that the frequency of fires was too high and that some areas needed to be left unburnt for many years.

6. SUGGESTED EXPERIMENTAL DESIGN, AND MONITORING PROTOCOL, FOR ASSESSING THE IMPACT OF FIRE ON REPTILES

The following two sub-sections will describe a proposed experimental for investigating the effects of fire on both reptiles, and the lowland heathland habitat, where they are found, and a proposed protocol for the 'post-fire' monitoring of burnt areas.

The experimental design will show three different sized areas that could be burnt, and then subsequently followed up, first, to see how the habitat recovers from the fire, and second, to see how the reptiles re-colonise the burnt area. The duration of the experiments, conditional on available funding, will determine how well 'post-fire' recovery can be studied. The monitoring of the habitat, and reptile populations, before and after fire will be done using a standardised method so that results from the different areas can be compared and will use hexagonal arrays of artificial refuges (tins) to estimate reptile numbers and diversity within the areas to be burnt, and the areas adjacent to it (Reading, 1997). Ideally, each of the experimental designs should be replicated so that variations between sites can be allowed for.

Each of the individual 'cells' depicted below represent an area of lowland heath measuring approximately 70m x 70m. Within each cell there will be an array of 37 refuges, spaced 10m apart. The red cells represent those areas that will be burnt and the green ones those adjacent to the burnt area that will not be burnt.

In each of the experiments the areas will be surveyed for reptiles for 3-5 years before the central areas are burnt. This length of time is necessary if as many as possible of the individual reptiles present are to be captured and individually marked for future identification. Reptiles will be searched for visually, whilst walking a transect between each of the refuges and also by using the refuges to find reptiles that use them to shelter beneath.

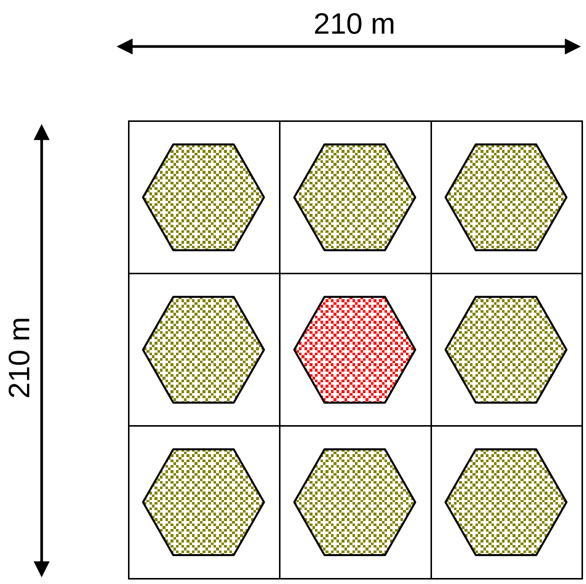
A single annual vegetation survey will also be done in each of the cells using 2m x 2m quadrats at 10 fixed positions within each cell so that changes in vegetation diversity, abundance and ground cover can be monitored over time.

Before the central area is burnt the array/s of refuges within them will be removed and only replaced once the first signs of post-fire vegetation re-colonisation are seen.

Immediate post-fire monitoring of the burnt area, for reptiles, will involve visual searching and then, once vegetation starts to reappear and refuges are replaced, searches will be made using both refuges and visual searching.

6.1 Suggested experimental design

<u>Design 1</u>



1. Area to be burnt: 70m x 70m (**0.49** hectares).
2. Total experimental area: 210m x 210m (**4.41** hectares)
3. Total number of arrays (9) comprising a total of 333 refuges.
4. 15 visits each year between May and October each year to search for reptiles.
5. 1 vegetation survey each year in each of the cells.
6. Approximate annual cost: (Pre-fire)

Approximate annual cost: (Pre-fire)	Reptile surveys:	15 days @ £20/hr	£2400.00
	Vegetation surveys:	4 days @ £20/hr	£ 640.00
	Data analysis and Report:	5 days @ £20/hr	£ 800.00
	TOTAL (annual staff cost):		**£3840.00**

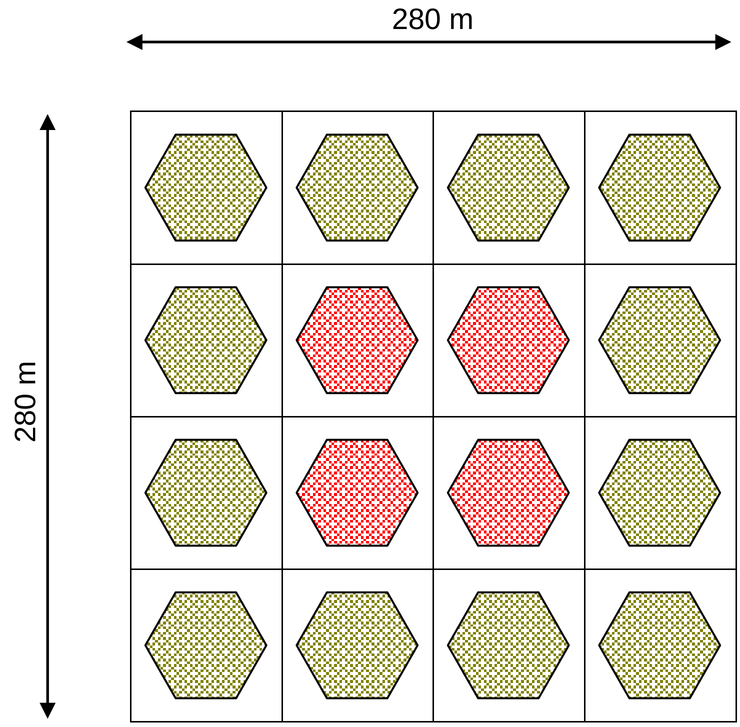
In addition there will be a 'one-off' purchase of150 pit-tags **£ 450.00**

The cost of purchasing refuges (a very rough estimate) **£1000.00**

Estimated 'post-fire' costs:

Essentially the same as those for the 'pre-fire' period though slightly less to take into account of the reduced time taken to survey the burnt area.

<u>Design 2</u>



1. Area to be burnt: 280m x 280m (**1.96** hectares).
2. Total experimental area: 280m x 280m (**7.84** hectares)
3. Total number of arrays (16) comprising a total of 592 refuges.
4. 15 visits each year between May and October each year to search for reptiles.
5. 1 vegetation survey each year in each of the cells.
6. Approximate annual cost: (Pre-fire)

	Reptile surveys:	22.5 days @ £20/hr	£3600.00
	Vegetation surveys:	8 days @ £20/hr	£1280.00
	Data analysis and Report:	5 days @ £20/hr	£ 800.00
	TOTAL (annual staff cost):		**£5680.00**

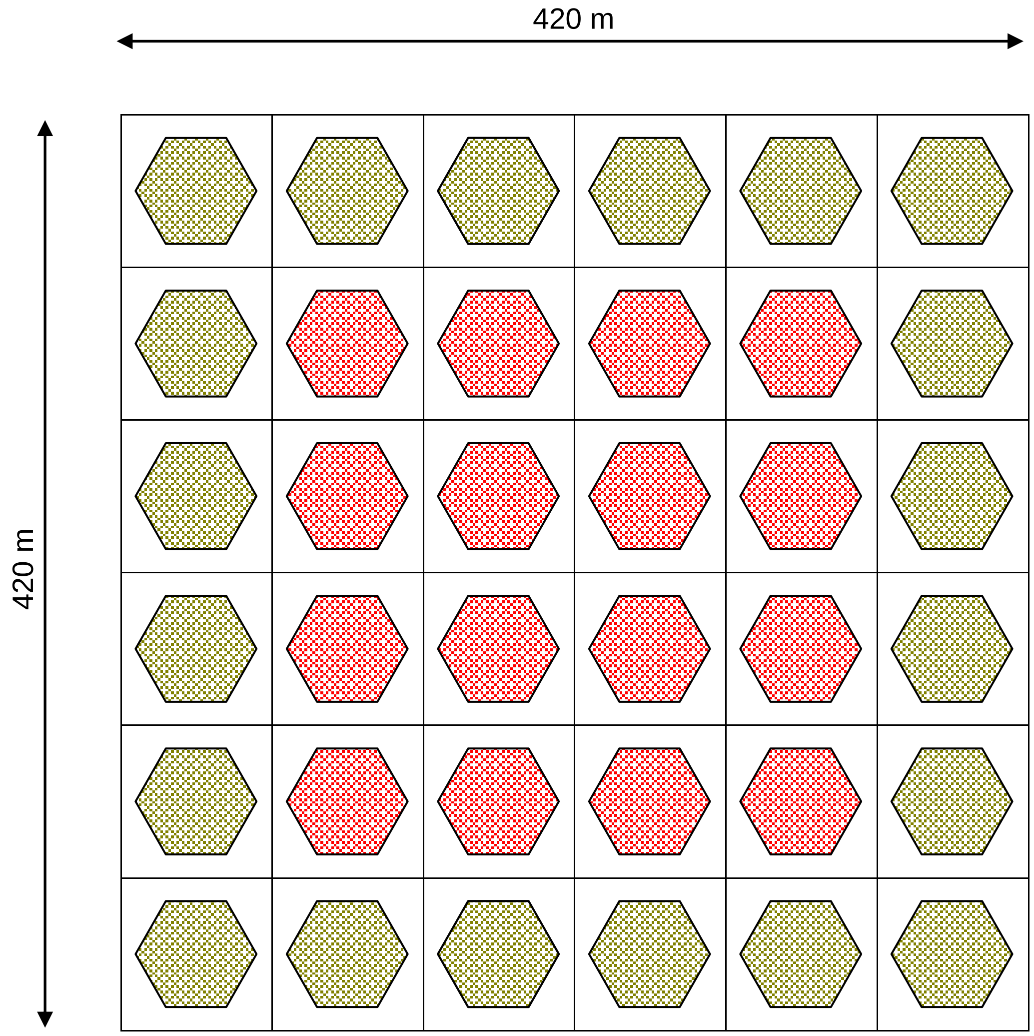
In addition there will be a one-off purchase of 200 pit-tags	**£ 600.00**
The cost of purchasing refuges (a very rough estimate)	**£1800.00**

Estimated 'post-fire' costs:

1. 15 visits each year between May and October each year to search for reptiles.
2. 1 vegetation survey each year in each of the cells.
3. Approximate annual cost:

Reptile surveys:	15 days @ £20/hr	£2400.00
Vegetation surveys:	6 days @ £20/hr	£ 960.00
Data analysis and Report:	5 days @ £20/hr	£ 800.00
TOTAL (annual staff cost):		**£4160.00**

<u>Design 3</u>



1. Area to be burnt: 280m x 280m (**7.84** hectares).
2. Total experimental area: 420m x 420m (**17.64** hectares)
3. Total number of arrays (36) comprising a total of 1332 refuges.
4. 15 visits each year between May and October each year to search for reptiles.
5. 1 vegetation survey each year in each of the cells.
6. Approximate annual cost: Reptile surveys: 45days @ £20/hr £ 7250.00

(Pre-fire)	Vegetation surveys:	18 days @ £20/hr	£ 2880.00
	Data analysis and Report:	5 days @ £20/hr	£ 800.00
	TOTAL (annual staff cost):		**£10930.00**

In addition there will be a one-off purchase of 600 pit-tags	**£ 1800.00**
The cost of purchasing refuges (a very rough estimate)	**£4000.00**

Estimated 'post-fire' costs:

1. 15 visits each year between May and October each year to search for reptiles.
2. 1 vegetation survey each year in each of the cells.
3. Approximate annual cost:

	Reptile surveys:	20 days @ £20/hr	£3200.00
	Vegetation surveys:	12 days @ £20/hr	£1920.00
	Vegetation surveys:	12 days @ £20/hr	£1920.00
	Data analysis and Report:	5 days @ £20/hr	£ 800.00
	TOTAL (annual staff cost):		**£5120.00**

The cost of the 'post-fire' monitoring will depend on its duration and will be a multiple of the annual cost for the selected experimental design. Ideally, it should continue until the vegetation structure has returned sufficiently well to support reptiles and reptile numbers, and diversity, are approaching those found either before the fire or those found in areas adjacent to the burnt area.

6.2 *Suggested 'post-fire' monitoring protocol*

A protocol for monitoring an area that has been burnt will, essentially, involve annual vegetation surveys, as outline above, and also frequent reptile surveys, all continued over a number of years and preferably until heathland vegetation has re-colonised the area sufficiently well to provide the habitat structure required to support reptile populations. During the first 1-3 years after a fire it is probably not worth laying out refuge arrays to survey for reptiles and simple visual searching would suffice. However, once the vegetation starts to return, and provide some degree of cover for reptiles, then refuge arrays should be set up so that between year changes in reptile abundance and species diversity can be compared.

Given the time required for mature heathland to re-establish on an area that has been burnt, 15-20 years, then monitoring should continue for at least this length of time.

6.3 Attributes of areas suitable for doing experiments

Given the time restraints for completing this report is has not been possible to suggest potential sites where experiments investigating the impact of controlled burning on reptile populations can be done. However, areas selected for such experiments should have, as far as is possible, the following attributes.

1. They should be large areas of mature *Calluna* heathland known to have as many of the six native British reptile species on them as possible, but particularly the two rarest species (sand lizard and smooth snake).
2. The heathland should be as homogeneous as possible so that variation due to vegetation, aspect and topography, can be minimised.
3. They should be areas that have not been subject to grazing or burning management.
4. They should be areas that are as remote as possible, or with limited or no public access, so that the likelihood of vandalism (arson, removal of animals, theft of tins) is reduced.
5. They must be areas where long-term studies can be done and not areas where disturbance may occur e.g. change in public access, management regime etc.

Given the increasing use of grazing to manage heathlands the opportunities for finding a suitable site where such experiments can be done appear to be very limited. In light of the estimated costs of each of the three experimental designs, the third, and probably the second, are extremely unlikely to be started. However, the first (smallest), may be feasible as it is both the cheapest to run and requires the smallest area of lowland heathland. An additional advantage of this, over the two larger designs, is that the size of the area to be burnt is also equal to that of each of the surrounding 'control' cells of heathland that will not be burnt.

7. DISCUSSION

The use of fire as a habitat management tool has been studied most intensively in Australia and, although neither the reptile species nor the habitats are the same as those occurring in the UK, its overall impacts are nevertheless relevant. These studies have shown that many of the reptiles surviving the flames died during the following few weeks due to starvation and/or avian predation resulting from the loss of the litter layer and overall vegetation cover (Friend, 1993). The main conclusions of a recent review about the use of fire as a biodiversity management tool highlighted three areas where current knowledge is lacking and needs to be addressed (Driscoll et al., 2010). These were:

- 'A mechanistic understanding of the responses of a range of plants and animals to fire regimes'.

- ‘Knowledge of how species are influenced by the spatial arrangement and temporal sequences of fires’.
- ‘Knowledge of how factors such as herbivory, predation, fragmentation, invasive species and weather interact with fire to alter species’ responses to fire directly, or via changes to the fire regime’.

The results of a study of the effects of fire on the development of post-fire vegetation on Scottish heathlands showed that the re-growth of both *Calluna vulgaris* and *Erica cinerea*, following a fire, declined with the ‘pre-burn’ age of the heathland, switching from vegetative growth in young stands to growth from seed germination in older stands (Hobbs & Gimingham, 1984b). Re-growth from seed takes longer than vegetative growth. This study also showed that in species-rich heath the numbers, and abundance of grass, forb and lichen species reappearing after a fire declined with pre-burn age with little grass or forb re-growth in older stands. The overall results of burning mature heathland were an extremely slow re-growth rate, a reduction in species diversity and the persistence of bare ground for many years.

The use of fire, on lowland heathland in the south of England, will have the effect of destroying the structure of the habitat that is essential for British reptile species and, due to the time taken for mature heath to re-establish, will cause the decline and loss of reptile populations, as has occurred, for example, in the New Forest.

The single most obvious impact of burning, controlled or otherwise, is the total removal of vegetation and, depending on the severity of the fire, and moisture content of the habitat when it is burnt, the partial or total removal of the bryophyte/litter layer. Both of these are vital parts of the habitat that are essential for many reptile species as they provide both shelter from predation, and extremes of temperature, and are also the places where reptiles hunt for prey (e.g. invertebrates and small mammals).

Animals exposed to fire can either try to escape from it by leaving an area (large ‘mobile’ animals such as mammals and birds), or stay where they are and try to seek refuge from it. Reptiles generally fall into the second category. Thus, depending on their ability to find underground shelter from fire rather than try to shelter within, or below the litter layer, they will either be killed directly (radiant heat) or be exposed to a significantly increased risk of predation from avian and other predators, once they emerge from underground refugia after a fire has passed.

In addition, any individuals successfully escaping to suitable habitat close to where a fire has occurred may experience reduced survivorship due the reptiles present in the areas they have escaped to. It is not unreasonable to assume that reptiles will exploit a habitat until it has reached its carrying capacity for a particular species and therefore the addition of new individuals will not be able to be supported and so they, or a proportion of ‘resident’ individuals may be lost. The impact of fire on reptiles is therefore potentially extremely severe, as a result of both direct and indirect effects.

The question is, therefore, not whether fire results in increased reptile mortality but rather, how quickly a burnt area can recover, to be able to once again support reptiles, and, how well reptiles are at colonising new areas.

The UK law, and associated codes, governing the burning of lowland heathland recommends burning once the vegetation has reached a height of 30cm but suggests leaving some areas with vegetation up to 40cm high for the ‘use of wildlife’. Heathland with heather of this height (30cm) is unlikely to be mature enough to contain the structural complexity that is required by reptiles (Jofré & Reading, 2012).

The rationale used by managers who use controlled burning to ‘manage’ heathland is that it removes old mature heath (precisely that which is important for reptiles) and encroaching conifer and birch trees, and stimulates the growth of new heather. However, the published data questions this assertion. Although relatively young heather plants are able to produce new shoots from burnt stems, older, mature heather (>15 years old) is killed by fire and the formation of new heathland is dependent on seed germination (Kayll & Gimingham, 1965). In addition, after heathland is burnt, the burnt areas lack a bryophyte/litter layer and are often first colonised by ruderal species and only later by heather. Studies on how lowland heathland, in the UK, recovers from fire have shown that the re-establishment of mature heathland, with the structure (including litter and bryophyte/lichen layers) required to support reptiles is a relatively slow process and may take in excess of 20 years (Corbett & Tamarind, 1979; Corbett, 1990; Moulton & Corbett, 1999). The speed with which reptiles colonise new areas depends on the species, the closeness of reptile populations to burnt areas and the rate at which the burnt areas are colonised by vegetation that can provide both shelter and food.

All the available information from both the UK, and around the world, shows that the management of heathland habitats, through the use of fire, is often severely damaging to reptile populations as the speed of habitat recovery, following a fire, is too slow to enable their survival. It also results in a very slow rate of re-colonisation due to the time taken for habitats to regain the structure that is required by reptiles. This is particularly true for British reptiles occurring on lowland heathland. The use of controlled burning is, therefore, <u>not</u> an appropriate method for managing lowland heathland where reptile conservation is a primary concern.

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