Observations on co-existing populations of adders, slow-worms and common lizards at Loch Lomond, Scotland: implications for conservation

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ABSTRACT

A population of reptiles containing European adders *Vipera berus*, slow-worms *Anguis fragilis* and common lizards *Zootoca vivipara* was studied over four years from 2012 to 2015 in an area adjacent to Loch Lomond, Scotland. Numbers, distribution and annual life cycles were monitored. The three species were active from mid-February to late October, with mating in April and May, and juveniles first appearing in August and September. All displayed site fidelity, with some animals using the same hibernation and sunning locations in consecutive years. The apparent co-existence of the three species in large numbers near human habitation suggests that in suitable habitat and the absence of persecution they can be present in high densities. The implications of these observations for reptile conservation are discussed.

INTRODUCTION

It is becoming increasingly apparent that many reptile species are declining in numbers and range throughout the UK and Europe, which has prompted research to understand the reasons for these trends (Corbett 1989; Beebee and Griffiths 2000). This has resulted in coordinated surveying and recommendations for conservation, including legal protection of animals and habitat, and changes to habitat management practices (Wild and Entwistle, 1997; Baker et al., 2004; Edgar et al., 2010; Gleed-Owen and Langham, 2012).

Scotland has in some areas healthy populations of adders, slow-worms and common lizards (Reading et al., 1994; Reading et al., 1996; McInerny and Minting, 2016). However, there is little published research on their breeding biology and habitat requirements in Scotland, which is surprising as adders and common lizards have been much studied both in England and in Europe (Avery, 1966; Avery, 1975a; Avery, 1975b; Viitanen, 1967; Prestt, 1971; Nilson, 1980; Andren, 1986; Neumeyer, 1987; Madsen, 1988; Avery and Bond, 1989; Capula and Luiselli, 1993; Madsen and Shine, 1993; Andren et al., 1997; Forsman, 1997; Andersson, 2003; Phelps, 2004). Even less is known about the distribution and status of the slow-worm and the common lizard in Scotland (Reading et al., 1994; McInerny and Minting, 2016), although it has been suggested that the range of the common lizard has increased (Bowles, 1995; Bowles, 2002).

One region in Scotland where adders, slow-worms and common lizards have been studied are the shores of Loch Lomond (McInerny, 2014a; McInerny, 2014b; McInerny, 2016). Here we report monitoring these reptiles at a Loch Lomond site over four years, and describe their numbers, breeding biology, movements and habitat preferences. This information will be useful for understanding and informing conservation approaches for these reptile species in Scotland.

MATERIALS AND METHODS

Study site

The site is a replanted native forest on south and west facing hills flanking the east shore of Loch Lomond, with the upper areas leading to heather *Calluna vulgaris* moorland. The forest contains oak *Quercus* spp., birch *Betula* spp., ash *Fraxinus* spp. and rowan *Sorbus* spp., with an adjacent mature conifer plantation; and open areas containing bracken *Pteridium* spp., bramble *Rubus fruticosus* agg., gorse *Ulex* spp., heather, and other plants and bushes. Boggy areas and patches of exposed rock are also present, with a small burn along the northern edge. The site is fenced, preventing the entry of red deer *Cervus elaphus*, to protect the flora; and is kept anonymous in this paper to protect both the habitat and reptiles.

Highest reptile densities were found in an area approximately 0.6 hectares in size at the lower part of the study site (Fig. 1). This area is bordered on the north side by a wooded area, of predominately oak and ash, and a burn; on the south by a grass field; and on the west by inhabited buildings. It was once part of a sheep-farm, where dry-stone walls were erected to make sheep pens. Many of the walls have collapsed and been grown over by vegetation, being covered in bracken, gorse and bramble, with scattered small trees and bushes. These piles of covered rocks appear to have created underground wintering sites, hibernacula, suitable for reptiles.

Fig. 1. Arial view of the reptile study site at Loch Lomond, Scotland, August 2014. This part of the site had the highest densities of adders *Vipera berus*, slow-worms *Anguis fragilis* and common lizards *Zootoca vivipara*. The area was once part of a sheep-farm, where dry-stone walls were erected to make sheep pens, but which have subsequently collapsed and become covered in bracken, gorse and bramble, with scattered small trees and bushes. The entrance path to the hydroelectric development can been seen, along with the reptile-proof fencing erected during construction, as described in McInerny (2016).

Survey work
Artificial cover objects, made from 50 x 50 cm roofing felt, were distributed in March 2012. These were examined about once a week from early February until November, from 2012 to 2015, and were successful at revealing slow-worms. Adders and common lizards did not use cover objects, but were located by inspection of sunning locations. The survey methods used are described in McInerny (2014a), and followed published protocols (Sewell et al., 2013).

The location, number, maturity and gender of reptiles were recorded on each visit. Adders were recognised through visual inspection and photographs of head patterns, these being unique to individuals (Sheldon and Bradley, 1989; Benson, 1999); thus, day counts were recorded and minimum population numbers estimated. Population numbers of common lizards and slow-worms were not estimated, as it was usually impossible to identify individuals without handling, which was not attempted (Riddell, 1997). These were instead recorded as day counts. However, a few individuals of both species were recognised by head markings and seen on multiple occasions (Fig. 2).

Fig. 2. Individual common lizards *Zootoca vivipara* can be distinguished by their head markings. An animal was photographed basking on the same bank in early spring in consecutive years (left, April 2013; right, March 2014). The digital images revealed identical head patterns in both photographs, confirming that it was the same individual.

The site was monitored 36 times in 2012, 47 times in 2013, 58 times in 2014, and 45 times in 2015. The results from the 2012 survey are published in McInerny (2014a).

Hydroelectric scheme
In 2014, a hydroelectric scheme was installed on the north side of the study site. The development is described in McInerny (2016), and appeared to not affect the breeding biology or distribution of reptiles at the site, at least in the short-term.

RESULTS
Adders
Adders were observed from mid-February to late October, and were the most regularly recorded reptile. The number, gender and maturity, and hibernation, sunning and mating locations, are shown in Table 1, and Figs 3, 4 and 5.

Increasing numbers were counted during the study period, from a minimum 40 individuals in 2012, to a maximum 148 in 2015. This included a record day count of 26. In total, over 200 different adders were recognised by their head patterns during 2012 to 2015, with 42 of these re-found over the period of the study. Estimated population densities varied from 62 per hectare in 2012, to 236 per hectare in 2014. Based on counts of individuals, the ratio of males to females varied between years, from 1.0:1.6 to 1.3:1.0, with an average over the period of 1.0:1.1, suggesting that similar numbers of the two genders were present.

Snakes hibernated singly, or in groups of up to three. Both males and females emerged from hibernation in early spring, first appearing in mid-February, with no evidence that males appeared before females. Snakes often shed skins on first emergence, leaving the old skin underground, with the new skin usually dark coloured in appearance. Numbers increased until mid- to late March, when a few juveniles appeared, which had been born the previous autumn. During this season snakes sunned for long periods in areas near to hibernation sites.

	Day Counts	Individuals			
	Total	Total	Male	Females	Juvenile
2012	149	40	15	24	1
2013	196	79	37	39	3
2014	316	151	61	78	12
2015	299	148	7	62	8

Table 1. Numbers of adders *Vipera berus* at a Loch Lomond site, 2012 to 2015. The total number of day counts for each year, and the minimum numbers of males, females and juveniles, are shown. Individuals were identified through their unique head patterns, allowing 42 to be re-found over the period of the study.

	Day Counts				
	Total	Male	Female	Juvenile	Gender unknown
2012	81	23	36	15	7
2013	149	23	50	35	41
2014	148	35	27	71	15
2015	77	10	13	54	0

Table 2. Numbers of slow-worms *Anguis fragilis* at a Loch Lomond site, 2012 to 2015. The total number of day counts for each year, and day counts of males, females, juveniles and gender unknown, are shown. Individuals were not identified.

	Day counts				
	Total	Male	Female	Juvenile	Gender unknown
2012	26	4	2	0	20
2013	23	3	3	4	13
2014	39	3	0	1	35
2015	30	2	2	1	25

Table 3. Numbers of common lizards *Zootoca vivipara* at a Loch Lomond site, 2012 to 2015. The total number of day counts for each year, and day counts of males, females, juveniles and gender unknown, are shown. Individuals were not identified.

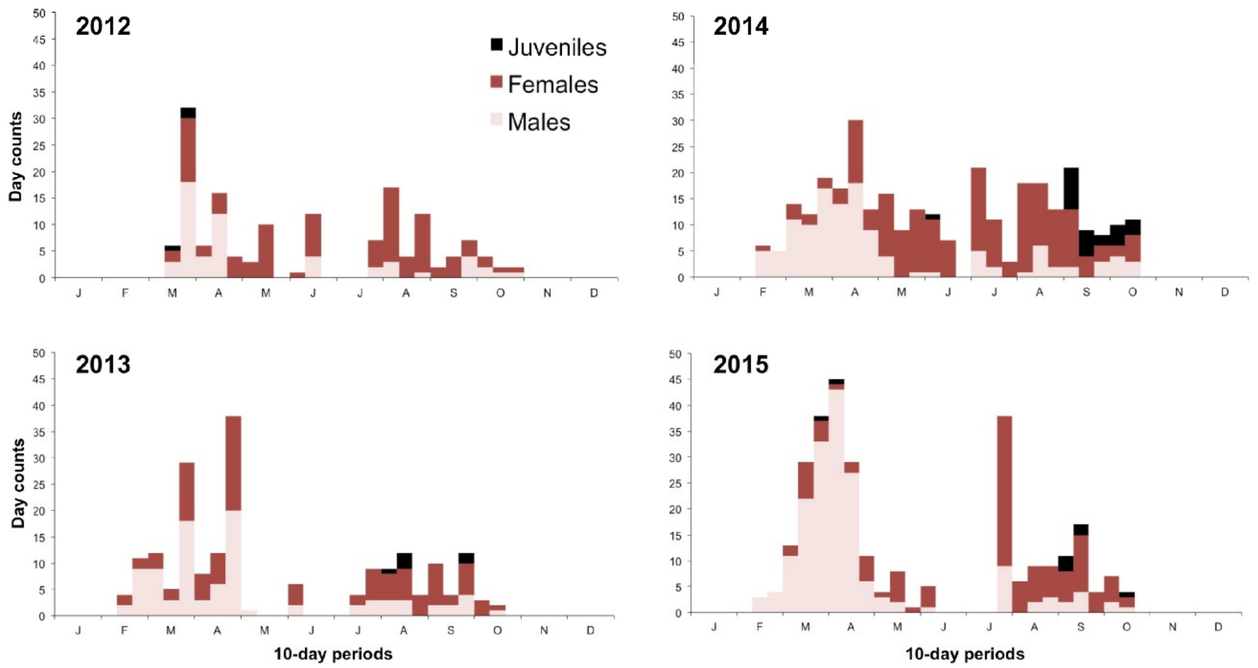

Fig. 3. Numbers of adders *Vipera berus* at a Loch Lomond site, 2012 to 2015. Day counts for 10-day periods for males, females, and juveniles are plotted.

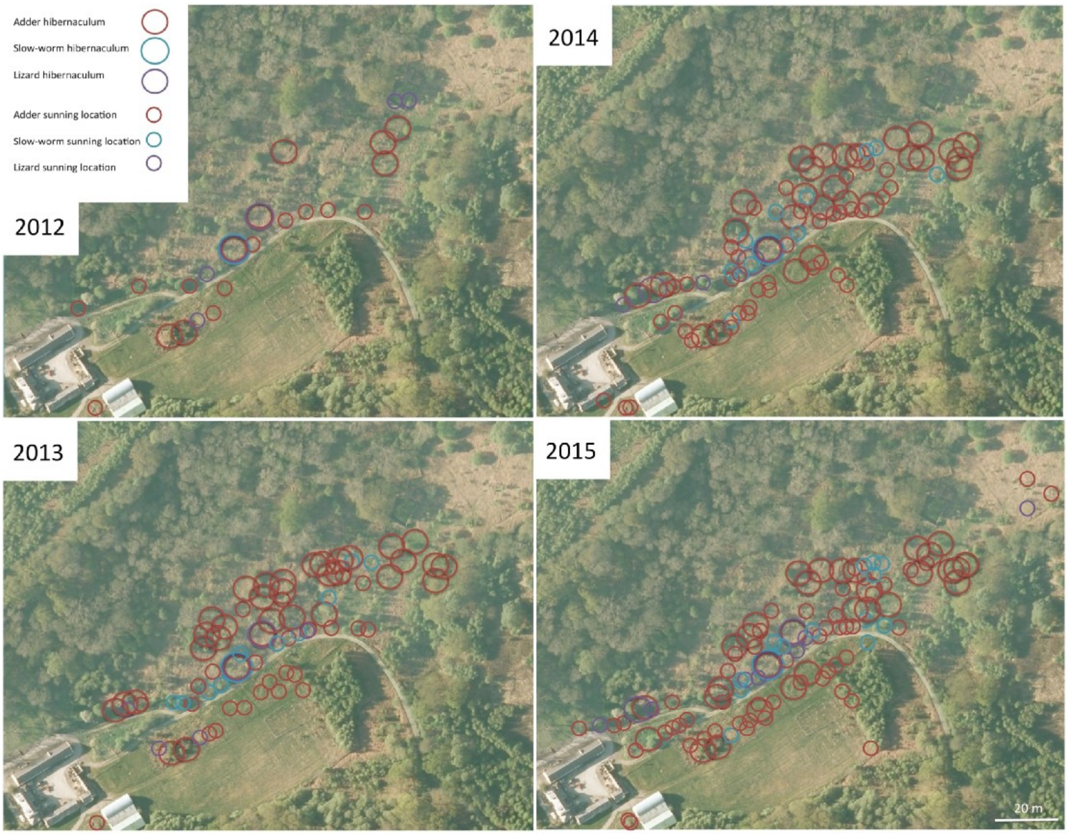

Fig. 4. Distribution of adders *Vipera berus*, slow-worms *Anguis fragilis* and common lizards *Zootoca vivipara* at a Loch Lomond site, 2012 to 2015. Hibernation sites (hibernacula), and sunning locations are indicated. The 2012 map is the same as shown in McInerny (2014a).

Fig. 5. Location of adder *Vipera berus* mating areas and gravid female sunning locations at a Loch Lomond site, 2012 to 2015. Though mating areas were close to hibernation and sunning locations, they varied between years. Gravid females used sunning locations for long periods during the summer, generating warmth to aid development of gestating young, sometimes in groups of up to three, and with gravid female slow-worms *Anguis fragilis*.

By early to mid-April both male and female adders shed their skins in preparation for mating. Skin shedding occurred on warm, sunny days, with males drying the new usually pale grey skin by basking, and then searching for freshly shed, brown-coloured females. If, instead, they encountered another male, wrestling contests sometimes occurred, with the dominant male chasing off the subordinate.

Snakes mated in mid- to late April, typically late in the morning on warm, sunny days, in areas where males and females congregated (Fig. 5). Males approached females, courted them by head bobbing, coiling and licking, and entered coitus, which usually lasted for 1-2 hours (Fig. 6). After mating, males often accompanied females, sometimes for multiple days, to prevent them from mating with other males. Even so, females mated with other partners on a number of occasions, sometimes immediately after the previous male had left; such promiscuity has been reported (Madsen et al., 2002).

Fig. 6. Adders *Vipera berus* undergoing courtship. Freshly shed males approach similarly shed females, court them by head bobbing, coiling and licking, and entered coitus, which usually lasts for 1-2 hours.

Following mating, males and most females disappeared, with just a few females remaining. After 1-2 months, in late spring and summer, gravid females returned to areas near to hibernation sites (Fig. 5). These sunned for extended periods, sometimes in groups coiled together, and occasionally with female gravid slow-worms.

Birthing occurred from early August, with females producing up to eight live young; stillborn young at birth were also observed. Juveniles were found until the end of October and in early spring the following year.

Skin shedding occurred from February through to September. When females shed, this sometimes coincided in the appearance of males nearby. In late spring this resulted in courtship and mating, though not in summer and autumn.

Individuals showed strong location fidelity, both within years and between years (Fig. 4). In a number of cases, adders used the same hibernation sites in consecutive winters, although in other cases, individuals changed hibernacula. Similarly, sunning locations were either re-used between years or not. In a number of cases individuals were recognised in all four years and remained within metres of their preferred location; observations elsewhere have shown that adders are long lived, with animals over 20 years old found in the wild that have used hibernation and sunning throughout their lives (Phelps, 2004).

Males and females congregated in specific areas to court and mate, though these changed each year during 2012 to 2015 (Fig. 5). Gravid females used various locations throughout the site for sunning during the summer; sometimes these were the same in different years (Fig. 5).

Snakes showed movements at certain times of the year. In late spring after mating most disappeared from the study site. Such behaviour has been reported and is thought to reflect animals moving to other areas to feed (Viitanen, 1967; Prestt 1971; Phelps, 1978; Andersson, 2003).

Hibernation and sunning locations were associated with open areas, near patches of bracken, gorse and bramble, with scattered small trees and bushes (Figs 4 and 5). Animals often basked on patches of moss, next to brambles and gorse, where they could retreat after disturbance, with the thorns or prickles offering protection. Adders were seen rarely in adjoining habitat, for example wooded areas or the grass field, and then only in mid-summer when transient, as they were not present in these places on following days.

Animals returned to hibernation sites from September and were observed to late October. Thus they were active for 36 weeks, longer than 30 weeks reported in England, Demark and southern Sweden (Prestt, 1971; Madsen, 1988; Höggren, 1995). In more northern latitudes, for example above the Arctic Circle in Sweden, adders are active for just 17-18 weeks (Andersson, 2003).

Slow-worms

Slow-worms were observed from mid-March through to mid-October. The number, gender and maturity, and hibernation and sunning locations, are shown in Table 2, and Figs 4 and 7.

Fluctuating numbers were counted during the study period, from a minimum 77 day counts in 2015 to a maximum 149 in 2013. Based on the days counts (and excluding those where gender was undetermined) the ratio of males to females varied between years, from 1.3:1.0 to 1.0:2.2, with an average over the period of 1.0:1.4, suggesting similar numbers of the two genders were present.

Animals emerged from hibernation in March and were active until early October. Males appeared first, with females a few weeks later in April. Juveniles were also found from April, which had been born the previous autumn.

Skin shedding was recorded from April through to August, with mating in late April and May. Males were seen pursuing females above ground on warm sunny banks.

Gravid females incubated developing young through the summer, often located under cover objects. However, in late July to mid-August they were also found above ground sunning. Sometimes gravid females were in groups, and more rarely with gravid female adders.

Birthing was not observed, but juveniles appeared from July, with most seen in August and September, usually under cover objects.

Only a small number of individuals were recognised by their face pattern (Riddell, 1997), and even fewer re-found. Even so, some re-used the same sunning and hibernation sites within and between years.

Little evidence for the movement of slow-worms was obtained. In the few cases where individual were recognised they were always found in the same location, consistent with previous studies which have shown that slow-worms have relatively small territories (Patterson, 1983; Stumpel, 1985; Platenberg and Griffiths, 1999).

Hibernation and sunning sites were associated with open areas, near patches of bracken and bramble, typically on banks (Fig. 4). Slow-worms were not seen in the adjoining wooded areas or grass field.

Animals were not observed after mid-October, thus active for 30 weeks.

Common lizards
Common lizards were observed from mid-March through to late September. The number, gender and maturity, and hibernation and sunning locations, are shown in Table 3, and Figs 4 and 8.

Fluctuating numbers were counted during the study period, from a minimum 23 day counts in 2013 to a maximum 39 in 2014. In most cases gender was undetermined, so the ratio of males to females was not estimated.

Animals emerged from hibernation in March, when both males and females were found, with no evidence that males appeared first.

Skin shedding was recorded from April through to August, with mating from late April, but mostly in May and early June, when males pursued females. Gravid females were seen in the summer, with the appearance of young in August and September; birthing was not observed.

In most cases it was impossible to recognise individuals. However, in one case photographs of the head pattern of an animal seen in early spring in consecutive years on the same bank, confirmed that it was the same individual (Fig. 2). This observation suggests that common lizards can show site fidelity between years.

Hibernation and sunning sites were associated with open areas, near patches of bracken and bramble, often on banks (Fig. 4). Common lizards were not seen in the adjoining wooded areas or grass field.

Animals were not observed after late September, thus active for 28 weeks.

DISCUSSION
This study describes observations on a population of adders, slow-worms and common lizards near Loch Lomond, Scotland.

The habitat in which the highest densities of reptiles were present was on a level area below hill slopes that had previously been a field containing sheep pens made from dry-stone walls, as part of a farm. The walls had subsequently collapsed, and natural vegetation regeneration had created stands of bracken, bramble and gorse, with scattered small trees and bushes. It seems likely that the collapsed walls have created underground hibernation sites suitable for reptiles. It is striking how all three species were restricted to the regenerated habitat, and were not found in surrounding areas which were either higher density mature trees, or a grass field (Figs 4 and 5). It will be interesting to see, as the regeneration continues and the trees and bushes become larger and closer, if this results in a reduction in reptile numbers and densities.

It is also noteworthy that the highest reptile densities were found in the lower level section of the study site. Apparently similar open habitat amongst trees with stands of bracken and gorse were present at higher elevations on the nearby hill slopes, but lower reptile densities were detected.

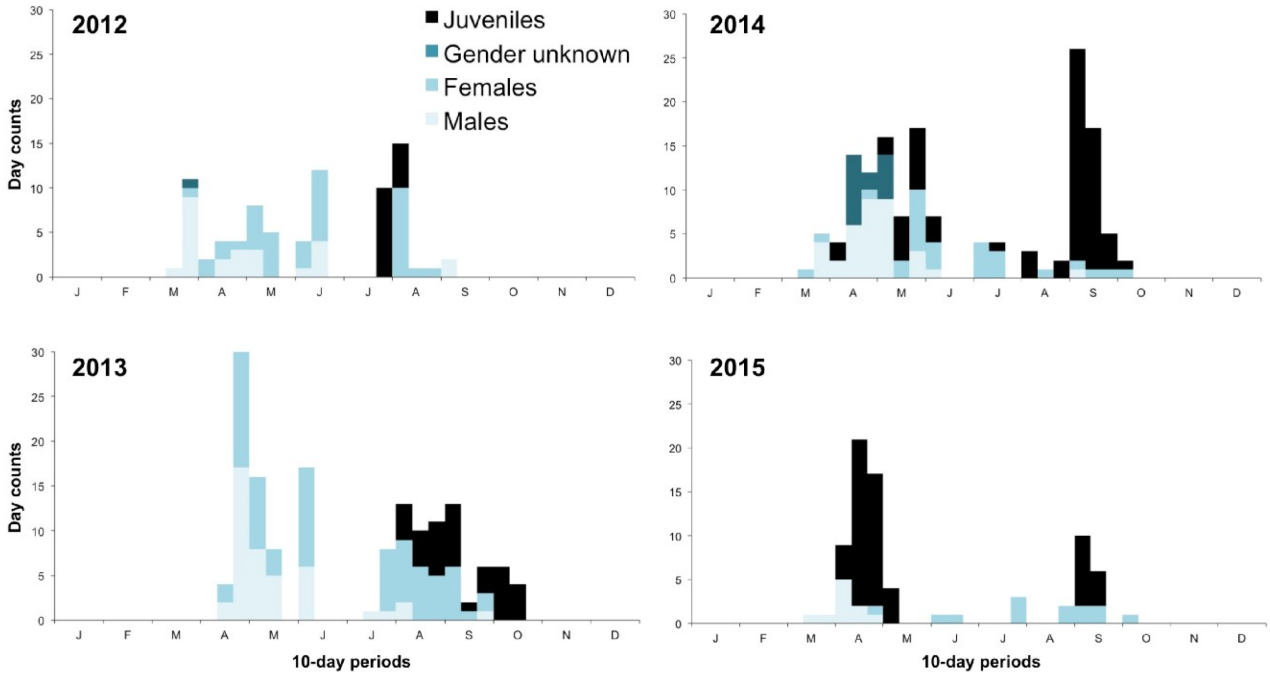

Fig. 7. Numbers of slow-worms *Anguis fragilis* at a Loch Lomond site, 2012 to 2015. Day counts for 10-day periods for males, females, gender unknown and juveniles are plotted.

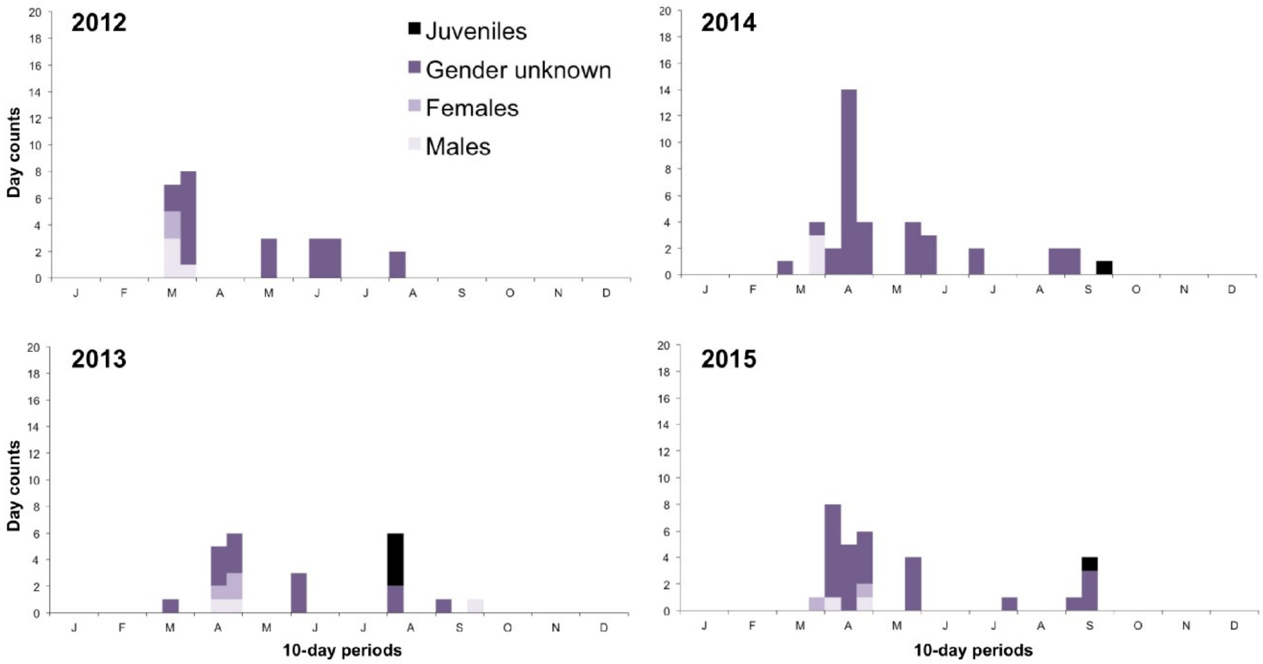

Fig. 8. Numbers of common lizards *Zootoca vivipara* at a Loch Lomond site, 2012 to 2015. Day counts for 10-day periods for males, females, gender unknown and juveniles are plotted.

Adders, slow-worms and common lizards were seen in these areas, but far less frequently and at lower densities. Thus, in spite of the lower area being close to human habitation and disturbance, it was the preferred location for these animals. This observation suggests that reptiles can inhabit suitable habitat close to humans where they are not persecuted.

The three species appeared to co-exist at the site. No predation of one reptile species by another was noted. At other locations elsewhere in the UK and Europe, where these reptiles are found together, common lizards and slow-worms are food items of adders (Prestt, 1971). So the apparent relative lower numbers of common lizards and slow-worms compared with the adders reported here suggests that the adders were consuming other food items. These could include small mammals, such as voles *Microtus* spp. and shrews *Sorex* spp., and common frogs *Rana temporaria*, which adders are known to eat (Prestt, 1971; McInerny & Minting 2016), and which were present at the site. Slow-worms have been reported attacking common lizards, though this is thought to be rare (Gleed-Owen, 2012), and was not observed.

On some occasions female adders and slow-worms were seen sunning together in groups, likely sharing body warmth to aid gestating young, so possibly benefitting from each other's presence. It is thought that such behaviour increases body warming to advance the rate of gestation of developing young (Phelps, 2004).

To varying extents, site fidelity was recorded for all three reptile species. In the case of adders, where individuals were routinely recognised, many used the same hibernation and sunning sites over the four year study period (Figs 4 and 5). Even when snakes were found in different locations, they were often located just a few metres away. Such fidelity has been noted elsewhere in the UK and Europe (Neumeyer, 1987; Andersson, 2003; Phelps, 2004). In the case of slow-worms and common lizards, less evidence for fidelity was noted, as it was more difficult to identify and recognise individuals. However, in a few cases, individuals were re-found and these showed site fidelity (Fig. 2).

That all three species showed site fidelity, with some individuals present for the four years of the study period, has implications for their conservation. It suggests that the habitat where they are located should be protected in the long-term to maintain populations. Highest densities were present in areas that contained stands of bracken, gorse and bramble, with scattered small trees and bushes. Though in some places in Scotland bracken is thought to have a negative effect on certain animal and plant species, and is cleared as part of management practices (Pakeman et al., 1996; SNH), it is also recognised that small stands can have an important ecological role for many vertebrates and invertebrates (Pakeman and Marrs, 1992; RSPB). The observations presented here, that show high densities of reptiles associated with bracken, have been reported elsewhere at Loch Lomond (McInerny, 2014b). Areas of bracken have also been shown to an important component of reptile habitat in the rest of the UK (Edgar et al., 2010). Thus the control of bracken in a refined way, that creates small stands, with adjacent open areas and slopes with trees and bushes, and associated bramble and/or gorse, should be considered in the management of reserves and areas where reptiles are present.

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