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Ranging behaviour of adders (*Vipera berus*) translocated from a development site

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Translocation of animals from sites scheduled for development is a widespread but controversial intervention to resolve human-wildlife conflicts. Indeed, reptiles are very frequently the subject of such translocations, but there is a paucity of information on the fate of such animals or how their behaviour compares to residents. In 2014, a population of adders (*Vipera berus*) was translocated from a development site in Essex, UK. A sample of snakes was fitted with external radio tags and tracked for a period of 10 days during the spring. This exercise was repeated during the summer using a combination of translocated and resident individuals. Translocated males exhibited significantly greater average daily movements than resident conspecifics. Furthermore, all translocated males undertook long-distance, unidirectional movements away from the release site. In contrast, all translocated females remained within 50 m of the point of release. One of the males returned to the donor site, crossing large areas of unsuitable habitat in doing so. Translocated males also maintained significantly larger total ranges than resident conspecifics. No differences in range sizes were observed between translocated and resident females. The dispersal of male snakes from the release site may increase the risk of mortality of translocated snakes and reduces the likelihood of establishing a new population. Interventions to encourage the establishment of new home ranges within the boundaries of release sites may include mechanisms to prevent dispersal immediately following release.

Key words: relocation, viper, radio-telemetry, reptile, human-wildlife conflict

INTRODUCTION

The translocation of animals from sites scheduled for development is a widespread but controversial intervention to resolve human-wildlife conflicts. The purpose of such 'mitigation translocations' is: (1) to prevent threatened wildlife being harmed through development activities; and (2) to encourage the establishment of a self-sustaining and viable population at sites protected from future development (Griffith et al., 1989). Over recent decades, the number of 'mitigation translocations' appears to be increasing exponentially and outnumbers translocations specifically carried out for conservation purposes (Germano et al., 2015).

Reptiles are frequently the subject of mitigation translocations despite questions being raised about their suitability for the practice (Dodd & Seigel, 1991; Germano & Bishop, 2008). European reptile populations have declined markedly over the past two decades (Cox & Temple, 2009; Reading et al., 2010). In the UK, all three native species of snake are legally protected from harm under the Wildlife and Countryside Act 1981. However, with the exception of the smooth snake (*Coronella austriaca*), this protection does not extend to their respective habitats. So if adders (*Vipera berus*) or grass snakes (*Natrix helvetica*) are found to be present on a site scheduled for development, developers simply need to relocate individuals to an alternative site. Unfortunately, legislation does not require that translocations are reported to national recording schemes nor does it include any provisions for post-translocation monitoring. As such, it is not known how many translocations are undertaken annually nor whether translocation is effective in conserving snake populations.

The ecology and behaviour of the adder and grass snake have been relatively well-documented. Both species exhibit clear and predictable annual movement patterns, implying that they are aware of both the spatial and temporal availability of local resources (Phelps, 2004). It follows that translocation - and thus the introduction of novel stimuli - is likely to disrupt these patterns. Currently, there are no rigorous studies of how adders or grass snakes respond to translocation. However, there are comparable studies from North America, Asia and Australia that allow some broad inferences to be drawn (Plummer & Mills, 2000; Nowak et al., 2002; Butler et al., 2005; Lee & Park, 2011; Barve et al., 2013). The removal of visual and chemical cues has been shown to have a disorientating effect on snakes (Hare & McNally, 1997; Plummer & Mills, 2000; Nowak et al., 2002). Individuals are forced to spend a greater proportion of their time exploring their environment, often at the expense of

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foraging and breeding behaviours (Wolf et al., 1996). Furthermore, studies of translocated snakes showed that individuals typically travelled further and occupied larger home ranges than their resident conspecifics (Reinert & Rupert, 1999; Butler et al., 2005; Lee & Park, 2011; Barve et al., 2013). Such long distance movements are often ascribed to the influence of philopatry; indeed, long-distance movements are likely to be more prevalent in species that exhibit strong homing behaviours (Sullivan et al., 2015).

As the human population in the UK continues to grow, more land will be required to satisfy the demand for housing. This in turn will exacerbate the need for and frequency of translocations. It is therefore important to understand how snakes respond spatially to novel environments. As the adder appears to be undergoing a decline in the UK (Baker et al., 2004), it is particularly important to ensure that translocation is effectively reducing impacts and ultimately conserving the species in the short-term.

The aim of this study was to ascertain the effects of translocation on the spatial ecology of adders. Specifically, for the first time we sought to determine whether adders translocated from a development site moved further and occupied larger home ranges than resident conspecifics.

MATERIALS AND METHODS

Study Site

The study site was a disused golf course located in the county of Essex, south-east UK. Planning permission was granted for the redevelopment of a 15 ha portion of the 75 ha site (Fig. 1). The remainder of the site was either to be retained as a golf course (14 ha) or re-graded and landscaped to become a country park (46 ha). Although the principal function of the country park was to provide residents with accessible 'open space', it was also designated as a receptor site to accommodate displaced wildlife. Both the donor and receptor sites were situated on the disused golf course albeit at opposite ends and separated by a minimum distance of 500 m.

Experimental Design

A total of 45 adders were translocated from the footprint of the development. Of these, eight snakes (six males and two females) were fitted with an external radio transmitter (1.1 g PicoPip tags) in April 2014. The tag attachment method followed the protocol described by Gent and Spellerberg (1993). This approach has been successfully applied to the tracking of adders in Britain and is well-suited to short-duration studies (Ujvari & Koros, 2000). The processing and study of adders was undertaken in accordance with the University of Kent's Ethics Policy, itself compliant with guidance from the Association for the Study of Animal Behaviour (2006).

The eight snakes were tracked for a period of 10 days following release. The location of each snake was recorded on three occasions each day: morning (08:00 – 10:00 hrs), afternoon (13:00 – 15:00 hrs) and evening (18:00 – 19:00 hrs). The frequency of sampling was balanced against the risk of causing disturbance; Ujvari and Koros (2000) recommend at least two hours between sampling viper species to allow the resumption of original behaviours. The location of the adders was recorded to 4 m using a handheld GPS device (Garmin™). A further 10-day tracking period was undertaken in late August 2014. This block of telemetry involved two translocated adders and four non-translocated adders that were residents at the receptor site.

Data Analysis

A maximum of 30 sampling occasions for each animal were recorded. However, several tags detached or malfunctioned resulting in fewer fixes for those individuals. Those adders with fewer than 15 sampling occasions were excluded from range analysis.

Movements were measured as a straight line between successive locations; in reality, these measurements would be underestimates as snakes rarely travel in a straight line (Whitaker & Shine, 2003). Snakes were scored as 'active' when the distance moved exceeded 4 m, the minimum resolution of the GPS device. Upon completion of each 10-day study, the average distance moved per day was calculated. A two-way ANOVA was used to test for differences in average movement by sex and status (translocated vs. resident).

With the exception of one male for which too few fixes were obtained for range analysis, the 100% Minimum Convex Polygon (MCP) and 95% Harmonic Mean were calculated for each snake using BIOTAS® v. 2.0 (Ecological Software Solutions, 2005). Following Butler et al. (2005), the MCP and 95% harmonic mean were calculated as a proxy for 'total' and 'home' ranges respectively. Individual ranges were compared for differences between sex and translocation status using a two-way ANOVA, and ranges were plotted using ArcGIS (v.10.3) (ESRI, 2014).

RESULTS

Fourteen adders, comprising ten translocated and four resident individuals, were tracked. Following a series of tag malfunctions, data were collected from 10 individuals including six and four translocated and resident adders respectively. Of these, adder AD4 was excluded from the range analyses due to too few data points.

Although the sample size was small, two-way ANOVA showed that males had higher mean daily movements than females ($F_{1,6}$=53.58; P<0.001) and that translocated adders on average moved further than residents ($F_{1,6}$=79.92; P=0.006). A significant interaction was also detected ($F_{1,6}$=55.3; P=0.012) indicating that the male and females responded differently to translocation. Indeed, translocated males moved between 1.1 and 2.6 times further than resident conspecifics (Table 1).

Estimates of total (MCP) and home ranges were calculated for the translocated adders and their resident conspecifics (Table 2). A two-way ANOVA revealed highly significant differences in MCP size by sex ($F_{1,5}$ = 59.97; P < 0.001) and translocation status ($F_{1,5}$ = 32.41; P < 0.001). Males held total ranges that were significantly larger than females and translocated adders exhibited total ranges that were larger than their resident conspecifics (Figures

Table 1. Mean daily movements of translocated and resident adders

Adder ID	Survey period	N	Sex	Movement (m)*
Translocated snakes				
AD1	April 2014	30	M	21.07 (SD 11.6)
AD2	April 2014	18	M	17.04 (SD 10.2)
AD4	April 2014	6	M	23.36 (SD 13.6)
AD5	April 2014	27	F	4.41 (SD 1.4)
AD8	April 2014	27	F	3.71 (SD 0.6)
AD11	August 2014	12	F	5.35 (SD 0.9)
Resident snakes				
AD9	August 2014	30	F	3.83 (SD 0.5)
AD10	August 2014	30	F	2.01 (SD 0.5)
AD13	August 2014	27	M	9.03 (SD 1.9)
AD14	August 2014	27	F	4.8 (SD 1.0)

Table 2. Range sizes in translocated and resident adders. Total Range = MCP, Minimum Convex Polygon; Home Range = 95% harmonic mean.

			Range size (ha)	
Adder ID	Survey period	Sex	Total range	Home range
Translocated snakes				
AD1	April 2014	M	2.38	3.02
AD2	April 2014	M	2.57	6.38
AD5	April 2014	F	0.04	0.23
AD8	April 2014	F	0.02	0.06
AD11	August 2014	F	0.01	0.03
Resident snakes				
AD9	August 2014	F	0.03	0.09
AD10	August 2014	F	0.006	0.05
AD13	August 2014	M	0.19	0.52
AD14	August 2014	F	0.05	0.55

provided as supplementary material). Furthermore, the interaction between translocation status and sex was highly significant ($F_{1,5}$ = 41.38; P = 0.001) indicating that males and females respond differently to translocation, with translocated male adders increasing their total range more than translocated females.

The analyses also identified significant differences in home range sizes by sex ($F_{1,5}$ = 9.85; P = 0.012) but not by translocation status ($F_{1,5}$ = 1.25; P = 0.29). However, significant differences between males and females was detected ($F_{1,6}$ = 5.87; P = 0.038). As previously, translocated males increased their home range sizes whilst translocated females did not.

DISCUSSION

Adders increased their movements post-translocation, but unlike other studies this response was exhibited solely by males. Although the sample sizes were small the movement patterns were compelling, and to our knowledge this is the first study to report that behavioural responses of snakes to translocation differ between the sexes. Translocated males undertook daily movements almost double those of the resident males and over three times those of the females (both translocated and resident). Indeed, all three telemetered males migrated away from the receptor site, crossing areas of unsuitable habitat in the process. As would be expected, the increased movements also resulted in larger range estimates.

There is a growing body of literature that criticises the use of mitigation-translocations (Dodd & Seigel, 1991; Reinhert & Rupert, 1999; Fischer & Lindenmayer, 2000; Butler et al., 2005; Germano & Bishop, 2008). The increased movements associated with translocated snakes can incur significant costs to the individual. Locomotion is energetically expensive, particularly so when it results in a behavioural shift from foraging to exploration. This combination of increased movements and reduced foraging is likely to have a deleterious effect on body condition (Reinert & Rupert, 1999) including diminutions in fecundity (Luiselli, 1992). Increased movements have also been associated with elevated risks of mortality (Andren, 1985; Madsen & Shine, 1993; Plummer & Mills, 2000; Butler et al., 2005). Highly mobile individuals are more likely to encounter predators or enter high-risk areas (Madsen & Shine, 1993; Shine & Fitzgerald, 1996). In a meta-review of published snake studies (which included the adder), Bonnet et al. (1999) reported that the highest levels of mortality coincided with dispersing neonates, males undertaking mate searching and females migrating to egg-deposition sites. Similarly, young adders experienced mortality rates of between 88% and 92% whilst undertaking dispersal (Prestt, 1971; Phelps, 2004). The results of this study provide further, albeit qualified, support to this criticism. The act of translocation appeared to disrupt typical courtship activities during April, a key period for breeding. Adders AD1 and AD2 undertook large, unidirectional movements back towards to the donor site where the former was observed courting a large female. It is not understood why the adders left the receptor site, which contained a high density of females (both translocated and resident), to return to the donor site. Male adders are able to detect females over considerable distances and would have been aware of the presence of females. Phelps (2004) described the formation of sub-groups within two adder populations across which there was no genetic exchange. If such a subdivision was present in the Essex adder population, it could explain why the males left the receptor site and perhaps resumed breeding activities with females in the donor site.

When developing mitigation strategies for adders, and in particular when designing receptor sites, it is important to account for this additional area requirement. However, given the absence of any published values for home ranges of adders in the UK, it is inconceivable that developers or their consultants are incorporating this important metric into mitigation strategies at present. Consideration should be given to whether short- or long-distance translocation would be the more appropriate technique. To answer this, further studies

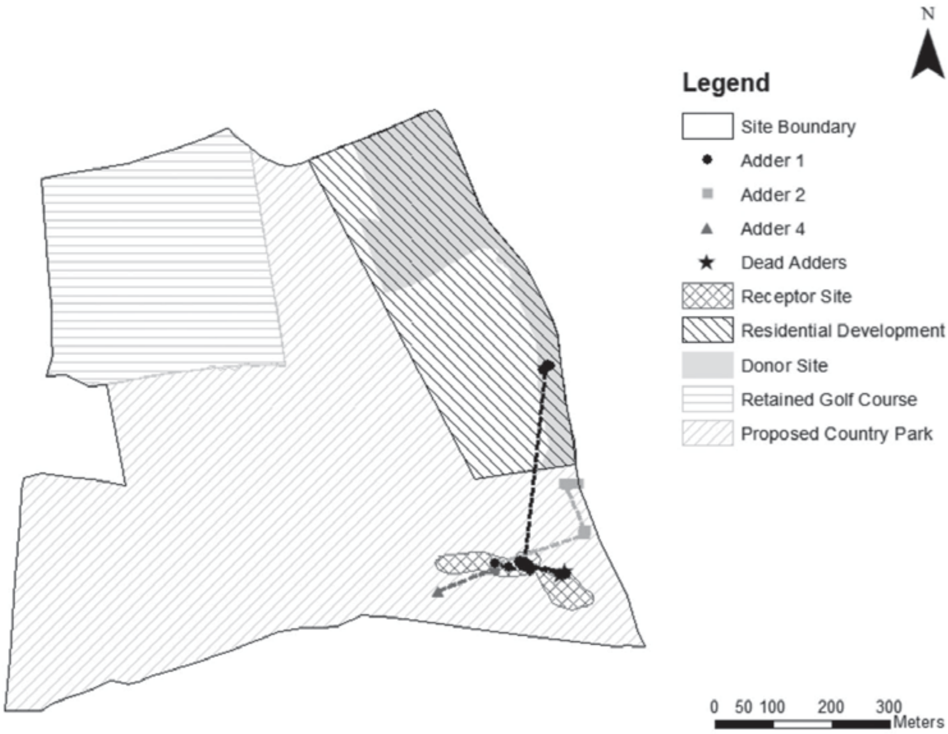

Figure 1. A map depicting the disused golf course and the proposed development plans. Following relocation from the donor, all male adders appeared to have left the receptor site. In contrast, female adders remained within 50 m of the point of release.

would be required to ascertain what constitutes 'typical' movements and home ranges for adders in the UK. Maintaining adders within their current range has clear benefits, such as the negation of extended movements and associated risks of mortality. Other factors, such as the transmission of disease and the mixing of locally adapted alleles, would also be mitigated. Conversely, the loss of part or all available habitat (including key features such as hibernacula and corridors) or the introduction of anthropogenic pressures (including domestic pet predation) could result in localised extirpation of retained populations. Any reductions in suitable habitat would correspondingly reduce the carrying capacity and thereby increase competition. Moreover, the introduction of high risks factors, such as a busy road, close to known adder population foci could adversely affect the population.

Homing behaviours could be managed through the construction of physical barriers such as strategically placed fences or, for more permanent developments, concrete walls (Kyek et al., 2007). Similar barriers could also be used to mitigate the propensity of translocated male adders to cross unsuitable and potentially unsafe habitat. However, the purchase and installation of fencing can be costly, extending to tens of thousands of pounds (Lewis, 2012). As a cheaper alternative to fencing, developers often intentionally degrade habitat making it unsuitable for reptiles. This 'buffer' is often considered to be sufficient for excluding reptiles from otherwise unfenced development sites. Whereas this approach may be effective for more sedentary species, such as viviparous lizards, the current study has demonstrated that its effectiveness cannot be guaranteed for adders.

Whether this translocation was a success or not depends on how success is defined. Forty-five adders were removed from the footprint of the development where the risk of harm was considerable. However, previous studies have indicated that the proportion of animals in a population that is detected and moved in a translocation is typically low (Platenberg & Griffiths, 1999; Germano et al., 2015). Consequently, any adders that remained undetected within the donor site along with those that returned post-translocation are likely to have been harmed through construction-related activities. In this context, for those individuals that were moved and did not return to the donor site, the translocation should be considered a success in the short-term at least. Although the current study did not include survival analyses, it is possible to infer increased risks of mortality post-translocation. A clear association exists between increased movements and mortality (Andren, 1985; Madsen & Shine, 1993; Plummer & Mills, 2000; Butler et al., 2005). Male adders, which exhibited both increased mean movements and ranges, would have experienced an increased risk of encountering predators or inhospitable habitat features. Indeed, two dead adders were recovered from adjacent to the release site (Fig. 1); both exhibited extensive musculoskeletal damage indicative of large mammals i.e. domestic cats, badger (*Meles meles*) or red fox (*Vulpes vulpes*). As both adders were decapitated, it was impossible to ascertain whether they were part of the translocated population. Longer-term comparisons of survival between natural and translocated populations obtained using capture-mark-recapture analysis would provide further information on the effects of translocation on snakes.

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