Post-release GPS tracking of hand-reared Irish hare *Lepus timidus hibernicus* leverets, Slemish, Co. Antrim, Northern Ireland

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SUMMARY

Animal rescue centres release large numbers of captive-bred, rehabilitated or translocated animals into the wild annually but little is known about their post-release survival and behaviour. We developed a novel and innovative coupling of traditional radio-tags with new GPS loggers to track hand-reared Irish hare *Lepus timidus hibernicus* leverets after release into the wild. Cyanoacrylate SuperGlue® proved a poor fixative with two out of three leverets managing to detach their tags within 24 hours. Nevertheless, a total of 2,505 GPS locations were recorded every 60 seconds for one leveret over three nights (approx. 835 per night). The leveret dispersed <410 m from the original release site. It demonstrated exploratory behaviour including an ability to navigate accurately in a complex and unfamiliar environment returning to a habitual lie-up site each day. Its survival was confirmed up to 9 days post-release at which time its radio-tag detached, however, similarly aged leverets were sighted in the area for up to 2 months post-release (suggesting possible longer term survival). This is the first study to publish data from any GPS tagged lagomorph and provides 'proof-of-concept' that large quantities of behavioural data can be recovered from small mammals 1-2 kg. Further development of these techniques will be highly valuable to future studies.

BACKGROUND

Animal rescue centres release large numbers of captive-bred, rehabilitated or translocated animals into the wild annually (L. Stocker pers. comm., cited in Moloney *et al.* 2006), including mammal species of conservation concern, for example, bats (Kelly *et al*. 2008) and water voles *Arvicola terrestris* (Moorhouse 2004, Mathews *et al.* 2005, 2006). However, such releases are frequently regarded as having little or no value by conservation biologists either due to the small numbers involved or their limited success (Beck *et al.* 1994, Ginsberg 1994, Mathews *et al*. 2005, Jule *et al.* 2008).

Hand-reared and rehabilitated individuals can have substantially lower survival rates following release compared to their wild counterparts (Fajardo *et al*. 2000, Robertson & Harris 1995, Werner *et al*. 1997). Post-release survival has been shown to depend on body condition both before captivity and at the time of release (Moorhouse *et al*. 2007), handling stress (Monnett *et al*., 1990), pre-release behavioural conditioning (Suarez *et al*. 2001) and the suitability of the release site (Monnett *et al*. 1990). Consequently, conservation strategies involving hand-rearing and release have important animal welfare implications (Cayford & Percival 1992, International Academy of Animal Welfare Sciences 1992, International Wildlife Rehabilitation Council 2005). Nevertheless, few studies have examined post-release survival and behaviour of hand-reared animals, most likely for two principal reasons; i) until relatively recently tagging technology was expensive and data acquisition labour intensive and ii) the large size of many tracking devices precluded tagging small animals, including many young mammals.

The maternal strategy of female hares *Lepus* spp. is to leave their leverets hidden near the natal area and return for only the briefest period each evening to suckle. Consequently, leverets are particularly vulnerable to being found, presumed abandoned and donated to animal rescue centres for hand-rearing (Anon. 2009). However, post-release survival and

behaviour of hand-reared leverets is entirely unknown.

The Irish hare *Lepus timidus hibernicus* (Bell, 1837), is listed as an endemic subspecies of mountain hare *L. timidus* to Ireland. It is protected under Appendix III of the Bern Convention (Anon. 1979), Annex V(a) of the EC Habitats Directive (92/43/EEC) and is listed as an internationally important species in the Irish Red Data Book (Whilde 1993). It is subject to both a Northern Ireland and an All-Ireland Species Action Plan (Anon. 2002, 2005) and consequently is one of the highest priority species for conservation action in Ireland.

This paper attempts to examine the post-release survival and behaviour of three hand-reared Irish hare leverets using a combination of traditional radio-tags and relatively new GPS loggers which are small, light weight and inexpensive. The goal was to demonstrate the 'proof-of-concept' that GPS loggers can be deployed to collect useful data from relatively small mammals (1-2 kg). Demonstration of the feasibility of GPS tagging will benefit the design of future conservation projects that wish to evaluate post-release survival and behaviour of hand-reared, captive-bred or translocated animals.

ACTION

Radio- and GPS-tagging: The spatial and temporal resolution of data on behaviour and survival is most critical immediate after release, as this is the period during which mortality is likely to be greatest. Spatial triangulation using traditional radio-tags can have a large margin of locational error whilst the frequency of data acquisition is dependent on the availability of labour and financial resources. GPS loggers acquire high resolution spatial data at a fixed rate but their drawback is that they must be retrieved in order to download the data.

The present study used homemade devices which incorporated a traditional radio-tag (TW-4 backpack with thermistor mortality sensor; Biotrack Ltd., Dorest, UK) and an i-gotU GT-120 travel and sports GPS logger (MobileAction, Taipei, Taiwan). The latter can be purchased relatively cheaply (£30 or $35) and was designed for backpackers, hikers and other travellers so that they may map their spatial tracks (see: http://global.mobileaction.com/product/product_i-gotU_USB.jsp).

We deconstructed each i-gotU GT-120 to remove its bulky outer casing, coupled it with a TW-4 radio-tag and sealed both inside heat shrink tubing to create a 40 x 20 mm, 17 g watertight unit (Fig. 1). Each i-gotU GT-120 was pre-programmed to acquire data at an interval of 60 seconds only during the crepuscular and nocturnal periods (17:00 – 09:00 during October). Battery life dictated that only three nights of data could be recorded.

It was imperative that hand-reared animals were not hindered by the tag but that it would remain attached for a minimum of 4 days prior to dropping-off so that data were acquired and retrieved. The latter function was facilitated by the radio-tag, which had a battery life longer than the GPS logger, enabling the location of the entire unit to be triangulated and thus retrieved. Each unit was glued to the fur of the nape of the neck on each leveret using cyanoacrylate SuperGlue®; this was expected to hold for a few days or weeks before falling off.

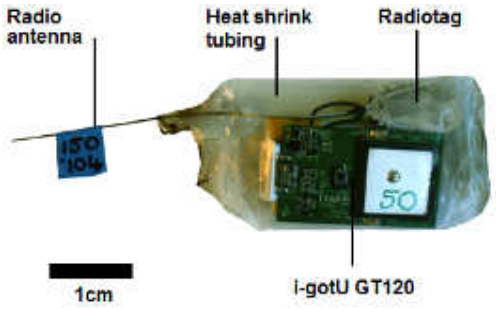

Figure 1. Custom made radio- and GPS-tag containing a TW-4 radio-transmitter with thermistor mortality sensor (Biotrack Ltd., Dorest, UK) and a deconstructed i-gotU GT-120 travel and sports GPS logger (MobileAction, Taipei, Taiwan) sealed inside heat shrink tubing to create a 40 x 20 mm, 17 g watertight unit.

Release: The Dublin Society for the Prevention of Cruelty to Animals (DSCPA) recovered three Irish hare leverets close-by a dead adult female. A number of suspected poisoning events had been previously recorded in the area. The leverets were approximately 3 weeks old and hand-reared by the 'Hogs of the Gods' Animal Rescue Centre, Dublin. All three leverets were released at approximately 16 weeks of age ensuring that they were fully weaned and independent. The release site was situated at Slemish Mountain, County Antrim, Northern Ireland and was chosen due to the suitability of appropriate habitat, being a mix of good quality agricultural grassland providing forage and rush *Juncus* or heather *Calluna vulgaris* -dominated rough pasture providing shelter. Moreover, the site was remote from urban and rural developments and was known to support a resident population of wild hares.

Two leverets (1 male and 1 female) were tagged and released on 15 October 2009, whilst a third (a male) was released on 22 October 2009. All handling, tagging and release was done under Government licence TSA/12/09 (Licensee No. 961).

Data manipulation: The accuracy of the i-gotU GT-120 units was tested by leaving three devices in a known location over night with a 60 second data acquisition regime. Mean locational error was calculated. Leveret activity was described throughout the night by plotting the interfix distance against time. However, the mean locational error measured from test devices was subtracted from each interfix movement and all negative values replaced with zero. Consequently, movements less than the mean locational error for each device were attributed to the same spatial location and it was assumed the animal did not move. The interfix distance was then divided by the time elapsed between successive points to determine mean travelling speed, expressed in kph. The mean running speed of an Irish hare travelling at maximum velocity has been measured at 43.3 ± 1.8 kph (Reid *et al*. 2007). Any sequential GPS fixes that exceeded this speed or those that were inconsistent with the overall direction of travel were also removed from analysis.

Analyses: The minimum convex polygon (MCP) method (Harris *et al*. 1990) was used to determine the 'home range' per night whilst the 'range' and 'core range' were determined using the 95% and 50% probabilistic kernel method respectively (Worton 1987). All radiotelemetric analyses were conducted using the Animal Movement extension (Hooge & Eichenlaub 2000) for Arcview GIS 3.3 software. Leveret activity was described throughout the night by plotting the interfix distance against time. Activity patterns were compared between nights using Spearman's rho correlation on the mean interfix distance per hour.

CONSEQUENCES

Of the three leverets released, two removed their tags within 24 hours suggesting that cyanoacrylate SuperGlue® was a poor choice of fixative. One GPS logger failed to activate whilst the other had acquired 4 hours of data before detachment. The latter indicated that the animal moved <210 m from the release site. No evaluation of survival could be made for either animal (Table 1).

Table 1. Summary of Irish hare leverets that were tagged and the outcome post-release.

Leveret ID	Sex	Weight (kg)	Date of tagging & release	Outcome	Date of retagging	Outcome	Date of cessation of study
150.104	M	2.00	22/11/2009	Tag detached within 24 hours. GPS logger failed to activate.	-	-	22/11/2009
150.155	M	1.65	15/11/2009	Tag detached within 24 hours; 4 hours of GPS telemetry acquired.	-	-	15/11/2009
150.032	F	1.65	15/11/2009	Tag remained attached for 4 days; GPS logger destroyed due to chewing.	20/11/2009	3 nights of GPS telemetry recovered.	24/10/2009

The third leveret retained its tag for three days (sufficient to exhaust the battery life of the GPS logger) and it was decided to remove the tag manually to retrieve the data. The animal was triangulated using the radio-signal and was approached to within 1.5 m. A net was placed over it and the tag removed using a scalpel to cut the fur to which it was attached. Unfortunately, the animal had chewed the shrink-wrap casing and had damaged the USB connector preventing the downloading of any data. Subsequent attempts to fix the damaged tag, including contacting the manufacturer, failed. Consequently, it was retagged, released *in situ* and three days later recaptured. The second logger was removed intact and the hare retagged with a radio-tag only, to continue monitoring survival (Table 1).

Survival of this leveret could only be confirmed up to 9 days post-release before the tag detached. It remained within <350 m of the release site for the first four days prior to recapture and GPS retagging. It subsequently dispersed <200 m from the second release site. Over the three nights during which GPS telemetry were retrieved, a total of 2,618 GPS locations were recorded. A total of 113 locations (<5%) were discarded as they either violated the maximum possible running speed of a hare or were inconsistent with previous activity. Consequently, a total of 2,505 GPS locations were retained for analysis (approx. 835 per night).

The total home range (MCP) of the leveret during each night (nights 3-5 post-initial release) was 11.25 ha, 3.63 ha and 13.67 ha respectively. The range of the animal (95% kernels) was significantly smaller at 0.40 ha, 0.28 ha and 0.63 ha respectively, whilst the core range (50% kernels) was 0.06 ha, 0.04 ha, 0.10 ha respectively. The ranges and core ranges overlapped between all three nights (by up to almost 100%) demonstrating a high degree of site fidelity (Fig. 2a-c). The diurnal lie-up location was at the centre of each core range and did not vary over the three days of tracking. The total distance between the initial release site and the centre of the core range during nights 3-5 was <410 m. During night 3, the leveret moved in multiple directions but never more than 400 m from the centre of its core range (Fig. 2a). During night 4, the leveret moved predominately in a north-westerly direction but not more than 325 m from its core range (Fig. 2b). In contrast, during night 5, the leveret made a number of repeated long-distance exploratory movements in a roughly easterly direction up to 1,000 m from its core range (Fig. 2c).

GPS loggers had a measured accuracy of 38.8 m and activity levels, determined by interfix distances, were adjusted accordingly. Levels of (corrected) activity varied significantly throughout each night between 0 - 475 m between successive fixes (Fig. 2e-f). The patterns of activity were very similar and were highly correlated between all three nights when generalised per hour (Fig. 3).

Discussion: To our knowledge this is the first study to publish results from any GPS tagged lagomorph and provides a proof-of-concept that satellite data can be retrieved from mammals <1.5 kg in size elucidating behaviour (in this case post-release dispersal and activity) in unprecedented detail. Moreover, the GPS loggers used here had a measurable mean error of <40 m which is substantially better than many traditional radio-tracking triangulation techniques.

Cyanoacrylate SuperGlue® proved a poor method of tag attachment suggesting that future models of the tags used here may be better designed as collars or backpack mounts. This presents significant problems in retrieving tags. Although, time release collars are now available they are generally too large for mammals as small as hares. Likewise 'degradable' backpack mounts are available but these are designed to fall off over longer time periods (several months).

In the case of the individual leveret tracked successfully, it dispersed <410 m from the initial release site and may not have moved that far if it had not been for the disturbance caused by recapture and retagging. Whilst its maximum home range (MCPs) did not differ in size from that of wild Irish hares elsewhere (Wolfe & Hayden 1996, Jeffery 1996) its range (95% kernels) and core range (50% kernels) was significantly smaller (Reid 2006). The leveret used a fixed lie-up site during the three days for which GPS telemetry were retrieved and was capable of returning to this spot despite moving beyond its core range each night. Moreover, long distance exploratory movements (up to 1 km) were direct and it followed the same path back to its core range with a high degree of precision. We tentatively suggest that despite being unfamiliar with the release site and surrounding area, the tagged leveret was evidently capable of accurate navigation in a complex landscape.

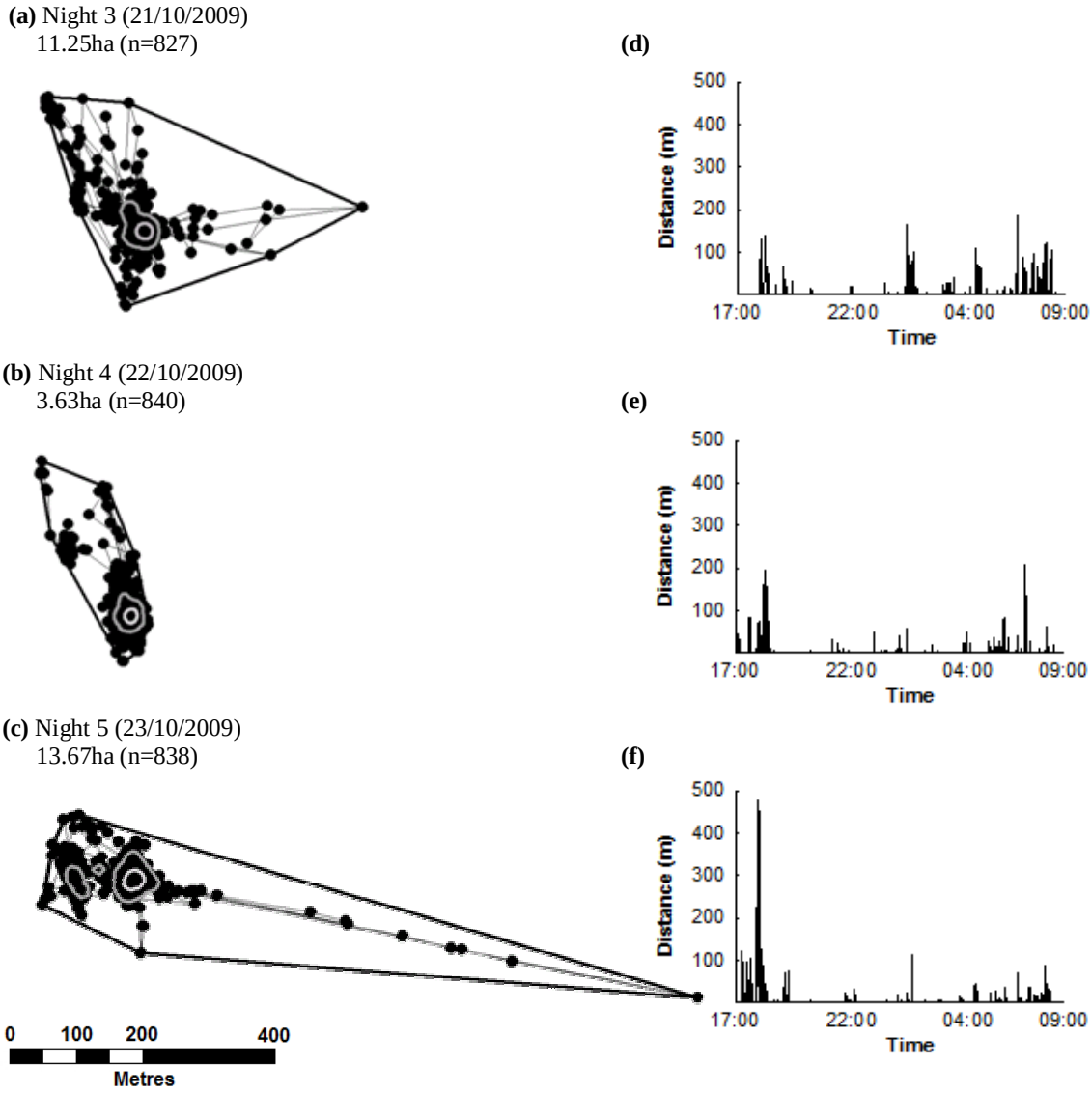

Figure 2. Minimum convex polygon home range of an Irish hare leveret during nights **a)** 3, **b)** 4 and **c)** 5 post-release (external bold line). Dots represent GPS locations taken every 60 seconds, thin lines represent movements, dark grey lines present the 95% kernel range and light grey lines represent the 50% kernel core range. **d-e)** show movement activity throughout each night using interfix distances.

The activity of the leveret was highly correlated between all three nights being greatest just after dusk and increasing steadily towards dawn with a discrete peak during the middle of the night at 01:00 hours. We tentatively suggest that the consistency of this pattern demonstrates a regular daily routine which may vary little over short periods of time.

Whilst the results of this study cannot be generalised it demonstrates the extraordinary quantity of behavioural data that can be collected using readily available, economically cheap GPS loggers. Moreover, this study raises the possibility of answering questions which hitherto have been precluded due to a lack of adequate technology. Further research will allow not only the post-release survival and behaviour of hand-reared leverets but also other small mammals as well as the behaviour of wild animals.

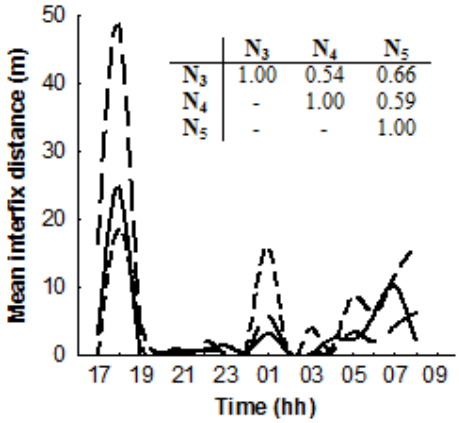

Figure 3. Leveret activity, defined as mean interfix distance (m) during each hour throughout the crepuscular and nocturnal periods for three nights (N_3, N_4 and N_5 shown as separate lines). Insert shows the Spearman's rho correlation coefficients between each night significant at $p<0.05$.

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