Trial of a bridge for reconnecting fragmented arboreal habitat for hazel dormouse *Muscardinus avellanarius* at Briddlesford Nature Reserve, Isle of Wight, UK

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SUMMARY

The hazel dormouse *Muscardinus avellanarius* has experienced a marked decline in the UK in recent years, attributable in part to habitat fragmentation associated with an expanding road and rail network. A number of arboreal crossing structures have been installed in the UK to reconnect fragmented habitat, but the only proven usage of such structures by wild hazel dormice has been associated with a large-scale land bridge. This has highlighted the need for affordable, evidence-based alternative designs. We tested the effectiveness of a new dormouse bridge, previously shown to be used by Japanese dormice *Glirulus japonicas* in Japan, in reconnecting two woodland patches bisected by a railway in southern England. Hazel dormice were recorded on the bridge within nine hours of its erection and exhibited a clear preference for using the bridge, with more than ten times more observations of dormice on the bridge compared to crossing the railway at ground level. Red squirrels *Sciurus vulgaris*, another rare UK mammal, were also recorded on the bridge. The trial provided evidence of the effectiveness of this design of crossing structure in reconnecting arboreal habitat for hazel dormice and other wildlife, with implications for hazel dormouse mitigation in infrastructure projects.

BACKGROUND

The hazel dormouse *Muscardinus avellanarius* is a nocturnal rodent native to Europe, including the United Kingdom. Hazel dormice live at low population densities and occupy small home ranges. Hazel dormice are adapted for a predominantly arboreal lifestyle, using aerial pathways in the tree and shrub canopies to move around. Although studies have illustrated that non-wooded habitat is not a complete barrier to their movement (Bright 1998, Buchner 2008, Chanin & Gubert 2012), they are reluctant to cross habitat gaps at ground level, often travelling out of their way to find arboreal opportunities (Bright & Morris 1992, Bright *et al.* 1994, Bright 1998, MacPherson *et al.* 2011, Schultz *et al.* 2012).

The most important habitat requirements of the hazel dormouse are the presence of a dense and varied tree and/or shrub cover to facilitate arboreal movement, accessibility to a range of natural food throughout the waking year, dense foliage for the construction of breeding nests and suitable undisturbed places to hibernate at ground level. The species therefore typically inhabits native broadleaved woodland with a vigorous, dense understory, interconnected dense scrub and connected dense hedgerows, although it has also been identified in other habitats such as conifer woodland and gardens. Studies have shown that roadside habitat is particularly important, due to the presence of species-rich, connected belts of woody vegetation (Shultz *et al.* 2012).

The UK hazel dormouse population has declined by approximately half in the last 100 years, including a drastic range contraction (Hurrell & McIntosh 1984, Bright *et al*., 1996). Consequentially, the hazel dormouse, its breeding sites and resting places are afforded full legal protection under both UK and European legislation. Biodiversity strategies require the species to be a material consideration in the planning process. Despite this, it is estimated that populations are still declining at a rate of 5.8% annually (Goodwin *et al.* 2017).

The ever-increasing urbanisation of the UK may be contributing to this decline. Railway and highway construction has led to large-scale habitat fragmentation. Highways reduce the potential for young hazel dormice to disperse, thereby reducing population strength through metapopulation establishment and gene transfer, as well as reducing accessibility to a suitable range of sequential foraging resources. Where hazel dormice do cross highways at ground level they are more vulnerable to predation as they have left the cover of vegetation, with vehicular collision an added threat. A further obstacle is the installation of solid concrete safety barriers within central reservations of major highways, which pose an almost total block to wildlife passage.

A number of small arboreal crossing structures have been installed in the UK in an attempt to maintain habitat connectivity for hazel dormice, in particular associated with highway schemes (from large scale motorway schemes to narrow access roads). The only proven usage of a 'dormouse bridge' is associated with a large-scale vegetated land bridge, where hazel dormice have been recorded breeding upon the bridge itself. Although obviously valuable for biodiversity, land bridges incur substantial cost, limiting their feasibility in most mitigation schemes.

A range of smaller designs have been installed, broadly following the principles of suspending lengths of rope or enclosed mesh tubes over habitat gaps. Concern exists regarding the suitability and effectiveness of these structures (Morris & Minato 2012), and there is a lack of evidence about such designs. Although captive-bred hazel dormice have crossed a gap of 50 m through a connecting mesh tube if enclosed within cages at either end of the tube (Woods & Creswell, pers comms; Stride 2009), such usage has never been shown in hazel dormice in wild situations. The mesh tube design requires individual hazel dormice to either find the small tube entrance (which is often located at ground level), or cross along the top of the bridge, breaking from the cover of vegetation. Rope bridges require similar behaviour.

No records appear to exist of the usage of these smaller bridge designs by wild hazel dormice. These structures can also

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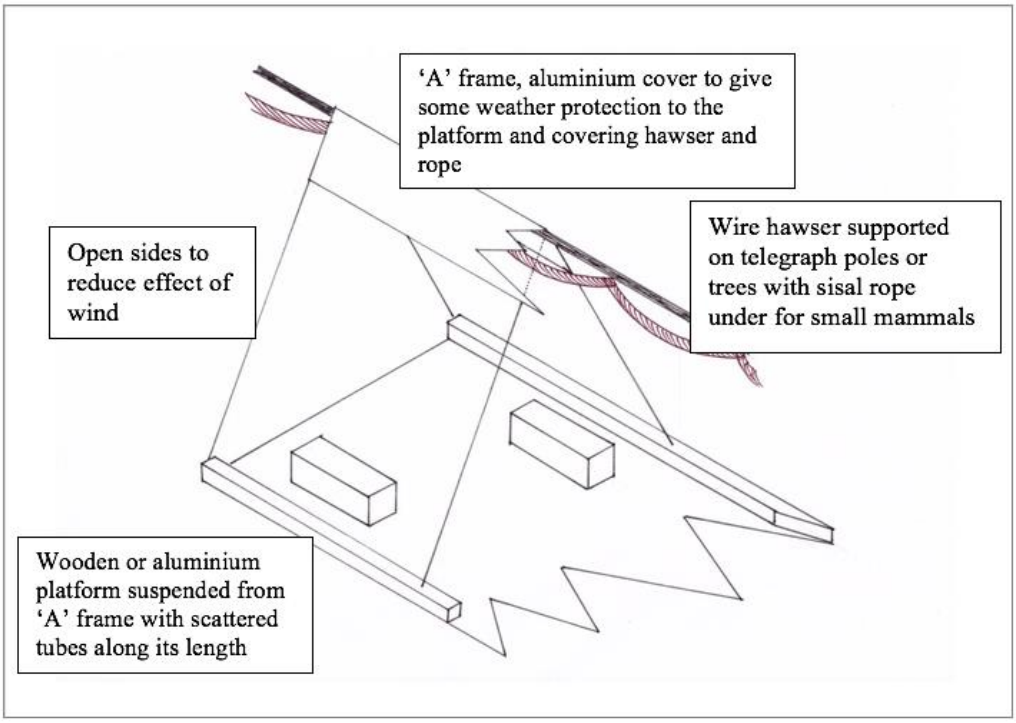

Figure 1. Schematic design of arboreal platform used successfully in Japan to reconnect fragmented Japanese dormouse habitat (Minato *et al.* 2012).

incur substantial cost, limiting the numbers that could be installed and therefore their accessibility to the local population. Many structures lack longevity, thereby representing only a short-term mitigation solution. Finally, many such structures have been installed in unsuitable locations with no natural habitat link with either the immediate or wider landscape. These issues prompted the need for evidence-based, affordable and reliable alternatives to mitigate the fragmentation of hazel dormouse habitat in anthropogenic situations.

A trial was undertaken in Japan to assess the effectiveness of a specific design of arboreal crossing structure in reconnecting habitat fragmented by a road for the Japanese dormouse *Glirulus japonicas* (Minato *et al.* 2012, Figure 1). CCTV monitoring of the structure recorded its use by at least four mammal species more than 800 times in a three month period, including the Japanese dormouse. The road that the structure crossed was only 10 m wide and not heavily used, suggesting a clear preference for arboreal crossings, even when ground-level crossing was easily possible and animals had to travel out of their way to use the bridge (Minato *et al.*, 2012).

The success of the Japanese study prompted a similar trial in the UK, in which we tested the effectiveness of a similar crossing in reconnecting woodland habitat bisected by a railway in southern England. We examined whether hazel dormice would exhibit a preference for using the bridge or crossing the habitat gap at ground level.

ACTION

Trial Setup: The trial site is located within Briddlesford Nature Reserve on the Isle of Wight, UK (OS Grid Reference SZ 54998 90227), where an existing railway dissects two halves of a woodland known to support healthy populations of hazel dormice.

The UK trial bridge was based upon the Japanese specification (Figures 1 & 2), comprising a modular structure of individual 1.8 m long modules with a triangular cross section (325 mm x 275 mm). A horizontal 3 mm square stainless steel mesh 'floor' was protected on either side by horizontal wooden batons and part-sheltered by a wooden triangular cap along the top of the bridge. The gap between the wooden side batons and the triangular cap was left open to provide multiple access points for hazel dormice at either end of the bridge, which extended three metres into the canopy, and to allow movement between the different elements of the structure. Two small shelters (square in cross-section, 65 mm^2 x 200 mm length) were secured to the mesh floor of each 1.8 m module for additional predator protection.

The trial bridge was suspended on a steel cable between mature trees either side of the railway, approximately 2 m above an existing railway bridge (as requested by the railway owners due to safety concerns associated with the regular checking of cameras). The total length of the bridge was 30 m, representing the approximate width of a UK dual carriageway. Branches were secured to both ends of the trial bridge to provide connections to surrounding vegetation.

Figure 2. The trial dormouse bridge in situ.

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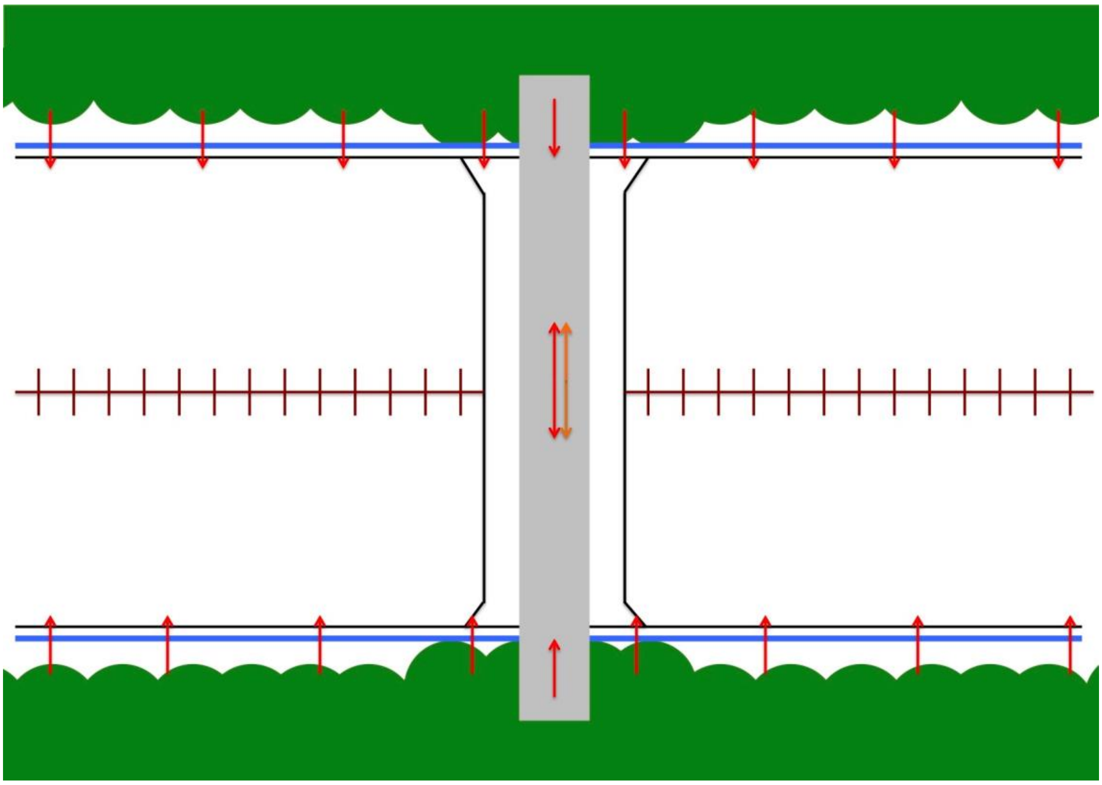

Figure 3. Trial setup. Grey block illustrates the dormouse bridge, suspended over an existing railway bridge. Arrows indicate locations and directions of motion-activated cameras: red on the ground and the 'floor' of the bridge, orange on the top of the bridge. Blue lines illustrate locations of polythene wildlife exclusion fencing.

To allow any ground-level hazel dormouse crossings to be recorded, 200 m of 1 m high polythene wildlife exclusion fencing was installed along either side of the railway, centred on the trial bridge (including both ends of the railway bridge, Figure 3), reflective of the usual home range of the hazel dormouse (approximately 0.5 ha for males and 0.2 ha for females (Bright & Morris 1991, Bright & Morris 1992)). Small holes, to allow passage of hazel dormice, were made through the fence at ground level at 30 m intervals.

Twenty-four motion-activated infra-red cameras were installed; one at each of the 18 fence holes and six on the bridge (Figures 3 & 4). Cameras were programmed to activate between dusk and dawn when motion occurred, and film for 20 s.

All natural aerial connectivity within the 200 m zone was severed, so that any hazel dormice crossing the gap would pass the cameras. Fifty wooden nest boxes were installed within the woodland either side of the crossing to increase the suitability of surrounding habitat, in an attempt to attract individuals to the site.

Figure 4. Photograph of end of trial dormouse bridge, well connected into surrounding dormouse habitat network.

Monitoring: The trial bridge was erected on 30 September 2015 to determine ease of installation, and was subsequently dismantled on 10 October 2015 to protect it from the winter weather. The bridge was then re-erected in April 2016 and monitored between 2 May and 24 November 2016 to coincide with a full hazel dormouse active season. Surveyors visited the site every two weeks during the 2016 trial, changing the batteries on the cameras and downloading the data.

Data evaluation: All video clips were collated and assessed to determine the species detected. Video clips were grouped into 'events' where necessary. A unique event was deemed to have occurred if a cluster of video clips were recorded within five minutes of each other with, where possible, the trigger species identified. Single clips spaced more than five minutes apart were considered to be individual events. Where a clip was generated with no obvious reason this was classified as a 'false trigger'.

CONSEQUENCES

Hazel dormice were recorded on the bridge immediately following the trial installation in 2015. The first event was recorded nine hours after its installation, at 20:56 on 1 October 2015. Prior to its dismantling for the winter, hazel dormice triggered the bridge cameras 59 times during the ten-day period. One red squirrel *Sciurus vulgaris* was recorded on the bridge during this period.

A total of 17,949 video clips were generated by the ground and bridge cameras during the 2016 trial period, comprising a total of 13,409 individual events; 841 on the bridge and 12,569

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Table 1. Events recorded by cameras on the bridge and the ground throughout the 2016 trial season, between 2 May and 24 November.

Events	All cameras		Bridge cameras		Ground cameras	
	Number	%	Number	%	Number	%
False Trigger	5277	39.4	324	38.5	4953	39.4
Wood mouse	4939	36.9	-	-	4939	39.3
Brown rat	1178	8.8	-	-	1178	9.4
Fault	459	3.4	-	-	459	3.7
Train	396	3.0	315*	37.5*	81	0.6
Bird	352	2.6	46	5.5	306	2.4
Bank vole	186	1.4	-	-	186	1.5
Red squirrel	138	1.0	94	11.2	44	0.4
Pheasant	106	0.8	-	-	106	0.8
Unknown	99	0.7	3	0.4	96	0.8
Shrew	73	0.5	-	-	73	0.6
Hazel dormouse	39	0.3	36	4.3	3	>0.0
Cat	39	0.3	-	-	39	0.3
Man	39	0.3	11*	1.3*	28	0.2
Badger	31	0.2	-	-	31	0.2
Insect	37	0.3	11	1.3	26	0.2
Rabbit	11	0.2	-	-	11	0.1
Fox	3	>0.0	-	-	3	>0.0
Frog	3	>0.0	-	-	3	>0.0
Stoat	2	>0.0	-	-	2	>0.0
Bat	1	>0.0	-	-	1	>0.0
Cattle	1	>0.0	1*	0.1*	-	-
Weasel	1	>0.0	-	-	1	>0.0
TOTAL EVENTS	13409		841		12569	

*Recordings by bridge cameras of trains, people and cattle were triggered by movements on the ground below the bridge.

on the ground (Table 1). Thirty-nine events were attributable to hazel dormice; 36 on the bridge and three on the ground.

Where hazel dormice were recorded on the ground, they were not observed to pass through the holes in the exclusion fence, therefore no individuals were recorded crossing the habitat gap at ground level.

Hazel dormice were first recorded on the bridge on 12th May 2016. The bridge was used by dormice throughout the trial period, apart from in August. Although issues were experienced with the accurate synchronisation of the individual cameras, complete bridge crossings were considered highly likely to have occurred when cameras targeted on the northern and then southern half of the bridge (or vice versa) were systematically triggered within a short period. Of the 36 individual hazel dormouse events recorded on the bridge during the trial period, a total of 16 full crossings were considered likely to have occurred, representing just under half of the total on-bridge events recorded.

Highest usage of the bridge by hazel dormice was recorded in May, June and October, and lowest usage during July and August (Figure 5). This largely correlated with the number of full crossings likely to have occurred; likely full crossings were recorded in May, June, September and October (Figure 6).

A number of other species were recorded by both the bridge and ground cameras, as well as a total of 5,277 false triggers. Of particular interest was red squirrel; 138 events were attributable to the species; 94 on the bridge and 44 on the ground.

Hazel dormouse behaviour on the bridge was studied. All aspects of the bridge structure were used by individuals, often within a single event. Individuals were recorded running along the mesh floor, along the wooden batons and also along the top of the bridge, although higher numbers were recorded using the sides and/or floor than the top (76% versus 23% respectively). Individuals would often also run through, and pause within, the periodic shelters attached to the bridge floor. Some individuals appeared to run quickly across the bridge, particularly when using its top, however many spent a number of minutes slowly moving around on the mesh floor.

DISCUSSION

It is believed that this trial represents the first recorded example of wild hazel dormice using a small arboreal bridge in the UK. The study illustrated that hazel dormice, as well as red

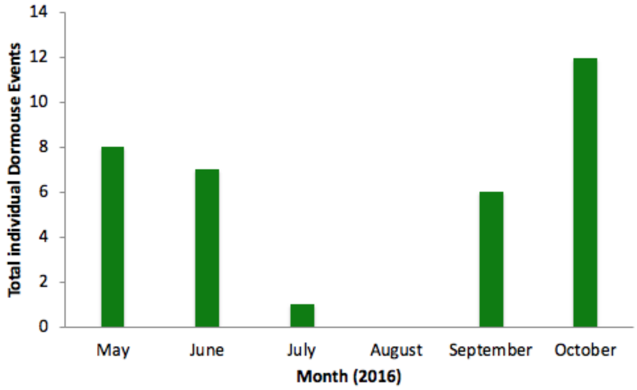

Figure 5. Total individual hazel dormouse events on the bridge per month during the survey period.

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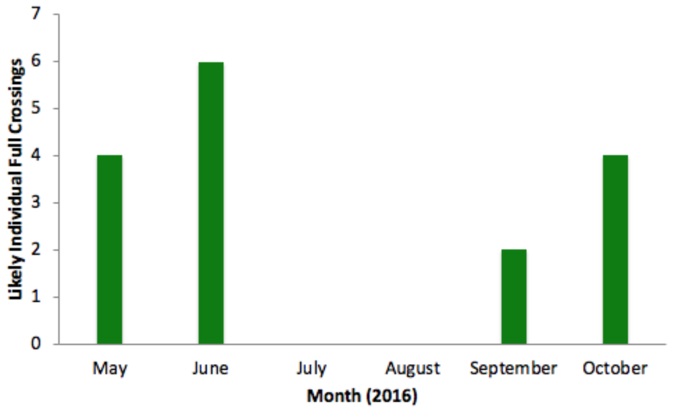

Figure 6. Total individual hazel dormouse likely full crossings of the bridge during each month of the survey period.

squirrels, exhibit a preference for the use of this bridge design to cross a habitat gap rather than crossing at ground level.

It is likely that the design of the structure contributed to its acceptability by hazel dormice. The structure provided multiple access points onto the bridge via the openings along the sides and by extending each end of the bridge well into the vegetation either side of the habitat gap, increasing the ease of it being found by hazel dormice and ensuring integration with the surrounding habitat network. The design allowed hazel dormice to move between the multiple elements of the bridge, with opportunities to seek cover at all times, representative of the species' natural behaviour. Detailed consideration was also given to the siting the bridge so that it was optimally located for hazel dormice to find. This was enhanced via the installation of dormouse boxes within the surrounding habitat to encourage individuals to the bridge site.

The behaviour exhibited by hazel dormice on the bridge suggests that individuals were relatively at ease on the bridge. They often spent an extended period of time moving around on the floor, possibly due to the element of protection afforded by the sides and periodic shelters, rather than merely running across as quickly as possible. Where individuals were recorded using the top of the bridge, they appeared less at ease, crossing quickly or periodically dropping down to the lower elements of the structure.

It is likely that the higher level of usage during May, June, September and October was reflective of the time of year when hazel dormice are most mobile. In May and June hazel dormice will be foraging after the hibernation season and searching for nest sites. In September and October juveniles will be dispersing from their birth site. The bridge is therefore considered to be of particular value at these times of year.

Hazel dormice live in low population densities; the National Dormouse Monitoring Programme suggests an average adult density of between 1.75 and 2.5 adults per hectare, based on 83 sites in various habitats (1993 to 2000 inclusive; Bright & Sanderson, pers. comm.; Bright *et al.* 2006). Within Briddlesford Woods, where over 500 next boxes are surveyed each spring and autumn, the average estimated spring and autumn densities of adult hazel dormice per hectare between 2010 and 2017 were 1.73 and 4.93 respectively (total numbers of adults recorded have been doubled as chipping studies suggest surveys typically identify between a third and a half of any individuals in the vicinity). Hazel dormouse populations also fluctuate by site and year. Comparing the monitoring data of mature animals in the autumn in 2016 with the annual data between 2006 - 2016, the year the trial was undertaken ranked fourth lowest over the decade. Therefore, whilst the number of individual hazel dormouse events recorded on the bridge might be considered low, the data must be considered in light of the state of the population in the wider area and the low population densities of the species as a whole.

A possible limitation of the trial was the sensitivity of the motion-activated cameras. The majority of false triggers were likely attributable to the environment, such as the movement of a leaf or the swaying of the bridge in the wind. It is, however, possible that the slow trigger speed of the cameras resulted in hazel dormice not being recorded when they had passed by a camera, particularly when false triggers occurred within a few minutes of a confirmed hazel dormouse record. Although this has likely resulted in the under-counting of individuals on the bridge, it is not considered to represent a significant limitation of the overall study as the methodology still allowed both study aims to be met.

The trial design has now been updated such that it can be implemented within hazel dormouse mitigation schemes, allowing infrastructure projects to comply with both planning policy and wildlife legislation whilst also benefiting the continued conservation status of the species. The new design retains the same overall appearance. However the structure has been upgraded to a fixed construction rather than one suspended on a cable, and the materials have been upgraded. This increases the durability of the bridge, allowing it to provide viable long-term habitat connectivity opportunities as well as ensuring compliance with highways legislation. Two design options have been developed: a standalone structure and one that can be retrospectively fitted to existing features such as concrete road bridges, gantries and underpasses, allowing it to be used in a range of fragmentation situations. Best practice guidelines have also been produced, to ensure future dormouse bridges are suitably positioned and monitored, thereby ensuring their long-term effectiveness.

This successful trial has demonstrated an effective design of arboreal pathway which, if suitably located, provides habitat connectivity for hazel dormice where habitat fragmentation would otherwise limit movement. The trial bridge spanned a gap of 30 m, the approximate width of a UK dual carriageway. This suggests the design could provide suitable habitat connectivity across highways and other infrastructure of this width. The design has also proven effective in aiding other arboreal species in fragmented landscapes, as demonstrated by both the UK and Japanese trials. This has clear implications for the future of conservation efforts associated with arboreal species.

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REFERENCES

Bright P. (1998) Behaviour of specialist species to habitat corridors: arboreal dormice avoid corridor gaps. *Animal Behaviour*, **56**, 1485-1490.

Bright P.W. & Morris P.A. (1991) Ranging and nesting behaviour of the dormouse *Muscardinus avellanarius* in

ISSN 1758-2067

diverse low-growing woodland. *Journal of Zoology*, **224**, 177-190.

Bright P. & Morris P. (1992) Ranging and nesting behaviour of the dormouse (*Muscardinus avellanarius*) in coppice with standards woodland. *Journal of Zoology*, **226**, 589-600.

Bright P. W., Morris P. A. & Mitchel-Jones A.J. (1996) A new survey of the Dormouse Muscardinus avellanarius in Britain, 1993-4. *Mammal Review* **26,** 189-195.

Bright P. W., Mitchel P. & Morris P. A. (1994) Dormouse distribution: survey techniques, insular ecology and selection of sites for conservation. *Journal of Applied Ecology*, **31**, 329-339.

Bright P., Morris P. & Mitchell-Jones T. (2006) *The dormouse conservation handbook.* 2nd edition. English Nature, Worcester.

Buchner S. (2008) Dispersal of common dormice *Muscardinus avellanarius* in a habitat mosaic. *Acta Theriologica*, **53**, 259-262.

Chanin P. & Gubert L. (2012) Common dormouse (*Muscardinus avellanarius*) movements in a landscape fragmented by roads. *Lutra*, **55**, 3-15.

Goodwin C. E., Hodgeson D. J., Al-Fulaij N., Bailey S., Langton S. & McDonald R. A. (2017) Voluntary recording scheme reveals on going decline in the United Kingdom hazel dormouse *Muscardinus avellanarius* population. *Mammal Review*, **47,** 183-197.

Hurrell E. & McIntosh G. (1984) Mammal Society dormouse survey, January 1975 – April 1979. *Mammal Review*, **14,** 1-18.

MacPherson D., MacPherson J. L. & Morris P. (2011) Rural roads as barriers to the movement of small mammals. *Applied Ecology and Environmental Research*, **9**, 167-180.

Minato S., Ohtake K. & Morris P. (2012) Helping (Japanese) dormice to cross the road. *Oryx*, **46**, 325-32.

Morris P. & Minato S. (2012) Wildlife Bridges for Small Mammals. *British Wildlife*, **23**, 153-157.

Schulz B., Ehlers S., Lang J. & Buchner S. (2012) Hazel dormice in roadside habitats. *Peckiana*, **8**, 49-55.

Stride I. (2009) *Dormouse bridge report, Wildwood, Kent.* The Dormouse Monitor **(2)**, 8.

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