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An overview of *Rhinolophus hipposideros* in Ireland (1994–2014)

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Abstract. The conservation of the lesser horseshoe bat (*Rhinolophus hipposideros*) in Ireland stands at an interesting juncture in the second decade of the 21st century. A substantial volume of information has been gathered now on its distribution, roost and foraging preferences, commuting behaviour and genetics. Roost data collected over several decades have been subjected to robust statistical analysis and modelling exercises that have yielded reliable information on the number of horseshoes in the country, detected an increase and determined the monitoring effort needed to detect future declines. Many major maternity and hibernation roosts have been repaired and are legally protected. However, separate studies have identified the existence of two distinct regions within the species' core area that contain two distinct genetic clusters – one in the north and one in the south of its range. This situation, if not appropriately addressed by conservation measures at a broad landscape level, could pose a long-term risk to the future survival of this species in Ireland.

Lesser horseshoe bat, population increase, research, conservation, habitat fragmentation, restricted gene flow

Introduction

The research conducted by Professor Jiří Gaisler on the lesser horseshoe bat during the 1960s (Gaisler 1963) was the primary source of information for the first major study of this species in Ireland, which was undertaken during the 1980s (McAney & Fairley 1988, 1989). A review paper of the species in Ireland was published to mark his 60th birthday (McAney 1994) in which its future status was speculated upon. This review paper is written to mark his 80th birthday and offers a welcome opportunity to assess the considerable progress that has been made in Ireland in the related areas of research and conservation of this small horseshoe species. However, it also highlights some issues that, if not addressed, could reverse the significant progress that has been made.

Background to the lesser horseshoe bat in Ireland

The lesser horseshoe bat holds a unique position within the Irish bat fauna. It is the only member of the Rhinolophidae to occur on the island (which marks its northern distribution point) and the only Irish bat species listed in Annex II of the EC Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora, thus requiring Special Areas of Conservation (SACs) to be designated for its protection, of which there are currently 44. It is one of just two species with a limited distribution, currently only found in six western counties, Mayo, Galway, Clare, Limerick, Kerry and Cork (Fig. 1). However, there are areas within this core region where there are few or no colonies. Currently the population is estimated to be 14,010 (NPWS 2014).

The population genetics of the species indicate that it colonized Ireland at a time when the island was covered by deciduous woodland following the end of the last ice age and that it subsequently underwent a population expansion about 6,000 years ago (Dool pers. comm.). It is assumed that the lesser horseshoe was once widespread throughout the island when suitable habitat was available and fossil remains of it from a cave in County Waterford, outside its current range, would support this assumption (Movius et al. 1935). Clearance of woodland and urbanisation may explain why this bat is now confined to the west and south-west of the island.

The lesser horseshoe is the only species for which substantial hibernation data are available; counts at some winter sites date back to the late 1970s before systematic monitoring of other bat species was considered. Monitoring at summer sites began in the 1980s and today counts at over 200 winter and summer sites are conducted annually to satisfy monitoring and reporting obligations under the Habitats Directive. A number of surveys contributed to our early knowledge of its

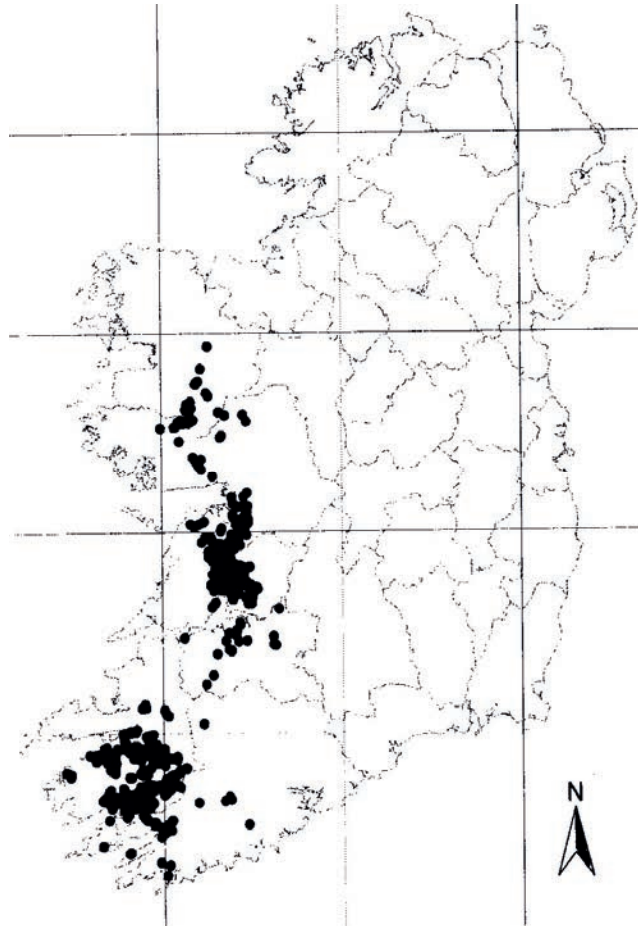


Fig. 1. Irish lesser horseshoe bat distribution. Map courtesy of Bat Co. Map courtesy of Bat Conservation Ireland.

distribution. O'Sullivan (1994) provided information on 157 horseshoe roosts found during the 1980s. Many of the roosts recorded by O'Sullivan were in large, unoccupied old buildings, where he noted the bats formed large colonies. However, later visits to a number of these in the 1990s revealed that they were no longer suitable (due to deterioration of the building) or available (due to demolition or blocking of access points) as horseshoe roosts (McAney 1994).

Recent surveys

McGuire (1998) surveyed an area of north County Clare in 1995 and documented 75 bat roosts, 24 of which held 990 lesser horseshoes. Eight horseshoe bat roosts with between 20–150 bats were found in derelict houses with galvanised roofs. The two largest maternity roosts were in the attics of a mansion and an old stable.

A series of surveys, throughout its range, of winter and summer sites were undertaken by The Vincent Wildlife Trust (VWT) between the years 1994 to 2004 (Roche 2001, McAney et al. 2013). These surveys and a number of other sources yielded information on hundreds of roosts, ranging from major breeding and hibernation sites to structures used at night by <10 bats.

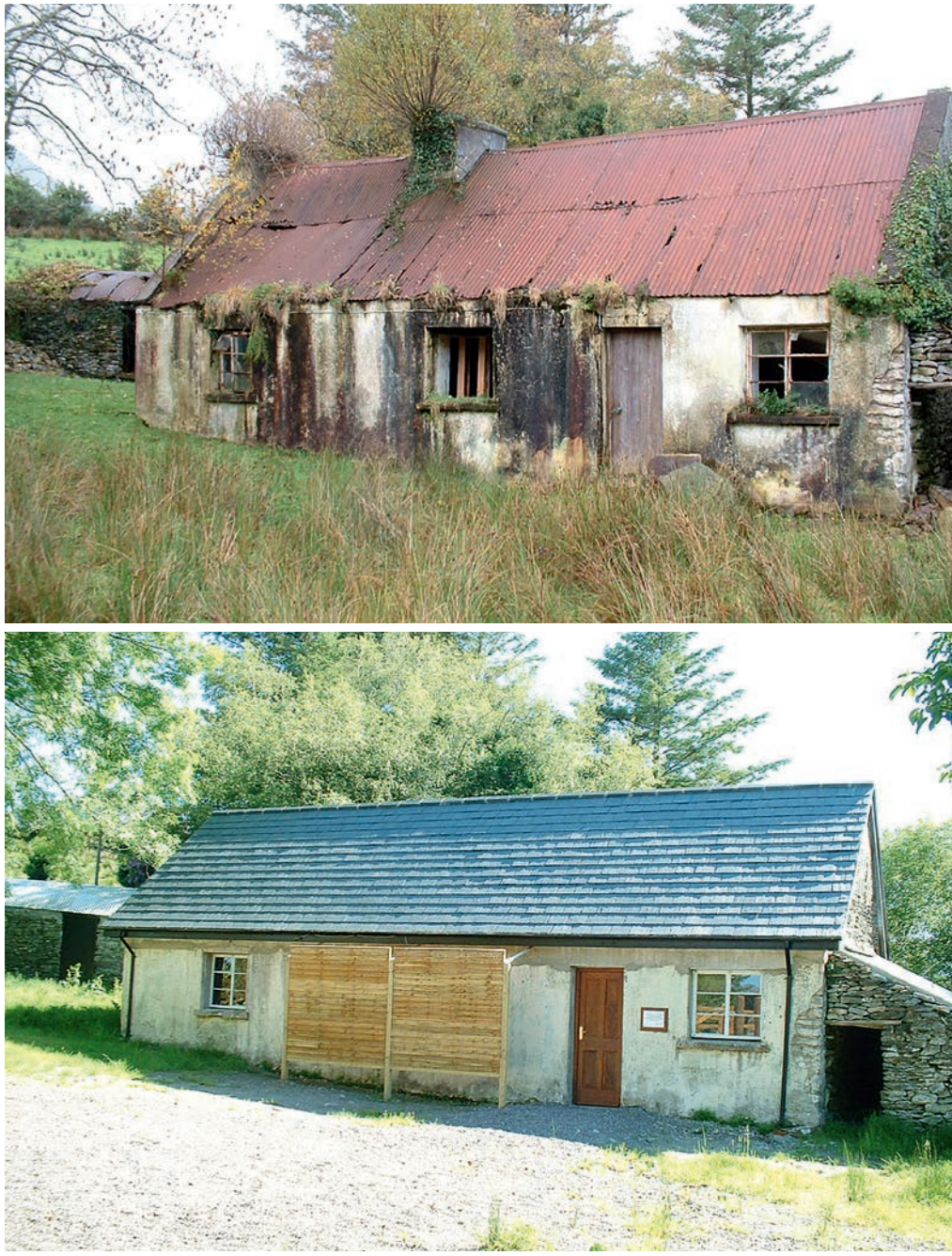
A total of 166 structures were surveyed during the winters of 1994 and 1997 (McAney et al. 2013), of which 108 were natural sites (e.g. caves, fissures) and 58 man-made (e.g. cellars, mines). Out of the 789 bats recorded from 66 sites, 757 or 96% were lesser horseshoe. Forty six natural sites held 593 of all the bats recorded (the other bat species were 22 *Myotis* bats and 10 brown long-eared *Plecotus auritus*).

Roche (2001) undertook the first of nine summer surveys by the VWT in County Limerick, which is now known to be a marginal area for the lesser horseshoe. One hundred and eighty five properties were visited. Although over 142 new bat records were established, only four new horseshoe roosts (with live bats) were found, and the largest number of bats at one site was fifty. Anecdotal evidence gathered by Roche suggests that the species was once more common, and evidence of suitable buildings that had been renovated or demolished point to a loss of suitable roosts.

A total of 3,276 structures in 3,003 km^2 were visited in Counties Mayo, Galway, Clare, Kerry and Cork during the other VWT summer surveys (McAney et al. 2013) and, of these, 508 were classified as lesser horseshoe roosts based on the presence of bats or their droppings. Fifty nine maternity roosts were recorded, containing 4,322 bats. Almost all of the roosts were in old, unoccupied buildings, with open doors/and or windows serving as the access points. The majority of these sites were stone-built with natural slate roofs. It is believed that many of the colonies found in small cottages or sheds may have relocated to these when larger, more suitable, sites were no longer available to them, due to deterioration. The surveys highlighted the ongoing loss of important summer roost sites through dereliction, renovation or demolition. However, as a result of this study seven maternity roosts (six newly discovered and one previously known) were subsequently acquired and renovated by the VWT and contained 1,598 horseshoes in 2013 (Figs. 2, 3).

Data analysis and modelling

Kelleher (2004) collated all the documented roost data on the lesser horseshoe to determine its roosting preferences, distribution and population trends over a thirty-year period. He considered that it was unlikely that any major maternity sites had been overlooked (183 were identified), but that data were deficient for winter roosts. He also pointed out that there was almost no information on the foraging and commuting habits of the bat in Ireland and that foraging areas and commuting routes in the vicinity of known roosts needed to be identified and included within the



Figs. 2, 3. Maternity roost of *Rhinolophus hipposideros* in Kerry. 2 (above) – the roost before renovation. 3 (below) – the roost after renovation by the VWT.

SAC designations. Kelleher (2006) also conducted analysis on the range of structures used during summer and reported that the lesser horseshoe bat selects stone built and slate roofed buildings, although it will use buildings with corrugated iron as the roofing material. Stone and slate appear to provide similar roosting conditions to those found in caves, the natural roosting site for this bat. Of concern was the observation that modern buildings are constructed with block and tile and thus are not suitable as horseshoe roosts, even if they subsequently become accessible to the bats. Thus, this species may face a lack of suitable roosting sites in the future.

Lundy et al. (2011) included data on the lesser horseshoe bat during their study of the roosting and landscape associations of Irish bats, the aim of which was to provide a landscape conservation guide for all species. Using an existing database of records collated by Bat Conservation Ireland (www.batconservationireland.org) they analysed the habitat and landscape associations of all Irish bats. The variables included in the model to predict occurrence were land cover, topography, climate, riparian habitat and human influence. The landscape models were constructed using a Maximum Entropy Model (MEM) fitted in MaxEnt 2.2. Individual MEMs were constructed for each bat species. The constructed models were projected across the entire land area of Ireland and the average probability of occurrence calculated on a 5 km grid.

The results for the lesser horseshoe bat, based on 494 roost records, showed this species had a positive association for both broadleaf woodland and mixed forest, but a negative association for arable land. In common with other bat species it selected roosts constructed of stone rather than brick material, but avoided occupied houses. The core area occupied by the lesser horseshoe is the smallest of all the species modelled (5,933 km^2) and is restricted to karst landscapes in the west of the country. Two distinct regions within the core area, one in Kerry/west Cork in the south and one in Mayo/Clare/Galway in the north, were identified. These two areas are divided by marginally favourable habitat in Limerick and north Kerry. Lundy et al. (2011) point out that although Limerick/north Kerry is a marginal area, the continued presence of the lesser horseshoe bat here has significant conservation implications, if further fragmentation of the national population is to be prevented.

Roche (2012) analysed count data on the lesser horseshoe from summer and winter sites covering the years 1986 to 2012 in order to determine an accurate population figure and to identify trends and threats. The statistical software, Genstat, was used to carry out trend, power and simulation analyses. A total of 2,864 records were subjected to statistical and other data analysis, giving rise to a population estimate of 14,010 for the period 2010–2011, which is considered to be the current population size. Results from the trend analysis suggests the number of horseshoe bats counted at summer roosts increased for most of the study period, with significant increases from 2003–2005, followed by a levelling-off or slight decline since 2008. However, the authors urge caution in the interpretation of the results due to the fact that the time of counting at the roosts changed from late summer to pre-parturition during the latter years of the study period. Although this was factored into the modelling process, its effect is not fully known. The number of bats counted at summer roosts increases from May through to August, with higher numbers found in buildings described as disused, derelict or in disrepair.

Trend analysis for a longer time series was possible with data from winter sites because, as stated earlier, counts began in the late 1970s. The analysis revealed that the number of bats in winter has been increasing but, as with the summer data, a decline since 2008 was detected. The results from the Power Analysis revealed that an annual count at both summer and winter sites is sufficient to detect an increase or decline and that a second count did not improve the detection rate. It also indicated the number of sites that should be counted in order to detect a 50% decline over 25 years (red alert) or a 25% decline over 25 years (amber alert). In the case of summer sites

just 50 sites are required to detect a red alert decline within ten years, but 100 sites are needed to detect an amber alert within 15 years. An annual count at 50 winter sites will detect a red alert within 13 years, but an amber alert will only be detected over a 27 year period.

Finally, the study considered the effect of activities at the roosts, although for most of the period no data were collected on this. When reporting began during the years 2000–2009, urbanisation was noted as a negative factor at 24 out of 36 sites, while other human activities having a negative effect were recorded at 14 out of 19 sites. However, there appears to have been a decrease in negative activities at winter sites since 2010, with a considerable decline in the number of sites and individual bats affected, although the reasons for this decline were not documented. For the period 2010 to 2011 there was an increase in the number of negative activities impacting on summer roosts, but fewer bats were affected than in previous years. Deterioration of the structure being used is the main factor adversely affecting bats at these sites. However, the authors make the point that deterioration may coincide with an initial increase in the number of bats that are able to access the structure.

Positive activities (e.g. roost renovation, grilling of cave entrances, forest management) were not recorded prior to 2006. However, between the years 2006–2009 such activities were recorded at 19 sites, benefitting 1,707 bats. Between the years 2010–2011 beneficial activities were recorded at 18 sites, benefitting 1,927 bats.

Recent research on the lesser horseshoe bat – ecology and genetics

Biggane (2003) investigated the diet, foraging activity, habitat selection and nocturnal behaviour of the lesser horseshoe bat at a summer maternity roost in County Clare during the years 1999–2002. This involved diet analysis using droppings collected on a weekly basis over one year (October 1999 to October 2000) and the first radio tracking study of the species in Ireland, which was undertaken in 2001 and 2002.

A total of 1,480 droppings were analysed and 6,939 prey items identified. The diet varied seasonally with more orders of arthropod eaten during the summer months compared to the winter. The main prey items eaten in summer were nematoceran Diptera, Trichoptera, Neuroptera, Lepidoptera, Pscoptera and Hemiptera. In winter two dipteran Sub-orders dominated the diet, Nematocera and Cyclorrhapha, and fewer Trichoptera and Lepidoptera were eaten. The presence of Diptera varied from 38.4% in August to 93.1% in December (results expressed as percentage frequency). Between the months of October to March there was a significant increase in the occurrence of insects belonging to the Families Scathophagidae and Sphaeroceridae (Sub-order Cyclorrhapha), both of which depend on cow dung for their larval stages. Biggane raised the issue of the possible adverse effect the use of Ivermectin in cattle in the vicinity of hibernation sites could have on the availability of these insects to the bats during winter. Several insect families identified from the droppings (Miridae, Psylloidae, Aphidoidae, Cicadellidae and Curculionidae) live primarily on vegetation, thus providing evidence that these were gleaned off leaves and branches by the bats, as opposed to being caught by aerial hawking.

During the summers of 2001 and 2002 twenty-one horseshoe bats were fitted with transmitters (Titley LTM, <0.4 g), of which sixteen yielded results on the foraging areas, commuting routes and night roosts used by adult females. Bats were only radio tracked in the weeks leading up to and following parturition. Home ranges were determined using Minimum Convex Polygons and core foraging areas by Kernel Analysis. The size of home ranges varied from 42.4 ha to 270 ha. The average home range of lactating bats was 149 ha, larger than that for bats prior to parturition (96 ha) and prior to hibernation (134.5 ha). The core foraging areas varied from 14.24 ha to

31.14 ha. The average core foraging areas showed little variation between the three periods of pre-parturition, post-parturition and pre-hibernation, ranging 22.80 ha, 24.17 ha and 20.57 ha respectively. The average core foraging area for all bats, regardless of reproductive state, was 22.74 ha. The maximum distance travelled by a bat from the roost was 3.22 km and the shortest distance was 0.95 km. Lactating bats travelled the least, averaging 1.69 km, while the longest distance of 3.22 km was recorded post lactation. The average distance travelled during pre-parturition was 1.75 km and during post-parturition was 2.31 km.

Compositional analysis was used to determine habitat use and was studied at two levels; by comparing the habitats available in the home range of the colony to that selected by individual bats, and then at a finer scale by comparing habitats available in individual core ranges to those selected by each bat. This analysis revealed that the preferred foraging habitats were riparian woodland, mixed broadleaf woodland and associated riparian habitats, such as wetlands. These results mirror the data obtained from the diet analysis, because these habitats were also those used by several of the insect families identified in the droppings.

The bats used tree lines, hedgerows, stone walls and reed beds at the edges of lakes to commute from the day roost to their foraging grounds. A number of night roosts were used and these appeared to be more important in the weeks prior to hibernation when groups of bats were observed, rather than single bats as was observed earlier in the season. They were also used more on mild nights than cold nights, reflecting the fact that the bats foraged more during milder nights. Individuals showed strong fidelity to particular night roosts.

Biggane also observed the behaviour of juvenile bats from late July onwards as they learned to fly. They were recognised by their short, slow and erratic flights close to the maternity roost. Juvenile bats were repeatedly seen hanging outside the roost, flexing their wings and making short flights, before returning to hang again outside the exits. She also observed what she believed to have been an adult teaching her pup to forage as she observed a bat hanging from a branch of a tree, flexing its wings, while a second bat flew continuously around it. The first bat repeatedly made a series of short flights around the tree, coming to rest again, while producing weak echolocating calls.

Abbott et al. (2012) conducted research on the use of under-motorway passageways associated with a new motorway in County Clare, an area with approximately 3,000 horseshoes (Kelleher 2004). Her study area consisted of three adjacent under-motorway passages of varying dimensions, two long, narrow drainage pipes either side of a larger road underpass. The distance of the entrances of the three passages from tree and shrub cover varied from 10m to a maximum of 50m. The presence or absence of bat species within the passageways was quantified from dusk to dawn by continuous recording of bat echolocation calls. Bat activity in the larger underpass was recorded on 16 nights in May 2009. The two narrow pipes were each surveyed for 17 nights in August and September 2010. Bats were detected flying within the underpass and the narrow pipes on each study night, but significant differences between the species recorded in the three locations were observed. Only those species adapted for flying within clutter, the lesser horseshoe, Natterer's (*Myotis nattereri*) and brown long-eared used the two narrow pipes. All three species were also detected in the larger underpass, as were both pipistrelle species (*Pipistrellus pygmaeus*, *P. pipistrellus*). Both pipes were regularly used at night by the lesser horseshoe. The majority of calls by this bat were recorded from within the larger underpass, but it was also detected flying over the motorway. Concurrent radio-tracking of horseshoe bats confirmed their use of the three passages as commuting routes. It further confirmed that they regularly flew over the motorway's four traffic lanes while commuting between patches of tree cover and generally only made short detours to use the passageways (Abbott, Harrison & Butler, unpubl. data).

Abbott et al. (2012) concluded that the traits that make species such as the lesser horseshoe bat more vulnerable to habitat fragmentation (short range echolocation, slow energy-intensive flight) also confers upon them the ability to utilise narrow passageways. Such structures are less expensive to install and can be built into lower elevation sections of motorways where larger underpasses are not feasible. An important recommendation from this study is that where sections of woodland have been severed by a new road, incorporating narrow passages at these junctions may reduce lesser horseshoe bat mortality.

Dool et al. (2013) collected DNA samples from lesser horseshoe bats throughout their Irish distribution during her study of the phylogeography and postglacial recolonization of Europe by this species. Dool et al. reconstructed its demographic history across its European, North African and Middle-Eastern distribution prior to, during and following the most recent glaciations using mitochondrial DNA, a nuclear intron and microsatellites. Data generated from the mitochondrial DNA point to a population expansion by this species within Ireland at about 6,000 years ago, at a time when the country was almost entirely covered in oak woodlands. The highest genetic diversity, using this genetic marker, was found in the north of the species' range and significant genetic differences were found between colonies in the north of the country when compared with colonies in the south. These results support the presence of two distinct clusters within Ireland, one in the north and one in the south (Dool, pers. comm.).

Recent conservation measures

Minor works undertaken in the mid-1980s and early 1990s to protect winter hibernacula from vandalism and disturbance and to repair summer sites were described by McAney (1994). However, it was not until 1998 that the first major initiative to fully protect a large maternity roost site was taken by The Heritage Council (www.heritagecouncil.ie) when it purchased Dromore Stables, County Clare, at a time when the building was offered for sale and the colony potentially at risk. Since then the council has maintained the building, planted trees and facilitated the research of Biggane (2003). The colony is monitored annually and consists of approximately 230 adult bats in June (McAney, pers. comm.). 1998 was also the year The Vincent Wildlife Trust (www.mammals-in-ireland.ie) began purchasing or long-term leasing thirteen maternity roosts in Counties Mayo, Galway, Clare and Kerry. A total of 2,762 bats were recorded at these sites during summer 2013, comprising just under 20% of the national population. In 1999 the VWT and National Park and Wildlife Service (NPWS) cooperated to reopen a cave in County Clare where lesser horseshoe bats had been recorded in 1859 but which had subsequently been blocked in the interest of livestock safety. The average number of bats now using this cave is 23, but a maximum of 49 has been recorded (Lyons, pers. comm.). A number of successful artificial hibernation sites have been created in County Cork by regional staff of NPWS, with one now being used by over 100 bats (Heardman, pers. comm.). In addition, minor repair and improvement works have been carried out at a range of summer sites in private ownership by NPWS personnel in other areas. New roosts, both winter and summer, have been built as mitigation measures when developments impacted on existing roosts or new roads were constructed. An annual workshop on the lesser horseshoe bat is organised by NPWS to facilitate the exchange of data on roosts and to review the national monitoring programme for the species, the latter now managed by Bat Conservation Ireland. Training workshops for local authorities and specialist groups on protecting the lesser horseshoe are regularly run by the VWT, based on its handbook of conservation measures (Schofield 2008). In 2012 the VWT produced a leaflet aimed at farmers containing a range of simple measures they could take to improve their farms for the lesser horseshoe bat (www.mammals-in-ireland.ie/Resources).

Future conservation

Although the lesser horseshoe bat is considered to be *Near Threatened* within Europe, within Ireland it is classified as a species of *Least Concern*, on the basis of its range, population size and trends (Marnell et al., 2009). In recent years it has extended its range both in a south-easterly (County Cork) and in a north-easterly (Counties Roscommon and Sligo) direction, based on the discovery of a single bat or droppings (Keeley, pers. comm.; Kelleher, pers. comm.). The results from the national monitoring programme point to an increase in the number of horseshoes, even allowing for differences in when the bats were counted in some years (Roche et al. 2012) and the effects of unusually cold winters and springs during the years 2010–2012 (pers. obs.).

In the most recent Article 17 report from Ireland to the European Commission in 2013 (http://www.npws.ie/publications/article17assessments/), the overall assessment of the conservation status of this species was considered to be *Favourable*.

Nonetheless, the threats currently facing this species will continue to affect it, including the loss of suitable summer and winter roosts, fragmentation of the landscape by the removal of hedgerows and treelines, and urbanisation. These threats have long been recognised as adversely affecting the lesser horseshoe, relating to the availability of its roosts, commuting routes and foraging areas.

However, these threats have now been translated into two new conservation concerns – that of loss of genetic diversity in the south and the creation of two distinct population clusters in Ireland, one in the north and one in the south.

Addressing this will require a different approach to that needed to repair a roof or grill a cave entrance. The private funding that was available to directly protect the roosts used by almost 20% of the population will not be available within the foreseeable future. Limited government resources will also not be available, understandably, for a species that currently has a favourable status label, at a time when other fauna and flora are at risk of extinction. Therefore, a new broader approach for conserving this species must be found if the gap that has created these two sub-populations, is to be bridged.

Landscape approach to conserve the lesser horseshoe bat in Ireland

There are now many examples in Ireland of projects involving multiple landowners that include measures to protect species and enhance habitats. The BurrenLIFE Project in Clare (www.burrenlife.com) was the first major farming for conservation project in Ireland and formed the basis for the AranLIfe Project off the coast of Galway (www.ahg.gov.ie/en/Islands/AranLIFE/). The wildlife associated with waterways – Atlantic salmon (*Salmo salar*), European otter (*Lutra lutra*), kingfisher (*Alcedo atthis*), Irish dipper (*Cinclus cinclus hibernicus*) and freshwater pearl mussel (*Margaritifera margaritifera*) – was the focus of the Duhallow LIFE Project (www.duhallowlife.com), while enhancing the Mulkear River Catchment for sea lamprey (*Petromyzon marinus*), Atlantic salmon and European otter was the objective of the MulkearLIFE project (www.mulkearlife.com).

A similar approach is needed for the lesser horseshoe bat in Ireland in order to address the lack of roosts and suitable habitat in the Limerick/north Kerry areas of its distribution, which will in turn enable bats to move along the west coast of Ireland and facilitate contact between colonies north and south. This species has already responded well to a range of targeted conservation actions: creating openings into suitable buildings; installing hot boxes; re-roofing structures; building artificial summer and winter roosts; positioning night roosts; and providing commuting routes such as hedgerows, tree lines and small tunnels under motorways. All of these measures could

be incorporated into a high nature value (HNV) farmland agri-environmental scheme or a LIFE project, if willing partners could be identified.

Conclusions

Since the last review publication of the lesser horseshoe (McAney 1994), this species has been the focus of ten new publications and many roosts have been protected. Currently the overall assessment of its conservation status is favourable. The national population has increased in recent years and the estimate of 14,010 animals is the most statistically robust to date. However, despite these improvements, there are causes for concern. Future expansion in range will be limited by the availability of suitable roosts and habitat. The Irish population is now represented by what could be considered two sub-populations, with restricted gene flow along a north-south axis, as a result of habitat fragmentation, loss of suitable habitat and urbanisation**.** The necessary conservation measures to address this issue are tried and trusted, all that is required is the commitment and finances to translate these into a conservation project that will operate at the appropriate landscape scale. Several LIFE projects to protect habitats and species have been successfully implemented in Ireland and are templates for a future project on the lesser horseshoe bat.

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