



Using Species Distribution Models to Identify Potential New Roost Sites of the Lesser Horseshoe Bat in Ireland

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Table of Contents

Executive Summary	4
1. Introduction	5
2. Method	6
2.1 Bat Data	6
2.2 Environmental Variables and GIS Data	6
2.3 Modelling Procedure	6
2.4 County Reviews	8
3. Results	9
3.1 Species distribution model performance and current pattern of roosting areas	9
3.2 Potential new roost site habitat - overall	9
3.3 Potential new roosting habitat locations - by county	
3.3.1 Cork	
3.3.2 Kerry	17
3.3.3 Limerick	20
3.3.4 Clare	23
3.3.5 Galway	27
3.3.6 Mayo	
3.3.7 Waterford, Tipperary, Sligo, Leitrim, Roscommon	
4. Discussion	36
5. References	38
6. Appendix 1: Figures 3-17 from the Main Report	41

Executive Summary

Species distribution modelling was carried out on the known lesser horseshoe bat summer and winter roost network to create landcover favourability maps for the species across the Republic of Ireland, in both winter and summer.

The resulting maps indicate that there are some noticeable gaps in the species roost network - even within its core areas. It is possible that the species is already present in some of these areas but unrecorded, or that the creation of artificial roosts would benefit it and allow it to move into these locations. Some of these 'gaps' include in Cork - Baltimore, Dunmanway (for winter sites), Ballincollig and Blarney (summer), in Kerry - Kells Bay, Knockmanagh, Lacka and the western Iveragh Peninsula for winter sites. In Limerick the east of the county has high potential particularly around Glenstal, Clare Glens and Gortavalla with some additional, although limited, potential around Croom. In Clare there is a noticeable lack of summer sites in its core area in the Burren while in Galway some work to encourage the bat to roost in good habitat south of Galway City may help support the population and facilitate more movement there. Mayo has a lot of potential in the Pontoon area.

There are also reasonably extensive areas of highly suitable habitat for the species in west Waterford, and particularly large tracts of suitable land cover throughout Counties Sligo, Leitrim and north Roscommon.

Extensive areas of moderately suitable habitat are also found in west Limerick. We suggest that small pockets of native woodland, scrub and agroforestry may boost the habitat sufficiently there to facilitate movement of the species north/south through the county.

1. Introduction

The lesser horseshoe bat has an estimated population of around 15,000 individuals in Ireland (Roche, 2024). The species is listed in Annex II of the EU Habitats Directive and requires special conservation measures to ensure its protection, such as the designation of Special Areas of Conservation to protect its larger roosting sites.

Winter and summers roosts of the species are found mainly in Counties Cork, Kerry, Limerick, Clare, Galway and Mayo. A small number of ad hoc records for the species have also been collected for Counties Tipperary, Roscommon and Sligo, in addition to historical (neolithic) records for a cave in Waterford (Movius *et al.*, 1935).

Genetic studies have indicated that the Irish population now consists of four distinct subpopulations. These have arisen due to habitat fragmentation caused by agricultural intensification and urbanisation, and by Lough Corrib and the Shannon Estuary possibly posing additional barriers to movement (Dool, 2010; Harrington, 2018).

The species is the subject of a Species Action Plan that was devised in 2022 (NPWS & VWT, 2022). The present modelling project has been undertaken to address Action 4.1b in the Action Plan:

'Undertake a review of the roost network across the species' range to identify those areas without adequate roosting opportunities, for example, winter hibernation sites, night roosts and maternity roosts.'

There have been radiotracking studies that have indicated the core area for foraging lesser horseshoe bats in the summer months is generally within 0.5km of the roost, while most bats stay within 2.5km of the roost (e.g. Bontadina *et al.*, 2002). However, there is little information that describes the area of habitat needed in the vicinity of a roost to support colonies or particular numbers of bats. This is further complicated by the fact that different habitat types may vary in quality for foraging bats, and other factors such as levels of human disturbance and barriers to movement, may reduce habitat useability for bats.

2. Method

2.1 Bat Data

The Lesser Horseshoe Bat Roost Monitoring Database (MS Access) which hosts all known roosts of the species, was queried to determine locations of bat roosts for which non-zero counts have been recorded in either winter or summer in the past 10 years. This omits sites where there are no recent counts and counts where just bat droppings have been recorded. In total 315 locations where bats have been recorded in summer, and 232 sites with bats in winter (2015-2024) were included in the modelling dataset. Sites were categorised as winter/hibernacula if there was a positive count in December to February in the 10-year time frame. Sites were categorised as summer where there was a positive count from May to September. Transitional sites were not included as there were too few to model.

2.2 Environmental Variables and GIS Data

Drawing on existing literature, expert assessments, and prior research into the movement and dispersal behaviour of the lesser horseshoe bat (*Rhinolophus hipposideros*) (e.g. Glover *et al.*, 2018; Schofield, 2008) a total of 12 landscape features were identified. For each of these features, Geographical Information System (GIS) data at a 100-metre resolution were collected from CORINE Land cover maps and NASA light map to generate four distinct environmental variable datasets (see Table1). We removed intercorrelated variables with variation inflation factor >10 and Spearman correlation rho >|0.7|. The final dataset included ten variables (Table 1).

2.3 Modelling Procedure

Species distribution models (SDMs) were generated to predict potential new roosting sites of the lesser horseshoe bat across the study area. Two datasets were created, one of winter roost sites and one of summer roost sites. Occurrence records of each dataset were split into 70% training and 30% testing data. For each dataset we generated 10,000 random background points with the "dismo" package (Hijmans *et al.*, 2017). Following best practices (Araújo *et al.*, 2019), SDMs were fitted using an ensemble approach with four different algorithms: generalized additive models (McCullagh and Nelder, 1989), boosted regression trees (Elith *et al.*, 2008), artificial neural networks (Lek & Guégan, 1999) and maximum entropy (Phillips *et al.* 2006). We used the R package "biomod2" 4.3.2 (Thuiller *et al.*, 2016) to generate the models. The model parameters of each algorithm were adjusted with SDMtune" (Vignali *et al.*, 2020) to improve model performance (Merow *et al.*, 2013; Table 2).

True skill statistics (TSS) and area under the curve (AUC) of receiver operating characteristic were used to evaluate model performance. Random cross-validation was employed to estimate the binary threshold for predictions and then assessed the model's performance with geographic block cross-validation with the R package "blockCV" (Valavi *et al.*, 2019). Models generated from different algorithms were combined into an ensemble model by averaging their outputs, weighing each model's contribution based on its AUC scores, and excluding models with low discrimination ability (AUC <0.75). Final individual models were then run with all location records. Continuous predictions of the single models were then converted to binary presence-absence maps with the approach that maximizes sum of model sensitivity and specificity (Liu *et al.*, 2013).

Environmental Variable	Feature	Grouped Layers	Source
Land Cover	Broadleaved forest	Broadleaved forest	CORINE 2018
	Coniferous forest	Coniferous forest	CORINE 2018
	Mixed forest	Mixed forest	CORINE 2018
	Scrub	Transitional-woodland shrub	CORINE 2018
	Semi-natural areas	Land principally occupied by agriculture with significant areas of natural vegetation, Agro- forestry areas, Natural grasslands, Sclerophyllous vegetation	CORINE 2018
	Mosaic of habitats	Moors and heathland, Bare rocks, Sparsley vegetated areas, Inland marshes, Peat bogs	CORINE 2018
	Arable	Non-irrigated arable land, permanently irrigated land, Annual crops associated with permanent crops, Complex cultivation patterns	CORINE 2018
	Pasture	Pasture	CORINE 2018

Table 1. Initial environmental variables used for the species distribution modelling. Variables in red were removed because they were highly correlated.

	Water bodies	Water courses, Water bodies	CORINE 2018
	Urban	Continuous urban fabric, Discontinuous urban fabric, Industrial or commercial units, Port areas, Airports, Mineral extraction sites, Dump sites, Construction sites, Sport and leisure facilities	CORINE 2018
Distance to water bodies		Euclidean distance to water bodies class	CORINE 2018
Light pollution			NASA

 Table 2. Parameters tuned for each dataset using "SDMtune" R package.

Dataset	ANN	ANN	ANN	ANN	BRT_di	BRT_	BRT_inter	BRT_s	BRT_ba	Max	Maxe	Maxe	GA
	_size	_dec	_ran	_max	stributi	n.tre	action.de	hrinka	g.fracti	ent_	nt_re	nt_it	M_
		ау	g	it	on	es	pth	ge	on	fc	g	er	k
Summer	67	0.01	0.7	1000	bernou	740	2	0.06	0.5	lq	1.68	1000	3
roosts					li								
Winter	52	0.05	0.7	100	bernou	960	3	0.09	0.5	lq	4.06	500	3
roosts					li		λ.						

2.4 County Reviews

The models generated for this project were subjectively reviewed at County level to highlight locations where further conservation measures may be needed and yield results for the species. This review is not necessarily comprehensive and further detailed scrutiny of these maps at regional level may reveal other areas that could benefit from conservation measures or roost creation.

3. Results

3.1 Species distribution model performance and current pattern of roosting areas

The average performance of the four algorithms for the summer dataset was good (0.759), as indicated by the relatively high cross-validation data mean AUC scores (AUC = 0.759 ± 0.059 , range 0.638 – 0.841). The winter dataset mean AUC scores were also good (AUC = 0.722 ± 0.074 , range 0.597 – 0.82). The contribution of predictor variables in the model varied among datasets. For both summer and winter datasets the average variable of the ensembled models that contributed most was semi-natural areas (Table 3).

Summer dataset variable	Variable importance	Winter dataset variable	Variable importance
Semi-natural areas	0.485	Semi-natural areas	0.505
Broad-leaved Forest	0.151	Broad-leaved Forest	0.156
Pasture	0.136	Arable	0.137
Light	0.120	Mixed Forest	0.114
Arable	0.116	Urban	0.057
Mixed Forest	0.114	Pasture	0.030
Mosaic	0.072	light	0.026
Urban	0.060	Water	0.011
Water	0.015	Mosaic	0.009
Scrub	0.015	Scrub	0.001

Table 3. Contribution of the environmental variables to species distribution models for each dataset.

3.2 Potential new roost site habitat - overall

The final species distribution model highlights several areas across the Republic of Ireland with high potential for previously unidentified roosts, particularly concentrated in the northwest and southwest (Figure 1; Figure 2). These high-potential zones align closely with semi-natural habitats, which emerged as the most influential environmental variable across all models. This reinforces the ecological relevance of semi-natural landscapes for the species' winter roosting behaviour and provides a valuable focus for future survey efforts and conservation planning. In general, the Irish landscape is more suitable for winter sites than for summer sites. This probably reflects the need for large areas of semi-natural habitat or core sustenance zones around summer roosting sites, when bats are most active, while limited foraging tends to be carried out around hibernacula.



Figure 1. Predicted winter roost suitability for the lesser horseshoe bat across the Republic of Ireland, based on ensemble species distribution modelling. Yellow areas represent the highest suitability and blue areas the lowest suitability. White stars indicate known winter roost locations.



Figure 2. Predicted summer roost suitability for the lesser horseshoe bat across the Republic of Ireland, based on ensemble species distribution modelling. Yellow areas represent the highest suitability and blue areas the lowest suitability. Orange diamonds indicate known summer roost locations.

3.3 Potential new roosting habitat locations - by county

We have reviewed the maps of modelled summer and winter suitability, along with known winter and summer sites. The following, County-based, subjective assessment highlights in white boxes, some of the areas where a tiered approach to conservation measures may be suitable. These highlighted areas are intended to be used for guidance and are not drawn with definitive or exact boundaries.

ROOST MEASURES IN HIGHLIGHTED AREAS (white boxes)

1. Highlighted areas should first be ground-truthed to confirm that the presence of suitable foraging habitat corresponds with modelled suitability, and the area is likely to support a local lesser horseshoe bat population.

2. Where suitable habitat is confirmed, a thorough assessment of existing structures should be carried out to determine whether bats are already present in either or both seasons, depending on available records.

3. Where sites are confirmed to be absent in either or both seasons - new roosts could be constructed or existing structures could be modified, to facilitate expansion of the lesser horseshoe population.

LANDSCAPE/LANDCOVER

4. In a number of locations there are large expanses of 'moderately suitable' landcover. If landowners could be encouraged and facilitated to expand native woodland and broadleaved agroforestry, along with native hedgerows and tree lines, even in relatively small pockets, these improvements could potentially facilitate movement of bats. This is particularly the case for northwest Cork and west Limerick where we suggest that a landscape and land cover management approach should be applied in the first instance to encourage bats into this area and help close the Limerick Gap (Finch & McAney 2020). Since much of this landscape is modelled as being moderately suitable for the species it may not require much improvement to support local populations. Other measures such as site searches and trial roost creation may also be beneficial, but boosting existing habitat may be necessary in the first instance.

3.3.1 Cork

3.3.1.1 Summer



Figure 3. Summer roost suitability for the lesser horseshoe bat in County Cork. Yellow areas represent the highest suitability and dark blue areas the lowest suitability. White stars = winter sites, Orange diamonds = summer sites. White boxes = areas of substantial potential habitat but with no known summer roosts. In some of these winter sites are present - thus a local summer population may be present but as yet unrecorded. Some good habitat is predicted to occur throughout Cork City but this is not necessarily recommended for artificial roosts due to high potential for disturbance.

Box 1a: Ballycommane (Figure 3) - there are two existing winter sites known for the species in this area. Given the extent of moderately and highly favourable landcover it is possible that there is already a summer roost for the species in this area. However, if a comprehensive assessment does not result in any summer records, this area may be suitable for a new summer site. It is suggested that it should be located in the northerly section of the white box.

Box 1b: Baltimore (Figure 3) - there is a relatively small area of suitable habitat east of Baltimore and to the east along the coast. This area should be checked for existing roosts first, and targeted for roost creation if none are confirmed present.

Box 2: Ballincollig & Blarney (Figure 3)

Overwintering bats have been recorded at Ovens Cave and Blarney Castle, albeit in small numbers. This general area is subject to pressures due to artificial light at night, busy roads and urban expansion. Nonetheless, considerable suitable habitat occurs here, and with good connectivity via woodland-lined river valleys. Bats may already be present in summer but remain unrecorded, but there may also be potential for summer roost creation in the vicinity of existing wintering sites.

Box 3: Blackwater Valley - Mallow/Ballyhooly/Fermoy (Figure 3)

A single overwintering bat has been recorded for a couple of years at Ballyhooly (2023 and 2024). The Blackwater Valley in Cork has a number of discrete blocks of suitable habitat and would likely support a small population of bats. The presence of a population of bats along this river corridor would also provide potential for further west to east movement through Cork and into Waterford where there is substantial cover of highly suitable habitat around Lismore. Further south along the Lee, in contrast, Cork City forms a considerable barrier to west - east movement. Work to promote riparian woodland along the River Blackwater would potentially improve connectivity for the species and should, arguably, be the first measure carried out to encourage the species in this area. In addition to this, searches should be carried out to determine whether there are already summer populations along the river. And finally, construction or modification of suitable structures to facilitate bats.

Box 4: Lighthouse/Rockchapel (Figure 3) There are no known roosts (winter or summer) in this area of northwest Cork. However, in light of the Limerick Gap, this area could be key to facilitating movement of the species between Kerry and Limerick. There are large tracts of moderately suitable landcover for both summer and winter sites. Efforts should initially be focused on creating pockets of highly suitable habitat via agroforestry, native woodland and other schemes. Searches of suitable structures should be carried out to indicate if bats are already present.



Figure 4. Winter roost suitability for the lesser horseshoe bat in County Cork. Yellow areas represent the highest suitability and dark blue areas the lowest suitability. White stars = winter sites, Orange diamonds = summer sites. White boxes indicate areas of substantial potential habitat but with no known winter roosts. In some of these summer sites may be present and/or a winter population may be present but as yet unrecorded. Some good habitat is predicted to occur throughout Cork City but this is necessarily not recommended for artificial roosts due to high potential for disturbance.

Box 5: Baltimore (Figure 4) - this is the same area as 1b above. There is a relatively small area of suitable habitat east of Baltimore and to the east along the coast. This area should be checked for existing winter roosts first, and could be targeted for winter roost creation if none are confirmed present.

Box 6: Dunmanway (Figure 4) - west of Dunmanway there are a number of known summer sites and large areas of suitable habitat for winter roosts. However, no hibernacula have been recorded from the area. This area should be checked for existing winter roosts first, and targeted for winter roost creation if none are confirmed present. Note - a hibernation site with one bat near Dunmanway was found in winter 2025 (and is therefore not included in this modelling exercise).

Box 7: Ballyvourney (Figure 4) -a relatively large summer roost was recently discovered in this area and the models indicate that there is good coverage of moderately suitable habitat with pockets of highly suitable habitat. Efforts should initially be focused on creating additional pockets of highly suitable habitat via agroforestry, native woodland and other schemes. Searches of suitable structures should be carried out to indicate if bats are already present in winter. If no winter sites are confirmed, construction or modification of suitable structures to facilitate bats.

Box 8: Blackwater Valley - Mallow (Figure 4).

See 3 above.

Box 9: Lighthouse/Rockchapel (Figure 4)

See 4 above

3.3.2 Kerry

Kerry is relatively intensively populated with lesser horseshoe bat roosts with few gaps in coverage. However, there are some locations where there are currently no records but with reasonably good coverage of suitable habitats.

3.3.2.1 Kerry: Summer



Figure 5. Summer roost suitability for the lesser horseshoe bat in County Kerry. Yellow areas represent the highest suitability and dark blue areas the lowest suitability. White stars = winter sites, Orange diamonds = summer sites. White boxes = areas of substantial potential habitat but with no known summer roosts. In some of these winter sites are present - thus a local summer population may be present but as yet unrecorded.

Box 10: Kells/Gowlane (Figure 5)

This relatively small area of the Iveragh Peninsula is noticeably lacking in bat roosts. An area of high suitability habitat exists around Kells and another at Gowlane that appears to be centred on new broadleaved woodland (or extensification/rewilding). There is also good coverage of moderately suitable habitat. It is possible that there is/are already summer roost(s) for the species in this area. However, if a comprehensive survey does not result in any summer records, this area may be suitable for at least one, possibly two new summer sites, one in the north along the coast and another inland.

Box 11: Dingle Peninsula (Figure 5)

According to this model, a strip of moderately suitable habitat runs along the southern slopes of the mountains of the Dingle peninsula. Searches of suitable structures along the Dingle peninsula should be carried out to determine if bats are already present in more locations. Creating pockets of highly suitable habitat via agroforestry, native woodland and other schemes, provided this does not impact other conservation aims such as management of heath or blanket bog, would improve the likelihood of a local population becoming firmly established on the peninsula.

Box 12: Northeast Kerry/West Limerick/Northwest Cork (Figure 5)

This location incorporates 4 and 9 above.

An area around Knockmanagh in Kerry has highly suitable and moderately suitable habitat. It is possible that this area already supports a local population of lesser horseshoe bats and structures should be subject to a comprehensive search to determine if they are present. If not, then this location would be ideal for construction or modification of existing structures to facilitate roosting lesser horseshoe bats. This would also facilitate further linkages into northwest Cork and from there into west Limerick.

Lacka Cross/Ballydesmond on the Kerry/Cork border, along the Blackwater River has some suitable habitat. It is possible that this area already supports a local population of lesser horseshoe bats and structures should be subject to a comprehensive search to determine if they are present. If not, then this location would be ideal for construction or modification of existing structures to facilitate roosting lesser horseshoe bats. This would also facilitate further linkages into northwest Cork and from there into west Limerick.

Three Counties Scenic Area near Mount Collins has moderately suitable habitat for the species. It is unlikely that this area already supports a local population of lesser horseshoe bats but it would be worthwhile checking if structures have any signs of bats present. If not, then this location would be ideal for habitat improvements to facilitate lesser horseshoe bat connectivity. This would also facilitate further linkages into northwest Cork and from there into west Limerick.

3.3.2.2 Kerry: Winter



Figure 6. Winter roost suitability for the lesser horseshoe bat in County Kerry. Yellow areas represent the highest suitability and dark blue areas the lowest suitability. White stars = winter sites, Orange diamonds = summer sites. White boxes indicate areas of substantial potential habitat but with no known winter roosts. In some of these summer sites may be present and/or a winter population may be present but as yet unrecorded.

Box 13: West Iveragh (Figure 6)

Bats in summer sites near Cahersiveen or Caherdaniel have considerable distances to travel to the next nearest known winter sites. These locations may be suitable for constructed hibernacula, if none are found in the vicinity following comprehensive searches.

Box 14: Dingle Peninsula (Figure 6)

From the newly discovered site on the Dingle peninsula (Camp) where LHB droppings have been found, bats have a considerable distance to travel to the next nearest known winter site. A location near this roost may therefore be suitable for a constructed hibernacula, if none are found in the vicinity following comprehensive searches.

Box 15: Gneevegullia, Knocknamanagh (Figure 6)

A roost with LHB bat droppings has been recorded at Gneevegullia. This location is a considerable distance from the nearest known hibernacula, which are located around Killarney and Castleisland. There may be potential to support a new population in this location by providing an artificial winter roost if there are no winter roosts already present. At Knockmanagh there is reasonably good cover of suitable habitat - see 12 above.

Box 16: Northeast Kerry/Limerick Border (Figure 6)

There are very small pockets of suitable habitat for lesser horseshoe bats in winter in this part of Kerry, but this area would be ideal for habitat improvements to facilitate lesser horseshoe bat connectivity. This would also facilitate further linkages into northwest Cork and from there into west Limerick.

3.3.3 Limerick

3.3.3.1 Limerick: Summer



Figure 7. Summer roost suitability for the lesser horseshoe bat in County Limerick. Yellow areas represent the highest suitability and dark blue areas the lowest suitability. White stars = winter sites, Orange diamonds =

summer sites. White boxes = areas of substantial potential habitat but with no known summer roosts. In some of these winter sites are present - thus a local summer population may be present but as yet unrecorded.

Box 17: West Limerick/Kerry Border (Figure 7)

There are very extensive areas of moderately suitable habitat for lesser horseshoe bats in summer in west Limerick, but this area would be ideal for habitat improvements to facilitate lesser horseshoe bat connectivity. Efforts should initially be focused on creating pockets of highly suitable habitat via agroforestry, native woodland and other schemes. Searches of suitable structures should be carried out to indicate if bats are already present. This would also facilitate further linkages through Kerry and Cork and potentially from Limerick north across the Shannon Estuary to Clare. This area also contains pockets of highly suitable habitat for the bat in winter (see Figure 8) - these locations could be targeted for artificial roost construction if no roosts are found to be present.

Box 18: Croom (Figure 7)

A small area of highly suitable habitat is present in Croom. There may be potential to support a new population in this location by providing artificial roosts if there are no roosts already present. This area also contains some highly suitable habitat for the bat in winter (see Figure 8) - these locations could be targeted for artificial roost construction if no winter roosts are found to be present.

Box 19: Glenstal, Gortavalla, Clare Glens, Lower Annagh (Figure 7)

Highly suitable habitat for the species occurs around Glenstal Woods, Gortavalla/Doon, some moderate habitat also occurs along Clare Glens and highly suitable habitat at Lower Annagh. Since we know that the bats occur at Ardnacrusha and at Killaloe, and they have been recorded along the Mulkear River, there may be scope to develop linkages between Limerick and Clare via east Limerick and west Tipperary. Searches of suitable structures should be carried out to indicate if bats are already present. If not, then these locations may be suitable for construction or modification of existing structures to facilitate roosting lesser horseshoe bats. These locations also have large areas of highly suitable habitat for the bat in winter (see Figure 8) - and could be targeted for artificial roost construction if no winter roosts are found to be present.

The eastern suburbs of Limerick may support a small lesser horseshoe population and there could be an opportunity here for the Local Authority to construct and maintain one or more lesser horseshoe bat roosts to help ensure connectivity across and around the city for the species.

3.3.3.2 Limerick: Winter



Figure 8. Winter roost suitability for the lesser horseshoe bat in County Limerick. Yellow areas represent the highest suitability and dark blue areas the lowest suitability. White stars = winter sites, Orange diamonds = summer sites. White boxes indicate areas of substantial potential habitat but with no known winter roosts. In some of these summer sites may be present and/or a winter population may be present but as yet unrecorded.

The same white boxed areas in Figure 7 (17 - west Limerick, 18 - Croom and 19 Glenstal, Gortavalla, Clare Glens, Lower Annagh) apply for the species in winter in Limerick. Please refer to text above for details. An additional area highlighted for highly suitable winter habitat is shown in box 20, Figure 8 above.

Box 20: Ballyhoura Mountains (Figure 8)

The north facing slopes of this mountain range are highlighted as suitable for lesser horseshoe bats in winter. The area is moderately suitable for the species in summer. Land management to increase pockets of native woodland may facilitate the bat in summer, with construction of winter or summer sites here if none are present.

3.3.4 Clare

3.3.4.1 Clare: Summer



Figure 9. Summer roost suitability for the lesser horseshoe bat in County Clare. Yellow areas represent the highest suitability and dark blue areas the lowest suitability. White stars = winter sites, Orange diamonds = summer sites. White boxes = areas of substantial potential habitat but with no known summer roosts. In some of these winter sites are present - thus a local summer population may be present but as yet unrecorded.

Clare is well-populated with summer roosts of the lesser horseshoe bat. Nonetheless, some gaps between land cover suitability and known summer roosts do exist and could be addressed by construction of new summer roosts or adaptation of existing structures.

Box 21: Kilrush (Figure 9)

A small area of highly suitable, and more extensive area of moderately suitable landcover is located close to Kilrush, in the vicinity of Vandaleur. It is possible that there is/are already summer roost(s) for the species in this area. However, if a comprehensive survey does not yield any summer records, this area may be suitable for an artificial summer site.

Box 22: Ballylea - Inagh (Figure 9)

The model highlighted this area as highly & moderately suitable for the species however, from viewing the satellite imagery there seem to be mainly conifer plantations rather than broadleaved woodlands. Nonetheless it may be worth carrying out checks of any derelict buildings in the area to determine if the species is present.

Box 23: Burren Heartlands (Figure 9)

Around the Burren National Park/Carran there is an extensive area of highly favourable landcover for the species. While there are winter records for the bat, there are no known summer roosts. This would be an ideal location for several summer roosting sites if a comprehensive search indicates that there are none already present and it is possible to construct or adapt existing structures within the sensitive landscape.

Box 24: Lough Graney/Aylevaun/Kildavin (Figure 9)

There are highly suitable and moderately suitable habitats in the environs of Lough Graney and a little south of the lake at Aylevaun and Kildavin. It is possible that this area already supports a local population of lesser horseshoe bats and structures should be subject to a comprehensive search to determine if they are present. If not, then this location would be ideal for construction or modification of existing structures to facilitate roosting lesser horseshoe bats.

Box 25: Scarriff/Tuamgraney (Figure 9)

There are some highly suitable and moderately suitable habitats in the environs of Scarriff and Tuamgraney, in particular around Raheen Woods. It is possible that this area already supports a local population of lesser horseshoe bats and structures should be subject to a comprehensive search to determine if they are present. If not, then this location could be considered for construction or modification of existing structures to facilitate roosting lesser horseshoe bats.

Box 26: Shannon/Bunratty/Cratloe (Figure 9)

This area is subject to a high degree of disturbance with urbanisation, the N18 motorway, Shannon Airport and associated industrial developments. Nonetheless there is considerable habitat at Cratloe and providing linkages for the species to cross the Shannon should be a priority where possible. The Ratty River provides a potential crossing point of the N18, as does the R471 underpass. We suggest that a review of the existing Circuitscape model of landscape connectivity around the Shannon Estuary to determine where bats could cross so that any roost creation can be done in a targeted way (Finch & McAney, 2020). Roadstone Bunratty could be approached to determine whether the company would be willing to incorporate lesser horseshoe bat conservation measures by planting native species along boundaries of the quarry, facilitating bat-friendly rewilding of areas that are no longer in use, and/or creating suitable artificial roosts for the species along an undisturbed boundary.

No roosts have been recorded in the Cratloe area although it is possible that there may be some bats present. Given the high level of urbanisation a comprehensive search of buildings may be difficult. Creation of a summer and winter roost in suitable habitat in Cratloe Forest Park could be discussed with Coillte.



3.3.4.2 Clare: Winter

Figure 10. Winter roost suitability for the lesser horseshoe bat in County Clare. Yellow areas represent the highest suitability and dark blue areas the lowest suitability. White stars = winter sites, Orange diamonds = summer sites.

The same white boxed areas in Figure 9 (21 Kilrush, 22 Ballylea Inagh, 24 Lough Graney etc., 25 Tuamgraney/Scarriff and 26 Bunratty/Shannon/Cratloe) apply for the species in winter in Clare (Figure 10). Box 23 Burren Heartlands, where there is an absence of known summer sites, is not included in winter since there are many known and likely many unknown

hibernacula in the area and there is no need for artificial winter sites. Please refer to text above for further details.

3.3.4.3 Other Observations on Clare and the Shannon Estuary

Dromoland/Mooghaun is an area in Clare that is of concern, but which is not highlighted in the maps because there are records of two roosting sites. However, one of these is no longer viable and the other is highly disturbed. This area could therefore be targeted for roost creation to stabilise the roosting resource for the species in this area.

In addition, islands on the Shannon Estuary were not included in the models but may constitute stopover points for bats flying across the river. Two islands - Foynes Island and Canon Island have forested/scrub habitat and may benefit from the erection of shelters that could allow migrating bats to rest.

Launching points for the species to cross the estuary may include areas such as Tarbert where there is woodland that reaches into the estuary, and river estuaries - such as the Maigue, Ratty, Fergus and Cloon. It could be worth trialling the use of static detectors at possible hopoff locations and islands to determine if bats are crossing the river during the active season or prior to hibernation and then applying conservation measures such as constructed resting places, if there is evidence of movement.

3.3.5 Galway

3.3.5.1 Galway: Summer



Figure 11. Summer roost suitability for the lesser horseshoe bat in County Galway. Yellow areas represent the highest suitability and dark blue areas the lowest suitability. White stars = winter sites, Orange diamonds = summer sites. White boxes = areas of substantial potential habitat but with no known summer roosts. In some of these winter sites are present - thus a local summer population may be present but as yet unrecorded.

The majority of lesser horseshoe roosts in Galway are located in karst landscape of the south western boundary with County Clare. Galway City presents a considerable break in connectivity with the more northerly sub-population and from the model, there are very few pockets of even moderately suitable habitat in the city. Unlike Limerick where there may be possibilities for linkages around the city to the east, or across the Shannon estuary, potential for linkages around Galway City appear to be more limited.

Box 27: Portumna (Figure 11)

The considerable tract of broadleaved woodland at Portumna would be suitable for the species if it spreads to this part of Galway. It may be suitable for adaptive measures to existing structures or creation of artificial roosts in the future.

Box 28: Woodford/Derrycrag (Figure 11)

There are large areas of highly favourable and moderately favourable landcover in this area. Checks should be carried out to determine whether the bats are already present and they are using any structures in the area. If not, then this location could be considered for construction or modification of existing structures to facilitate roosting lesser horseshoe bats.

Box 29: Derrykeel (Figure 11)

There are large areas of highly favourable and moderately favourable landcover in this area. Checks should be carried out to determine whether the bats are already present and they are using any structures in the area. If not, then this location could be considered for construction or modification of existing structures to facilitate roosting lesser horseshoe bats.

Box 30: Creganna/Clarinbridge (Figure 11)

There are some areas of highly favourable and moderately favourable landcover in this area. Checks should be carried out to determine whether the bats are already present and they are using any structures in the area. If not, then these locations could be considered for construction or modification of existing structures to facilitate roosting lesser horseshoe bats. Conservation supports for lesser horseshoe bat populations in the vicinity of the city of Galway (and other cities such as Limerick) will be essential to prevent further deterioration in connectivity between sub-populations. Local Authority input to roost construction and maintenance in this area would be ideal.

Box 31: Currarevagh/Annaghwood (Figure 11)

Historical records exist for this area and there are still some habitats that are highly suitable for the species here. Checks should be carried out to determine whether the bats are present and they are using any structures in the area. If not, then these locations could be considered for construction or modification of existing structures to facilitate roosting lesser horseshoe bats.



Figure 12. Winter roost suitability for the lesser horseshoe bat in County Galway. Yellow areas represent the highest suitability and dark blue areas the lowest suitability. White stars = winter sites, Orange diamonds = summer sites.

The same white boxed areas in Figure 11 apply for the species in winter in Galway (Figure 12). Please refer to text above for details.

3.3.6 Mayo

3.3.6.1 Mayo: Summer



Figure 13. Summer roost suitability for the lesser horseshoe bat in County Mayo. Yellow areas represent the highest suitability and dark blue areas the lowest suitability. White stars = winter sites, Orange diamonds = summer sites. White boxes = areas of substantial potential habitat but with no known summer roosts. In some of these winter sites are present - thus a local summer population may be present but as yet unrecorded.

The majority of lesser horseshoe roosts in Mayo are located in favourable habitat around Loughs Mask and Carra. There is also, however, substantial potentially suitable habitat situated further north in the county around Pontoon Bridge and Lough Conn in general.

Box 32: Fox Hill (Figure 13)

This small area of highly suitable habitat may already support some lesser horseshoe bats. It would be ideal to conduct searches to determine whether the species is already present and ground truth the habitat to determine whether it is likely to support lesser horseshoe bats before installing any artificial roost sites.

Box 33: Westport (Figure 13)

At least one bat has been recorded in this area in hibernation (in Brackloon Woods). A new discovery of lesser horseshoe bats in Westport town in 2025 was not included in this model but suggests that the species is already established there in small numbers. Searches of suitable structures in the vicinity of Brackloon Wood may reveal summer or other wintering sites and if none are present there may be opportunity to create roosts.

Box 34: Parke/Pontoon Bridge (Figure 13)

The model indicates that there is considerable suitable habitat in Counties Sligo and Leitrim, however, for the bats to extend their range this distance, there first needs to be better connectivity between potentially favourable habitat locations. In this instance there is excellent habitat around Pontoon Bridge and elsewhere in the vicinity of Lough Conn but there are some pinch points between Castlebar and Parke and onwards from Parke up to Pontoon Bridge. Any measures here should probably be focussed on habitat connectivity, by adding hedgerows, treelines, agroforestry and pockets of native woodland.

Box 35: Ballintober/Ballyhean/Castlebar/Breaffy (Figure 13)

While a single bat has been recorded in Castlebar there are no known maternity sites in this area. The moderately suitable habitats along the N84 from Lough Carra could be improved for linking habitats, like those around Breaffy, to sites further south. Strips or pockets of native woodland, agroforestry and additional tree planting and hedgerows could boost the suitability here for the species and facilitate the move northwards. Checks to determine whether there are any existing roosts in this area would also be needed, in particular around Breaffy House. The winter and summer site at Ballinafad is further east and a little isolated in terms of suitable landcover, although numbers have been steadily increasing there.



Figure 14. Winter roost suitability for the lesser horseshoe bat in County Mayo. Yellow areas represent the highest suitability and dark blue areas the lowest suitability. White stars = winter sites, Orange diamonds = summer sites.

The same white boxed areas in Figure 13 apply for the species in winter in Mayo (Figure 14). For Box 33 Westport there is a known former hibernaculum in Brackloon Woods that needs some work to re-establish it as a safe wintering site, and a new artificial wintering site is under construction in Westport town as part of a development there. These sites should be monitored to determine whether they fulfill the needs of the species in the future or whether additional artificial sites should be constructed.

3.3.7 Waterford, Tipperary, Sligo, Leitrim, Roscommon



Figure 15. Summer roost suitability for the lesser horseshoe bat in County Waterford. Yellow areas represent the highest suitability and dark blue areas the lowest suitability. White stars = winter sites, Orange diamonds = summer sites. White boxes indicate areas of substantial potential habitat but with no known summer roosts.

Lesser horseshoe bats were present in Waterford in the neolithic past (Movius *et al.*, 1935). The Blackwater Valley around Lismore is highlighted in Figure 15 and seems the most likely location that the species would take up residence in the County, if at all. Measures to provide artificial roosts for lesser horseshoe bats are not necessarily recommended for Waterford, but suitable sites could be checked from time to time to see if there is any sign of the species appearing, given its apparent range expansion in east Cork. Further riparian woodland development along the Blackwater River from Cork to Waterford may be needed to help ensure connectivity.



Figure 16. Summer roost suitability for the lesser horseshoe bat in County Tipperary. Yellow areas represent the highest suitability and dark blue areas the lowest suitability. White stars = winter sites, Orange diamonds = summer sites. White boxes indicate areas of substantial potential habitat but with no known summer roosts.

The south side of the Galtees around Cahir in County Tipperary has some highly favourable land cover that should be suitable for the lesser horseshoe bat. Similar to Waterford above, artificial sites are not recommended here but sites could be checked from time to time to see if there is any sign of the species appearing.



Figure 17. Summer roost suitability for the lesser horseshoe bat in Counties Sligo, Leitrim and north Roscommon. Yellow areas represent the highest suitability and dark blue areas the lowest suitability. White stars = winter sites, Orange diamonds = summer sites.

Figure 17, which includes Sligo, Leitrim and north Roscommon, has no specific areas highlighted using white boxes. All three counties have extensive areas of moderately and highly favourable land cover areas for the species. Nonetheless, there is a considerable gap between the next nearest most northerly/easterly confirmed roost sites and the most favourable habitats in these counties. A single lesser horseshoe bat has been detected at St John's Wood in Roscommon and a single bat was found in Lough Key in the 2000s suggesting that there is some sporadic movement to Roscommon. There have been occasional records for Sligo too. A wait and see approach is suggested for these counties with occasional checks and monitoring to determine if the species is moving north east.

4. Discussion

The lesser horseshoe bat population has been significantly increasing in Ireland for the past 10+ years, possibly longer (Roche *et al.*, 2025). While this is good news in many respects, the main reason behind this increase is likely to be a warming climate as a result of anthropogenic carbon emissions. There is some evidence to suggest that higher early spring temperatures may be driving this (Aughney *et al.*, 2022). Recent work by Fialas *et al.* (2025) based on ensemble modelling of the species' distribution across Europe, clearly shows increased predicted range suitability for the lesser horseshoe bat in Ireland in future climate conditions (RCP 4.5 and RCP 8.5 emission scenarios, see supporting information available at this link

https://conbio.onlinelibrary.wiley.com/doi/10.1111/cobi.70025?af=R)

That the species appears to be spreading and increasing from its former core distribution areas is supported by the recent discovery of small roosts further east and north (e.g. recent discovery in Westport and along the Blackwater River in Cork). The Irish lesser horseshoe bat population increase is currently being mirrored by similar increases in England and Wales (Bat Conservation Trust, 2024).

While there is some expectation that the species may continue to move and spread in Ireland, it may be limited in doing so by available habitat, linkages through the landscape and availability of suitable structures for winter or summer roosting.

This report is mainly focussed on the six counties where the species currently resides and provides suggestions for improving links and habitat within those counties, as well as highlighting areas where there appears to be suitable habitat, but there are currently no known roosts. In favourable areas that are highlighted as having no known roosts we suggest that the first step could be a ground truthing exercise to confirm whether there is in fact, suitable habitat for the species as suggested in the model. Then if habitat to support the species does exist, there would be merit in conducting searches of existing structures to determine whether there are bats present already. Finally, in the event that no roosts or hibernacula are confirmed or where existing roosts are inadequate or deteriorating, construction of new artificial roosts or hibernacula, or adaptation of existing buildings, would be worthwhile.

This report provides grounds for further collaboration among state bodies and between state bodies and other organisations - e.g. potential for new roost structures within the existing state forests outside the current known roost distributions, and in city suburbs that could be created and maintained by Local Authorities (e.g. around Creganna in Galway and east Limerick). Continued work with Transport Infrastructure Ireland to facilitate crossing points on large motorways or N roads is also essential - particularly for new roads being constructed in Limerick, as well as older routes such as the N18 around Shannon and the N18 and N4 around Galway City (among others). Additional landscape and land cover measures are needed in collaboration with the Forest Service and DAFM. Across west Limerick there is huge potential for the species if small pockets of scrub, woodland or agroforestry could be added, bringing this moderately suitable landcover into highly favourable for the species. More habitat linkages will be needed across mid and northern Mayo if the bat is to successfully expand north and north east into new territories.

There is also a need for monitoring - examples of this include static surveillance of islands on the Shannon estuary and along the estuary to determine hop off points, and DNA analysis to determine whether newly established colonies in south Clare are more or less related to the southern sub-population.

5. References

- Araújo, M. B., Anderson, R. P., Márcia Barbosa, A., Beale, C. M., Dormann, C. F., Early, R., Garcia, R. A., Guisan, A., Maiorano, L., & Naimi, B. (2019). Standards for distribution models in biodiversity assessments. *Science Advances*, *5*(1), Article eaat4858.
- Aughney, T., Roche, N., & Langton, S. (2022). Irish Bat Monitoring Programme 2018-2022 (*Irish Wildlife Manuals* No. 137). National Parks and Wildlife Service, Department of Housing, Local Government and Heritage.
- Bat Conservation Trust. (2024). *The National Bat Monitoring Programme Annual Report* 2023. Bat Conservation Trust.
- Bontadina, F., Schofield, H., & Naef-Daenzer, B. (2002). Radio-tracking reveals that lesser horseshoe bats (*Rhinolophus hipposideros*) forage in woodland. *Journal of Zoology*, *258*(3), 281–290. https://doi.org/10.1017/S0952836902001401
- Dool, S. E. (2010). *Phylogeography, Population Genetics and Echolocation of Rhinolophus hipposideros* [Ph.D.]. University College Dublin.
- Elith, J., Leathwick, J. R., & Hastie, T. (2008). A working guide to boosted regression trees. *Journal of Animal Ecology*, 77(4), 802–813.
- Fialas, P. C., Santini, L., Russo, D., Amorim, F., Rebelo, H., Novella-Fernandez, R., Marques, F., Domer, A., Vella, A., Martinoli, A., Figurek, A., Tsoar, A., Sandor, A., Ibanez, C., Korine, C., Kerbiriou, C., Voigt, C., Mifsud, C., Jére, C., ... Razgour, O. (2025). Changes in community composition and functional diversity of European bats under climate change. *Conservation Biology*, e70025. https://doi.org/10.1111/cobi.70025

Finch, D., & McAney, K. (2020). Using Circuitscape to identify potential landscape corridors for the lesser horseshoe bat in Ireland (p. 20). The Vincent Wildlife Trust.

- Glover, A. M., Brown, E., & Finch, D. (2018). *Modelling habitat suitability and landscape permeability for lesser horseshoe bats in the Usk Valley*. The Vincent Wildlife Trust for The Woodland Trust.
- Harrington, A. (2018). The Development of Non-Invasive Genetic Methods for Bats of the British Isles. Waterford Institute of Technology [Ph.D.]. Waterford Institute of Technology.
- Hijmans, R. J., Phillips, S., Leathwick, J., Elith, J., & Hijmans, M. R. J. (2017). Package 'dismo'. *Circles*, 9, 1–68.
- Lek, S., & Guégan, J.-F. (1999). Artificial neural networks as a tool in ecological modelling, an introduction. *Ecological Modelling*, *120*(2–3), 65–73.
- Liu, C., White, M., Newell, G., & Griffioen, P. (2013). Species distribution modelling for conservation planning in Victoria, Australia. *Ecological Modelling*, *249*, 68–74.
- McCullagh, P., & Nelder, J. A. (1989). *Generalized Linear Models*. 2nd Edition, Chapman and Hall, London. http://dx.doi.org/10.1007/978-1-4899-3242-6
- Merow, C., Smith, M. J., & Silander, J. A. (2013). A practical guide to MaxEnt for modeling species' distributions: What it does, and why inputs and settings matter. *Ecography*, 36(10), 1058–1069.
- Movius, H. L., Roche, G., Stelfox, A. W., & Maby, J. C. (1935). Kilgreany Cave, County Waterford. *The Journal of the Royal Society of Antiquaries of Ireland*, *5*(2), 254–296.

Phillips, S. J., Anderson, R. P., & Schapire, R. E. (2006). Maximum entropy modeling of species geographic distributions. *Ecological Modelling*, *190*(3–4), 231–259.

- NPWS & VWT. (2022). *Lesser Horseshoe Bat Species Action Plan 2022-2026*. National Parks and Wildlife Service, Department of Housing, Local Government and Heritage.
- Roche, N. (2024) Lesser horseshoe bat population estimate 2024. Unpublished report to National Parks & Wildlife Service, Dublin.

https://www.npws.ie/sites/default/files/publications/pdf/LHB_PopulationEstimate_2 024.pdf

- Roche, N., Clarke, D., Healy, K., & Langton, S. (2025). *Irish Bat Monitoring Schemes: Annual Report for 2024*. Bat Conservation Ireland.
- Schofield, H. (2008). *The Lesser Horseshoe Bat Conservation Handbook*. The Vincent Wildlife Trust.
- Thuiller, W., Georges, D., Engler, R., Breiner, F., Georges, M. D., & Thuiller, C. W. (2016). Package
 'biomod2': Species distribution modeling within an ensemble forecasting framework.
 R package.
- Valavi, R., Elith, J., Lahoz-Monfort, J. J., & Guillera-Arroita, G. (2019). blockCV: An R package for generating spatially or environmentally separated folds for k-fold cross-validation of species distribution models. *Methods in Ecology and Evolution*, *10*(2), 225–232.
- Vignali, S., Barras, A. G., Arlettaz, R., & Braunisch, V. (2020). SDMtune: An R package to tune and evaluate species distribution models. *Ecology and Evolution*, *10*(20), 11488– 11506.

6. Appendix 1: Figures 3-17 from the Main Report

Figures 3-17 from the main report are provided here again at larger scale for ease of reference











Fig 7: Limerick summer



Fig 8: Limerick winter









Fig 11: Galway summer







Fig 13 Mayo summer



Fig 14 Mayo winter



counties

Summer_locations

 \overleftrightarrow Winter_locations

proj_Ensambled_present_BlockCVsummerLHB_LHB_ensemble

Band 1: LHB_EMwmeanByROC_mergedData_mergedRun_mergedAlgo (Gray)

- <= 0
- 0 385
- 385 578
- 578 796
- > 796

Fig 15 Waterford



Fig 16: Tipperary







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