A PRELIMINARY HABITAT CORRIDOR MAP FOR CO. WATERFORD

A report for Waterford County Council

by

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TECHNICAL SUMMARY

The aims of this project were to compile a digital habitat map and Geographical Information System (GIS) dataset for Co. Waterford that identifies all ecological corridors/habitat networks involving proposed Natural Heritage Areas (pNHAs), county wetland sites and Mammals in a Sustainable Environment project (MISE) survey sites, mapped to level 3 of the Heritage Council (Fossitt 2000) classification system; to compile supplementary information relating to habitats surveyed in the field for mapping at a local level; and to analyse the ecological connectivity within and between the sites of interest, to analyse existing habitat networks and areas of fragmentation, and to set conservation management objectives for areas of high ecological value. The project was focused on habitat connectivity for four mammal groups of interest: squirrel, pine marten, bats and otter.

The main GIS output of this project is a digital Mammal Corridor map, which was compiled from 17 existing digital datasets and supplemented at a local level by habitat mapping carried out specifically for the project. Each input dataset was ranked in terms of its relevance and reliability and the digital Mammal Corridor map was built up by successive GIS clipping operations to form a single digital mapping file. Each polygon in the file contains habitat information derived from the individual input data files, mostly defined to level 3 of the Heritage Council classification scheme, with a minority defined only to level 2. For this project, each habitat code was assigned a corridor value for each of the four mammal groups, ranging from 0 (limited value as a corridor), through 1 (moderate value) to 2 (high value).

The digital habitat map was analysed for the presence of suitable habitat for each of the four mammal groups, and habitat connectivity within Co. Waterford, particularly among sites of interest (pNHAs, county wetland sites and MISE survey sites) was examined. The mammal with the largest potential area of suitable habitat identified is pine marten (36,067 ha, of which 70% is highly suitable), followed by bats (33,940 ha, of which just 29% is highly suitable), squirrel (33,617 ha, of which 79% is highly suitable), and finally otter (6,776 ha, of which 76% is highly suitable). Of the broad types of suitable habitat identified during the study, Highly modified woodland (WD) was found to cover the greatest area, occupying 25,353 ha alone, with additional areas found in mosaic with other wooded habitats.

The report provides a series of general and species-specific recommendations to further the conservation aims for the four mammal groups of interest to the MISE project. Education and raising awareness are key to implementing some of the more difficult measures. Risk assessments should be carried out before implementing any new conservation measures, such as the installation of new ecological corridors; monitoring the success (or otherwise) of the measures after their implementation is also crucial. The importance of the digital Mammal Corridor mapping file in future conservation work in Co. Waterford is highlighted, and it is recommended to keep it updated as further surveys are carried out in the county.

INTRODUCTION

BEC Consultants Ltd. and Blackthorn Ecology were appointed by Waterford County Council (WCC) in May 2013 to carry out a survey of habitat networks and ecological corridors in Co. Waterford and to deliver recorded information in a Geographical Information System (GIS) dataset. Four mammal groups were identified towards which the habitat information would be targeted: squirrel (including both red squirrel and grey squirrel), pine marten, bats and otter. This project was carried out as part of the wider Mammals in a Sustainable Environment (MISE) project, a wildlife ecology and landscape genetics project with aims which include the monitoring of key mammal groups (squirrel, pine marten, bats and otter). The MISE project is funded under the INTERREG programme IVA-Climate Change and Sustainable Regeneration and has six project partners: Waterford Institute of Technology, Waterford County Council, National Biodiversity Data Centre, Natural Resources Wales, Vincent Wildlife Trust and Snowdonia National Park.

The MISE project in Ireland is involved in collating data on the distribution and numbers of the four target mammal species and is compiling a valuable baseline dataset that will in the long-term assist in the interpretation and monitoring of the effects of climate change, among other applications. In support of the species population data being collated through the MISE project, it is recognised that information is also required on habitat networks across the landscape, i.e. areas of habitat that are functionally connected, allowing species to move by means of connecting ecological corridors that provide food and cover. Habitat fragmentation is recognised as having a negative effect on biodiversity, impacting the size and viability of species populations and their ability to move within the landscape. By taking a landscape approach and compiling existing habitat datasets together with survey data collected specifically for this project, it will be possible to create a GIS that contains data on habitat networks and ecological connectivity across the county. This will allow a better understanding of how areas of habitat function in the landscape. These mapping data can inform actions to improve ecological connectivity within a policy framework as well as forming a valuable resource for WCC with multiple nature conservation applications.

Defining habitats and habitat connectivity

A habitat can be defined as "the area in which an organism or group of organisms lives, and is defined by the living (biotic) and non-living (abiotic) components of the environment" (Fossitt 2000). Each species has its own preferred range of habitats, and landscapes consist of a continuum of habitats, interacting with and grading into each other to varying degrees, with each different habitat type utilised by different sets of species. The habitat preferences of animal species are determined by factors such as foraging or shelter requirements, and animals may perceive the landscape as isolated patches (or, ideally, a more interconnected network) of their preferred habitats in mosaic with areas of unsuitable habitat. For an animal, risks are attached to spending time in unsuitable habitat, so the greater the distance between patches of suitable habitat, the less likely the animal will be to move from one patch to another. This in turn can lead to isolation of a population, which increases the risk of decline through inbreeding depression or local extinction without opportunities for recolonisation. It follows that a greater degree of interconnectedness between patches of an animal's preferred

habitat will facilitate its movement throughout the landscape; this results in a more healthy population that is better able to cope with disturbances such as disease or climate change.

Landscapes, in the context of habitat connectivity, are made up of patches that are used by species in a particular way, such as for foraging or breeding. Patches are relatively homogeneous areas that differ from their surroundings, and their distribution within a landscape is important as it affects interactions within and between species, both within and between patches (Kettunen *et al*. 2007). The area between patches (i.e. not used by species for any purpose other than to move between patches) is called the habitat matrix. The definition of what constitutes a patch and what constitutes habitat matrix is highly species-specific: one species's patch may be another species's habitat matrix (Kettunen *et al*. 2007). In order for a species to move from one patch to another, it must move through the habitat matrix. The permeability of this matrix to the species is important in that it determines the speed at which the species moves from patch to patch, and can even determine whether that movement is successful or not. For example, a pine marten moving from one area of hedgerow to another will find it much easier to cross a farm track than a busy road.

When reviewing habitat networks and ecological corridors in a region, Kettunen *et al.* (2007) recommend a few key considerations:

- The review should have clear biodiversity conservation objectives.
- Functional connectivity rather than structural (or physical) connectivity should be assessed, bearing in mind this is species specific.
- Landscape connectivity is neither inherently good nor bad. Greater connectivity can facilitate the spread of alien species and diseases and result in reductions in genetic diversity and fitness.
- Consideration should be given to improving the size and quality of core habitats as well as looking at connecting habitats.
- New habitat patches can form stepping stones across the landscape and increase permeability.

Habitat connectivity in the legal context

Article 10 of the EU Habitats Directive (92/43/EEC), as implemented in Irish law by the European Communities (Birds and Natural Habitats) Regulations 2011 (S.I. No. 477 of 2011), recognises the importance of habitat connectivity, which it refers to as "ecological coherence", and relates specifically to the improvement of the Natura 2000 network (SACs and SPAs) in this respect. The Article refers to features of the landscape which are of "major importance for wild flora and fauna", such features being those which, "by virtue of their linear and continuous structure (such as rivers with their banks or the traditional systems for marking field boundaries) or their function as stepping stones (such as ponds or small woods), are essential for the migration, dispersal and genetic exchange of wild species".

The Waterford County Development Plan 2011-2017 also recognises the importance of ecological connectivity (sometimes referred to as ecological corridors) and gives a commitment, through Policy NH 11, to "encourage the retention and creation of sites of local biodiversity value, ecological

corridors and networks that connect areas of high conservation value such as woodlands, hedgerows, earth banks and wetlands". This is followed by Policy NH 12: "To develop a habitat map for County Waterford in collaboration with other agencies to record the range of habitats and network of ecological corridors and integrate this information in the development planning process."

The target species for this project are all protected under Irish law through the Wildlife Act 1976 (listed under Section 23) and Wildlife (Amendment) Act 2000, which prohibits the hunting or harming of listed species, or interfering with or destroying their breeding places. Additional protection is provided through the Bern Convention of 1979, which lists all of the target species either in Appendix II of the Convention (strictly protected fauna species; includes otter and all bats except the common pipistrelle) or in Appendix III (protected fauna species; includes common pipistrelle, red squirrel and pine marten). Finally, the EU Habitats Directive of 1992 lists all bats found in Ireland in Annex IV (species in need of strict protection) and otter in Annex II and Annex IV, indicating that it is in need of strict protection and requires the designation of an appropriate number of Special Areas of Conservation (SACs).

The Irish Red List for terrestrial mammals (Marnell *et al.* 2009) lists otter, Leisler's bat and red squirrel with a status of *Near Threatened (NT)*, i.e. they are not yet threatened with extinction in Ireland but may become so if their rates of decline increase. Pine marten and other bat species found in Waterford have been assigned a status of *Least Concern*.

Geographical context of Co. Waterford

County Waterford, on the south coast of Ireland, borders counties Cork, Tipperary, Kilkenny and Wexford. The county covers an area of 1,857 km^2 and in 2011 had a population of 113,795 (CSO, 2013). The main urban centres in the county are Waterford City, Tramore and Dungarvan. The main geographic features of the Waterford landscape are the mountains, rivers and its coastline.

Waterford has two mountain ranges: Knockmealdown Mountains, which form the border with Tipperary, and the Comeragh & Monavullagh Mountains, which form a single range running down the centre of the county between Clonmel and Dungarvan. Knockmealdown is the highest mountain in the county, at a height of 794 m. Conifer plantations occupy a considerable area of these mountain ranges, particularly on the lower slopes.

The largest river in the county is the River Suir, which rises on the Devil's Bit Mountain, Co. Tipperary and reaches the sea just east of Waterford City. The river forms much of the border between Waterford and Tipperary, Kilkenny and Wexford. Major tributaries of the River Suir in Waterford include the Glasha River, which rises in the Comeragh Mountains and enters the Suir just east of Kilsheelan through a heavily-wooded valley, and the Glenary River and the River Nier, which meet the Suir between Clonmel and Newcastle. The Glenary River rises in the northwest of the Comeragh Mountains, while the source of the River Nier can be found in the corrie lakes of the Comeragh & Monavullagh Mountains. Numerous other smaller rivers and streams drain the River Suir catchment in Co. Waterford, including the River Douglas, John's River, Ballymoat Stream, Whelansbridge River, Dawn River and the Clodiagh River.

The second largest river in Waterford is the River Blackwater (Munster), which flows eastward into the county from Cork and turns south at Cappoquin, on the Waterford-Tipperary border, before

entering the sea at Youghal. This river rises in the Mullaghareirk Mountains in Co. Kerry before flowing through Cork and Waterford. Notable tributaries of the River Blackwater in Waterford include the River Bride, Licky River, Goish River, Finisk River, Glenshelane River and the Owennashad River, with other smaller rivers and streams also present.

Apart from the two main rivers, the Suir and the Blackwater, and their tributaries, a number of smaller rivers drain the Waterford landscape, flowing directly to the sea. The most notable of these is the River Colligan, which rises in the Monavullagh Mountains and collects a number of tributaries (Araglin, Knockanpower and Glendermot) before entering the sea at Dungarvan. Other rivers include the River Mahon, which enters the sea at Bunmahon, the River Tay, which enters the sea at Stradbally, and the Dalligan River, which enters the sea south of Ballyvoyle.

Many of the river valleys of Co. Waterford support areas of woodland, some planted and some semi-natural, including conifer plantations, oak woodland and wet woodland. Outside of river valleys, native woodland does not form a significant part of the landscape, though conifer plantations, with some areas of broadleaved trees, do account for a substantial part of Waterford's land-cover. Notable areas of semi-natural woodland include Portlaw Woods, Stradbally Woods and the Nier Valley woodlands.

The lowlands of Waterford are mainly characterised by farmland, both arable and pasture, with fields delineated by hedgerows, treelines, stone walls and stone-faced banks. While large fields have been created by the removal of hedgerows in some cases, as in much of Ireland, the fields of Waterford continue to remain relatively small when compared to the large arable field systems of other European countries. There is an east-west divide in Waterford with regard to field size, with field sizes in the western part of the county being on average larger than those in the east (Deverell 2009).

The Waterford coast comprises numerous sandy and cobble beaches, with headlands and large bays also present. Large estuaries, such as those of the River Suir and the River Blackwater, are major features of the coastline, with notable bays including Tramore (with its sand dune system and back strand) and Dungarvan. Stretches of rocky cliffs, some of which have been designated a European Geopark, are also features of the Waterford coast, both rising directly from the sea and formed above beaches.

General habitat preferences of the target mammals

Squirrel

There are two species of squirrel found in Ireland: the native red squirrel and the introduced eastern grey squirrel. Red squirrels have been present in Ireland since the last ice-age (Lawton 2012), but due to their dependence on woodland habitat the gradual and almost total deforestation of the country led to their decline and possible extinction in the 18th century (Ó Teangana *et al*. 2000). The current red squirrel population appears to derive mainly from reintroductions from England in the early 19th century (Ó Teangana *et al*. 2000); Marnell *et al.* 2009). Grey squirrels were introduced into Ireland in 1911 in Co. Longford, having originally come from the eastern states of the U.S.A., and have spread to many other parts of Ireland including Waterford (Carey *et al.* 2007). Carey *et al.* (2007) go on to suggest the spread of grey squirrel through Waterford is likely to continue as it has through the rest of the east of the country. Where grey squirrel occurs, red squirrel is found to decline and then

disappear, as has happened in most parts of England and Wales. This is due to competition for resources and to the squirrel pox virus that grey squirrels can carry and spread to red squirrels, which have little immunity to the disease (Lawton 2012).

The habitat preferences for the two species vary to a certain extent. Both species occur at higher densities in broadleaved and mixed broadleaved/coniferous woodland, but red squirrels can survive in homogenous coniferous areas, while grey squirrels do not tend to become established in such habitats (Ó Teangana *et al*. 2000; Lawton 2009). Wooded river valleys have been used by grey squirrels to spread through parts of Leinster (Carey *et al.* 2007) and the spread of this invasive species is an example of where habitat connectivity is not necessarily positive for nature conservation.

Pine marten

The pine marten was once common throughout the country but by the 20th century it was extinct from the majority of Ireland (O'Mahony 2012). It survived in a few isolated and fragmented populations mainly in the west but also in the Slieve Blooms, the Boyne Valley and Portlaw Woods in Co. Waterford (Hayden & Harrington 2000). It has now found its way back into the midlands, north-west and east, but despite this fact it is still one of Ireland's rarest native mammal species (NPWS 2013a). The MISE project has recorded pine marten from twelve 10 km grid squares in Co. Waterford. These are mainly distributed in the east of the county, though this is likely to be a reflection of survey effort rather than actual distribution (Andrew Harrington pers. comm.). Indeed the woodland cover in the west of the county is more extensive than in the east, so it appears likely that additional survey work for pine marten would extend the distribution within the county.

Pine marten typically inhabit woodlands and landscapes with substantial woodland or scrub. In a review of pine marten distribution in Ireland, O'Mahony *et al.* (2012) note that short rotation commercial forestry plantation is the largest habitat resource for the species. With current Government policy aiming to increase the forested area in Ireland to 17% by 2030 (DAFF 1996; Lawton 2009), it would appear that additional habitat for this species will be developed over the coming years. A radio-tracking study from continental Europe (Pereboom *et al.* 2008) concluded that monitored individuals were not confined to large forests and made use of small woodland plots and hedgerows. Movement was faster through forests than other habitats, indicating that pine marten preferentially foraged in small woods, woodland edges and hedgerows. As such, it does appear to be a species which would benefit from a landscape with high connectivity, not only to facilitate movement through the landscape into unoccupied territories but also for the additional habitat these connections provide. Home ranges can vary from 1.5 km² to 32.9 km², although in Ireland, evidence suggests a much smaller range, perhaps as little as 0.13 km² (O'Mahony *et al*. 2006), a finding which has been supported by recent studies in Co. Waterford (P. Turner, pers. comm.).

Bats

Lundy *et al.* (2011) list seven species of bat as commonly occurring in Co. Waterford: brown long-eared, common pipistrelle, soprano pipistrelle, Leisler's bat, Daubenton's bat, whiskered bat and Natterer's bat. Suitable habitat also exists for an eighth species, Nathusius' pipistrelle, which has been found in the adjacent county at Fethard, Co. Tipperary (A. Harrington, pers. comm.). The habitat preferences of these species are subtly different, though each favour broadleaved woodland and avoid bog habitats (Russ and Montgomery 2002; Lundy *et al.* 2011). Other favoured habitat

includes mixed woodland habitat (brown long-eared, common pipistrelle, Leisler's bat, whiskered bat and Natterer's bat), riparian habitat (brown long-eared, common pipistrelle, soprano pipistrelle, Leisler's bat, Daubenton's bat and Natterer's bat) and urban (brown long-eared, common pipistrelle, soprano pipistrelle, Leisler's bat, Daubenton's bat and whiskered bat). Buckley *et al*. (2007) note the preferential selection of deciduous tree habitats by bats when they border another habitat, concluding that edges of woodlands or linear woodland habitats such as treelines are particularly attractive to bats; they also comment on the enhanced effect of treelines present on both side of a roadside, in which a tunnel effect is created, providing a sheltered microclimate for insects to gather. However, Buckley *et al.* (2007) also described different habitat preferences among four species of bat. Generalising about the habitat preferences of this group of species is therefore prone to over-simplification and inaccuracies.

Lundy *et al.* (2011) have assessed the relative importance of landscape and habitat associations across Ireland for different bat species. Their study combined data on bat distribution, Corine land cover, topography, climate and other environmental factors. The results explain patterns of species occurrence and predict where species may occur. Their map of habitat suitability for all bat species combined shows a centre of importance along the Suir Valley and through the east of the county. A further concentration occurs along the River Blackwater from approximately Lismore to Villierstown. Areas of least suitability for bats are dominated by the Comeraghs and the Knockmealdowns, as bog and high altitude are largely unsuitable for bat species. Lundy *et al.* (2011) do, however, emphasise that seasonal migrations across mountain ranges may occur to swarming sites in autumn and from hibernation sites in the spring.

Otter

The two basic requirements of otters are aquatic prey and safe refuges where they can rest (NPWS 2013b). They are found along clean rivers and lakes where fish and other prey are in abundance and where habitat adjacent to the waterbodies provides suitable shelter. Territories are maintained along stretches of lake shore or river bank. Where prey are plentiful, only small territories are needed, while on smaller rivers and upland locations where food tends to be less abundant otter territories can stretch to 10 or 20 km. Along coasts, otter require access to freshwater to wash their coats, and coastal territories will always include a freshwater stream or spring. Recent information on the distribution of otter indicates the species occurs through most of Co. Waterford, and notes the Suir and the Blackwater rivers as being among the more important SACs in the country for otters (NPWS 2013b).

Aims of the project

- To compile a digital habitat map and GIS dataset for Co. Waterford that identifies all ecological corridors/habitat networks involving pNHAs, county wetland sites and MISE survey sites, mapped to level 3 of the Heritage Council (Fossitt 2000) classification system;
- To compile supplementary information relating to habitats surveyed in the field for mapping at a local level;
- To analyse the ecological connectivity within and between the sites of interest, to analyse existing habitat networks and areas of fragmentation, and to set conservation management objectives for areas of high ecological value.

METHODOLOGY

Corine land cover maps

Corine land cover (CLC) dataset maps (available from www.epa.ie) were assessed to allow creation of a county-wide map of potential habitat value for each of the mammal species. The CLC dataset maps for Co. Waterford were clipped from the main dataset using the Waterford county boundary. The categories assigned by CLC were reviewed and columns added to the attributes table of the digital mapping file for each of the mammal species. A value of 1 to 4 was assigned to each of the classes based on the perceived value to the mammals of each habitat category (1 = low, 4 = high). A further column was added taking the maximum value score for the mammals in the other columns. This gives an overall county-wide map of the potential habitat value for the mammal species.

The limitations to these maps should be noted. The CLC dataset upon which the maps are based has its own limitations (http://www.epa.ie/soilandbiodiversity/soils/land/corine/uses/). It has a large minimum mapping unit of 25 hectares resulting in many features being omitted (e.g. rivers are particularly poorly represented) and, as it was designed as a pan-European dataset, some of the classes used do not occur in Ireland. The dataset is, however, in common use for presentation of county-wide assessments (e.g. the scenic landscape evaluation in the Waterford County Development Plan 2011-2017). The habitat values are assigned on a county-wide basis, taking no account of local topography or situation, e.g. an area of 'Unimproved pasture' on an exposed coastal headland gets the same score for bats as that habitat occurring in a sheltered position with nearby lakes and broadleaved woodland, a scenario which would be much more favourable for most bat species. The maps generated are based on the perceived value of habitats to the mammal species rather than on actual records of mammals. When assigning habitat values for squirrel, the values are assigned on the basis of suitability for red squirrel.

Creating the Mammal Corridor GIS

Compiling the data

A GIS was created by compiling existing habitat data available from sources including NPWS, Coillte, the Forest Service and Waterford County Council. Each of the datasets was examined for relevance and suitability for inclusion in the project. The aim was to evaluate the data and combine them into a single digital mapping file with an indicative corridor value for each of the mammal groups of interest, such that areas with the potential to act as habitat corridors for mammals could be displayed. The majority of datasets reviewed used the Heritage Council (Fossitt 2000) habitat classification system, with habitats assigned to level 3 of the classification. Some datasets, however, only classified habitats to level 2 of the system. Where datasets did not use the Heritage Council classification system, habitats were transposed to level 3 of the classification where possible, but in some cases it was only possible to transpose habitat types to level 2.

When reviewing the ecological network of a region, a first step is to identify core areas (Kettunen *et al.* 2007), which will typically include areas designated as being of conservation importance. Digital mapping files indicating the boundaries of designated sites are available on the NPWS website but

these do not contain habitat data for these sites. Data are available within other datasets, as indicated in Table 1, and these were added to the GIS. Though not providing specific habitat information, it was decided to include the SAC boundaries of the three main river SACs in Co. Waterford (Blackwater River, Lower River Suir, and River Barrow and River Nore) as a proxy for semi-natural habitat due to:

- the important role these rivers play in providing connectivity for the mammals being studied
- the fact that the boundaries had been drawn relatively recently and should represent extant semi-natural habitat within the sites
- a lack of full habitat information for these sites.

The SAC boundaries were, however, superseded by specific habitat data where these were available.

Table 1: Special Areas of Conservation (SACs) within or partially within Co. Waterford.

Site code	Site name	Main mapping data source*
2123	Ardmore Head	CPU, ISGS
2170	Blackwater River (Cork/Waterford)	SSCO, NSNW, FS, SMP, CT, ISGS. Additional areas indicated by SAC.shp.
1952	Comeragh Mountains	NSUH
2324	Glendine Wood	FS, CT, EPA.
665	Helvick Head	None.
2137	Lower River Suir	SMP, FS, NSNW, CT. Additional areas indicated by SAC.shp.
668	Nier Valley Woodlands	FS, NSNW, CT.
2162	River Barrow and River Nore	SSCO, FS. Additional areas indicated by SAC.shp.
671	Tramore Dunes and Backstrand	CMP, SMP, CPU, ISGS.

* Key to source abbreviations is given in Appendix 1.

There are no Natural Heritage Areas within Co. Waterford but there are 34 proposed Natural Heritage Areas (pNHAs) (Table 2) within, partially within or adjacent to Co. Waterford. Some of these occur fully or partially within SAC areas and, as with the SACs, mapping data for these sites are provided through a number of sources. There has been no systematic mapping of these areas since the 1970s (Young 1972), though some areas were surveyed in 2006 as part of the Waterford Wetland Survey (Anon. 2006). As such, the boundaries of the pNHAs were not included as a proxy for semi-natural habitat due to the unreliability of these data for this project. Habitat information for these sites is shown in the GIS through a number of sources (Table 2). In addition, some of these sites were selected for field survey in the current project.

Table 2: Proposed Natural Heritage Areas within, partially within or adjacent to Co. Waterford.

Site code	Site name	Main mapping data source*
1691	Ballin Lough (Waterford)	EPA.
1692	Ballyeelinan Wood	NSNW, FS.
1693	Ballyvoyle Head to Tramore	ISGS (minor coverage).
698	Barrow River Estuary	Within SAC.
659	Belle Lake	EPA, NSNW.
72	Blackwater River and Estuary	Within SAC.
73	Blackwater River Callows	Within SAC.
660	Carrickavrantry Reservoir	EPA, WWS (minor coverage).
1695	Castlecraddock Bog	ISGS, CFP.
1952	Comeragh Mountains	NSUH.
663	Dungarvan Harbour	SMP, CMP, ISGS, WCC; provide partial coverage.
664	Dunmore East Cliffs	None.
1697	Fennor Bog	None.
402	Fiddown Island	Within SAC. NSNW.
1698	Glenanna Wood	EPA (minor coverage).
2095	Glencairn	None.
1933	Glenmore Wood	Within SAC. NSNW, CT, FS.
665	Helvick Head	None.
666	Islandtarsney Fen	EPA (minor coverage).
1700	Kilbarry Bog	EPA (minor coverage).
1701	Kilsheelin Lake	Within SAC. EPA.
1702	King's Channel	Within SAC. SMP.
667	Lismore Woods	Within SAC. NSNW, FS.
1705	Lissaviron Bog	None.
399	Lower River Suir (Coolfin, Portlaw)	The section of the River Suir is within the SAC. EPA (minor coverage) for remaining area.
668	Nier Valley Woodlands	Within Nier Valley Woodlands SAC. FS, NSNW, CT.
669	Portlaw Woods	FS.
655	River Suir below Carrick-on-Suir	Within SAC.
1707	Stradbally Woods	NSNW, FS.
670	Tallow (disused church)	None.
411	Tibberaghny Marshes	Partly within SAC.
1708	Toor Wood	Coillte, NSNW.
671	Tramore Dunes and Backstrand	CMP, SMP, CPU, ISGS.
787	Waterford Harbour	Within River Barrow and River Nore SAC. SSCO, Forest Service.

* Key to source abbreviations is given in Appendix 1.

Combining datasets

Each dataset was assessed and given a score from 0 to 5 based on relevance to the project, reliability of the data, how recent the data were, and on expert judgement (Table 3). Datasets assigned a score of 0 were omitted from the GIS, either because on review they contained no information for Co. Waterford (e.g. the National Juniper Survey 2009-2012; Cooper *et al*. 2012) or the data were considered too unreliable (Teagasc indicative habitats). The datasets were then iteratively combined in the project GIS, starting with the lowest scoring dataset. Overlaps were removed after each addition by clipping the lower-scoring datasets with the higher-scoring data.

Table 3: Scoring of datasets used to create the GIS.

Dataset	Source	Summary	Ranking
Coastal Monitoring Project 2004-2006	NPWS	Mapping of coastal habitats	3.7
Coillte database	Coillte	Forestry database	3.1
Commonage Framework Plans	NPWS	Habitats in areas of commonage.	1
Conservation Planning Unit	NPWS	NPWS habitat mapping of some designated sites.	2.1
Dungarvan Habitat Map	Waterford County Council	Local habitat map.	3.4
EPA lakes	EPA	National dataset of lakes.	3.6
EPA rivers	EPA	National dataset of rivers.	4.9
Forestry Service	Forest Service	Forestry database.	2.5
Inventory of Coastal Lagoons 2007	NPWS	National lagoon inventory. No records in Co. Waterford	0
Inventory of fens and flushes in Ireland	NPWS	National fen inventory. Point features only.	2.6
Irish Semi-natural Grasslands Survey 2007-2012	NPWS	National inventory of semi-natural grassland.	4.7
Margaritifera sensitive areas map	NPWS	Records in Co. Waterford but not habitat data	0
National Juniper Survey 2009-2012	NPWS	No records in Co. Waterford	0
National Sea cliff Survey 2009-2011	NPWS	National sea cliffs database. Polylines only.	0
National Survey of Native Woodlands 2003-2008	NPWS	National woodland database.	4.8
National Survey of Upland Habitats	NPWS	Full habitat mapping of Comeragh Mountains SAC.	5
Proposed Natural Heritage Areas	NPWS	National dataset of pNHAs.	0
Saltmarsh Monitoring Project 2006-2008	NPWS	National dataset of saltmarsh.	3.8
Site-specific Conservation Objectives	NPWS	Records for Estuaries and Tidal mudflats and sandflats extracted.	3.2/3.3
Special Areas of Conservation	NPWS	National dataset of SACs.	0.9
Teagasc indicative habitats	Teagasc	Indicative habitats based largely on soils maps.	0
Tramore habitat survey	Waterford County Council	Local habitat map of area of back strand.	0
Tramore Town habitat survey	Waterford County Council	Local habitat map.	3.5
Waterford Wetland Survey	Waterford County Council	Habitat maps of 21 wetland sites in Waterford.	4.7

Assigning indicative corridor values

When the dataset was compiled, indicative corridor values were assigned to each polygon for each of the mammal groups of interest as follows:

0: No or limited use

1: Moderate value habitat

2: High value habitat

The default values for habitats are presented in Table 4. There was some departure from these values based on assumptions made about particular datasets. For example, records of semi-natural grassland

recorded from the Comeragh Mountains during the National Survey of Upland Habitats (NSUH; Roche *et al.* 2010) were considered to be too exposed to be of value to pine marten or bats.

Based on a review of aerial photography overlaid over the appropriate datasets, some assumptions were made regarding the data:

- As well as indicating the actual water course, the assumption was made that rivers and streams also have adjacent linear cover of vegetation (scrub, hedges or treelines) which would provide some habitat for pine marten and squirrel.
- Areas of semi-natural grassland were used to indicate smaller fields which would have a dense matrix of hedges.

River habitats are of particular importance to otters and also bats. Russ and Montgomery (2002) and McAney (2006) both note the strong association bats have with watercourses that have riparian vegetation. An assumption was made that higher-order streams were more likely to have better riparian vegetation and therefore to be of greater habitat value to bats than lower-order streams. Otters were noted by Bailey and Rochford (2006) as being significantly less abundant in streams < 2 m wide than in streams ≥ 2 m, but that there were no differences between streams 2-10m wide and > 10 m wide. Lundy and Montgomery (2010) found a significant but small association between stream width and otter use in Northern Ireland. As such, first-order streams were assessed as being of moderate use to otters and bats (value score = 1) and streams of order ≥2 were considered to be of high value (value score = 2).

The habitat value for otters was further refined based on water quality. The EPA river quality data were used to identify rivers with "Poor" and "Bad" water quality, according to EPA Q-value definitions (Biological Q Results 01/07/2013 at http://gis.epa.ie/DataDownload.aspx). Bailey and Rochford (2006) found no significant association between water quality and otter presence/absence, but this is likely in part due to small sample sizes of Q<3 streams. They reference previous Irish otter surveys that visually assessed pollution and found significant impacts. Lundy and Montgomery (2010) found a significant but small association between good water quality and otter use in NI. Rivers which had bad water quality were considered to have the habitat value to otters reduced to zero. Those with poor water quality had the value reduced by a factor of 1.

Table 4: Default indicative corridor values assigned to dataset polygons for target mammals, based on Heritage Council (Fossitt 2000) code.

Fossitt Code*	Habitat	Squirrel	Pine Marten	Bats	Otter	Notes
FL1	Dystrophic lakes	0	0	0	0	All in Comeraghs
FL2	Oligotrophic lakes	0	0	0	2	
FL4,5	Mesotrophic, eutrophic lakes	0	0	2	2	
FL7	Reservoirs	0	0	2	2	Additional resolution given based on water quality.
FL8	Artifical lakes	0	0	2	1	Ponds on golf courses & reedbed treatment beds
FP2	Non-calcareous springs	0	0	0	0	
FS1-2	Swamps	0	0	2	1	
FW1	Upland rivers	1	1	2	2	Additional resolution given based on stream order, water quality and altitude.
FW2	Lowland rivers	1	1	2	2	Additional resolution given based on stream order and water quality.
FW4	Drainage ditches	1	1	1	1	
GA1-2	Improved grassland	0	0	0	0	
GS1-4	Semi-natural grassland	1	1	1	0	Records from NSUH considered 0 for all species
GM1	Marsh	0	0	2	1	
HH1,3	Dry, wet heath	0	1	0	0	
HH4	Montane heath	0	0	0	0	
HD1	Dense bracken	0	1	0	0	Primarily fringing the Comeraghs
PB1,2,4,5	Bogs	0	0	0	0	
PF2	Poor fen and flush	0	0	1	1	Records from NSUH considered 0 for all species as too exposed.
PF3	Transition mire and quaking bog	0	0	1	1	
WD1-2	Mixed woodlands	2	2	2	0	
WD4	Conifer woodlands	2	2	1	0	
WD5	Scattered trees	1	1	2	0	
WN1,2,4	Semi-natural woodlands	2	2	2	0	
WN5	Riparian woodlands	2	2	2	2	
WN6	Wet woodlands	1	2	2	2	
WL2	Treelines	2	2	2	0	
WS1	Scrub	1	2	2	0	
WS2	Immature woodland	2	2	2	0	
WS5	Recently-felled woodland	1	1	1	0	
ER1,3	Exposed rock	0	0	0	0	
ED1-3	Disturbed ground	0	0	0	0	

Table 4: (continued)

Fossitt Code	Habitat	Squirrel	Pine Marten	Bats	Otter	Notes
BC1	Arable crops	0	0	0	0	
BL1,3	Built land	0	0	0	0	
CS1-3	Sea cliffs and islets	0	0	0	0	
CW2	Tidal rivers	0	0	0	2	
CM1-2	Salt marshes	0	0	0	1	
CD1,2,3,5	Sand dunes	0	0	0	0	
LR3	Littoral rock	0	0	0	1	
LS1,2,4,5	Littoral sediment	0	0	0	1	
MW1,2	Open sea, inlets bays	0	0	0	0	
MW4	Estuaries	0	0	0	2	
Mosaics						
GS/HH & HH/GS		0	0	0	0	These polygons are upland / upland fringe habitats from the CFP.
HH3/GS4		0	1	0	0	NSUH
PB/HH		0	0	0	0	
WN2/WN6	Dry/Wet woodland (dry predominant)	1	2	2	1	
WN6/WN2	Wet/Dry woodland (wet predominant)	2	2	2	1	
WN6/WD1		2	2	2	1	
WN6/WS1		1	2	2	2	
WS1/WD1		2	2	2	0	
WS1/GS1		2	2	2	0	
WS1/GS4/ HH1		2	2	2	0	
LR1/LS1		1	0	0	0	
CW2/MW4		0	0	0	2	
Fossitt level2						
FS	Swamps	0	0	2	1	
GS	Semi-natural grassland	0	0	0	0	These polygons are upland / upland fringe habitats from the CFP.
PF	Fens and flushes	0	0	1	1	Two lowland polygons with nearby streams.
WD	Highly modified woodland	2	2	1	0	
CM	Salt marsh	0	0	0	1	
LS	Littoral sediment	0	0	0	1	
Non-habitat data						
SAC		1	1	2	2	

* Note: Includes all habitats recorded in Co. Waterford to Level 3 of Heritage Council (Fossitt (2000)) classification system in datasets used to derive the Mammal Corridor map.

As no habitat information was associated with the SAC polygons, an assumption was made that these represented extant semi-natural habitat of value to the mammals being considered and scores were assigned accordingly. However, as the SACs include a variety of habitats from riverside woodland and fields through to estuaries and mudflats, the scores assigned should be considered provisional.

It should be noted that a score of zero does not suggest that the habitat type is devoid of the target mammals or of no value to mammals; rather it suggests the species are less likely to occur here. For example, the hedges alongside arable fields are likely to be used as commuting and/or foraging routes by pine marten and some bats, such as soprano pipistrelle and whiskered bat. For the purposes of this broad overview, however, they were considered of less value than hedges bordering semi-natural grassland as they would have greater amounts of pesticides and herbicides applied.

Additional mammal data obtained for the project

Data for the target mammal groups were primarily from the MISE project, but additional data were obtained from NPWS and the National Biodiversity Data Centre (NBDC) to gain a clearer picture of their distribution. Precision of data varied, however, with the MISE project providing 12-figure grid references, but the data from other sources sometimes only providing data at the 10 km grid square level. Where a location description was given, this was used to improve the accuracy of the location on the species distribution map.

Field surveys

Field surveys took place over six days: 29-31st July 2013 and 9-11th September 2013.

Field surveys were targeted towards a number of key site types, as specified in the project brief. These were pNHAs, county wetland sites identified during the county wetland survey (Anon. 2006) and MISE survey sites. The distribution of these sites throughout Co. Waterford is given in Fig. 1, together with the main Special Areas of Conservation (SACs). While these sites provided a focus for the field survey, the main consideration throughout was the habitat connectivity in the vicinity of these sites.

Field surveys for these areas consisted of habitat mapping to level 3 of the Heritage Council classification system (Fossitt 2000) within the sites themselves, and also in surrounding areas. Particular attention was paid to mapping habitats that could function as suitable mammal corridors. As well as habitat mapping, the sites were assessed in terms of their connectivity within the wider landscape. Photographs were taken of features of local interest. The habitat maps are given in Appendix 2 (Figures A1 – A10).

pNHAs:

Following consultation with Waterford County Council, a number of the smaller pNHAs in the east of the county were selected for field survey as they are generally data deficient. The pNHAs visited were:

- 000660 Carrickavrantry Reservoir
- 000666 Islandtarsney Fen

- 001691 Ballin Lough (Waterford)
- 001695 Castecraddock Bog
- 001705 Lissaviron Bog
- 001697 Fennor Bog

County wetland sites:

To ensure that field surveys covered both halves of the county, four wetland sites in the west of the county were selected for field survey:

- Wetland site 1 Kilbeg
- Wetland site 2 Kilmaloo Lough
- Wetland site 3 Duffcarrick
- Wetland site 4 Monaneea Lake

The habitats within the wetland boundary were visited and compared to the habitat assigned during the county wetland survey (Anon. 2006). If the habitat was judged to have changed in the intervening years since that survey, the habitat map was updated, but otherwise the 2006 classification was used for the mapping.

MISE survey sites:

Following consultation with Waterford County Council, the following MISE survey sites were included in the field survey:

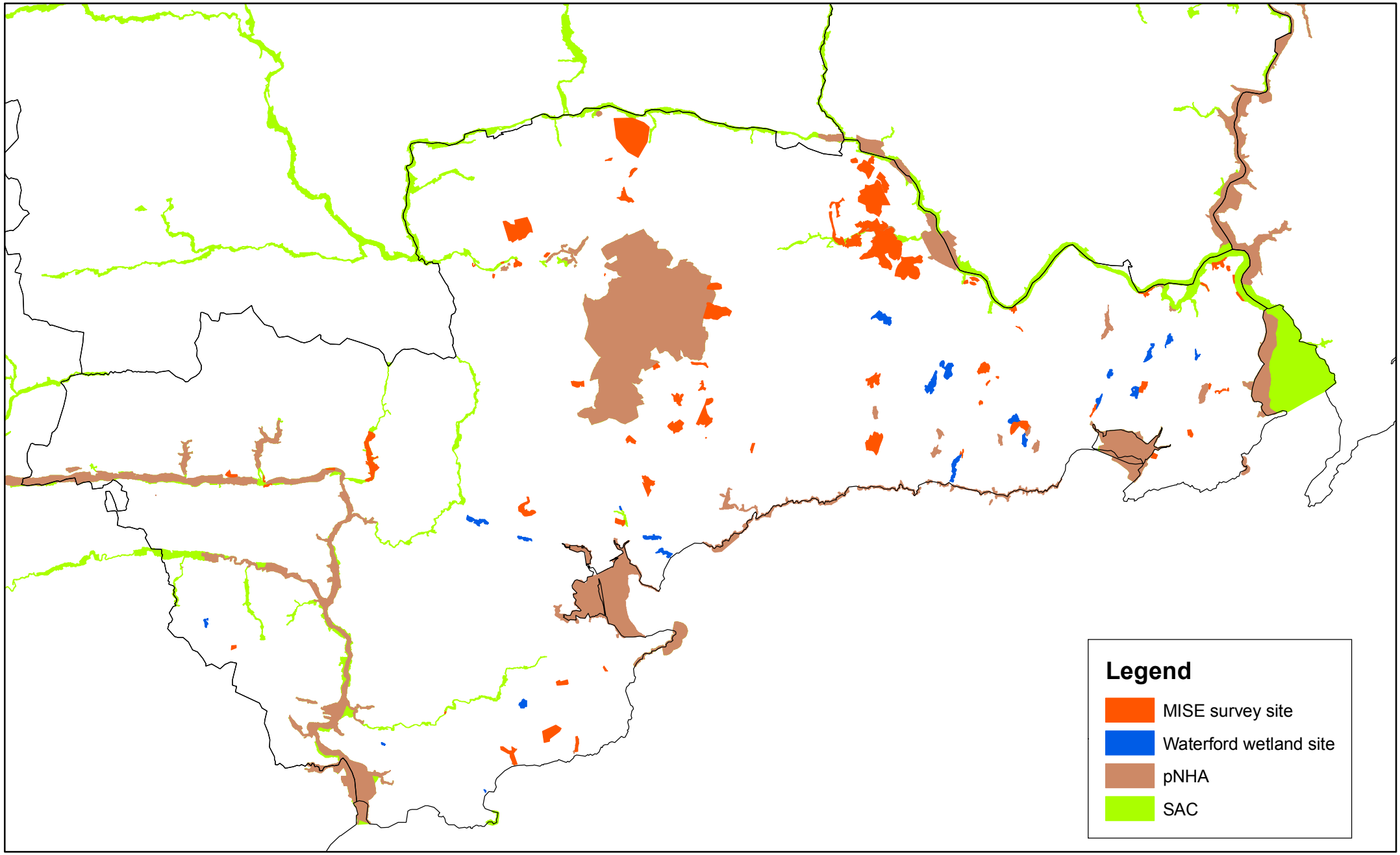
- Ballyeelinan Wood
- Ballytrisnane Wood
- Glenanna Wood

In addition to these sites, a number of other areas were targeted for assessment in a wider context. These additional surveyed areas were:

- A section of the Clodiagh River south of Rathgormack: selected because it links the lower slopes of the Comeragh Mountains with the Portlaw Woods/River Suir area
- A section of the Aughgarra Stream: selected because it has a range of suitable mammal habitats, including conifer plantations and stream
- Rathgormack: selected because it presents a gap in the habitat data.
- Newport East townland: selected because it has a range of different habitats as well as records of several of the target mammal species. The issue of townland hedgerow boundaries was also planned to be examined here.
- A section of the disused railway east of Lemybrien: selected for its potential as a mammal corridor, particularly for bats and pine marten.

Habitat mapping was not the focus of these five areas. Instead, they were assessed in a more general way across a larger area, with specific attention being paid to factors such as species composition of hedgerows. The exception was Newport East, which was mapped as it was a relatively discrete area. The habitat map for Newport East is given in Appendix 2 (Fig. A11) with the other habitat maps.

Figure 1: Key site types in the study: MISE survey sites, Waterford wetland sites and pNHAs



RESULTS

Corine land cover maps

Corine land cover (CLC) maps for each of the target mammals (squirrel, pine marten, bats and otter) are shown in Figs. 2-5, respectively. An overall map showing general suitability for all four target mammals combined is given in Fig. 6.

Despite the limitations noted in the Methodology section, the maps do show areas where there are concentrations of suitable habitat for particular species and where connectivity appears to be good. Areas with a lower proportion of suitable habitat can also be seen. It is important to note that areas indicated on these maps as having a low habitat value may still be of importance to mammals at a local level, and some habitats may harbour significant numbers of particular species (e.g. bats occurring within buildings in towns), but on a county-wide map it has not been possible to incorporate this variation.

Significant areas of suitable habitat for squirrel can be seen to occur mainly in the west of the county, particularly north of Lismore / Cappoquin, around Villierstown and on the Drum Hills. Other suitable areas include the northern and north-western slopes of the Comeragh Mountains. There are also substantial areas of woodland areas around Portlaw, but the remainder of the east of the county, east of Lemybrien, has only small, scattered areas of suitable habitat.

Pine marten appear to have suitable habitat throughout the county, though again with a greater distribution through the west of the county. The habitats flanking the Comeragh Mountains appear to provide suitable corridors through the centre of the county. The habitats in the north from Portlaw Woods also show connectivity to these central areas. The Drum Hills / Villierstown area has a high amount of woodland habitat, as does the area north of Lismore / Cappoquin. Being a more opportunistic species than red squirrel, there appears to be some suitable habitat east of Annestown and also scattered habitat to the east of Tramore.

Habitat for bats is indicated throughout the county despite watercourses being a relatively minor component of the dataset. The upland areas of the Comeragh Mountains and the Knockmealdown Mountains would be too exposed for frequent use by bats, and the coastal habitats at Tramore Strand and Dungarvan estuary also show up as areas unsuited to bats.

As noted above, rivers and streams are not well represented in the Corine dataset, and as such, suitable habitat for otter, which would be restricted to having freshwater nearby, appears limited. Some sections of the largest rivers (the Suir and the Blackwater) are depicted, in addition to some lakes through the east of the county and the coastal habitats near Tramore and Dungarvan. What is not depicted through Corine is the network of rivers and streams which provide suitable habitat throughout the county.

Figure 2: Habitat suitability for squirrel based on Corine Land Cover

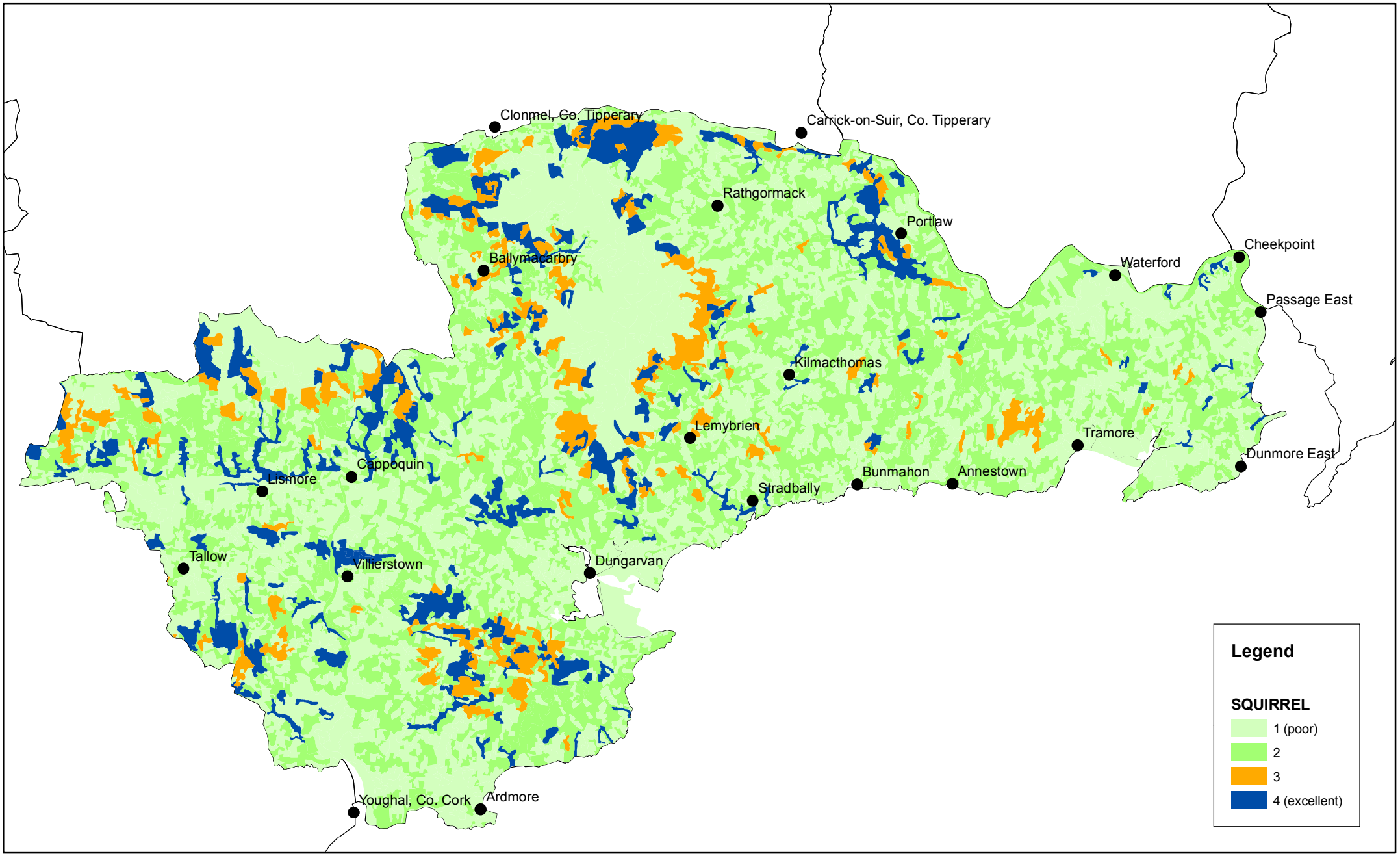
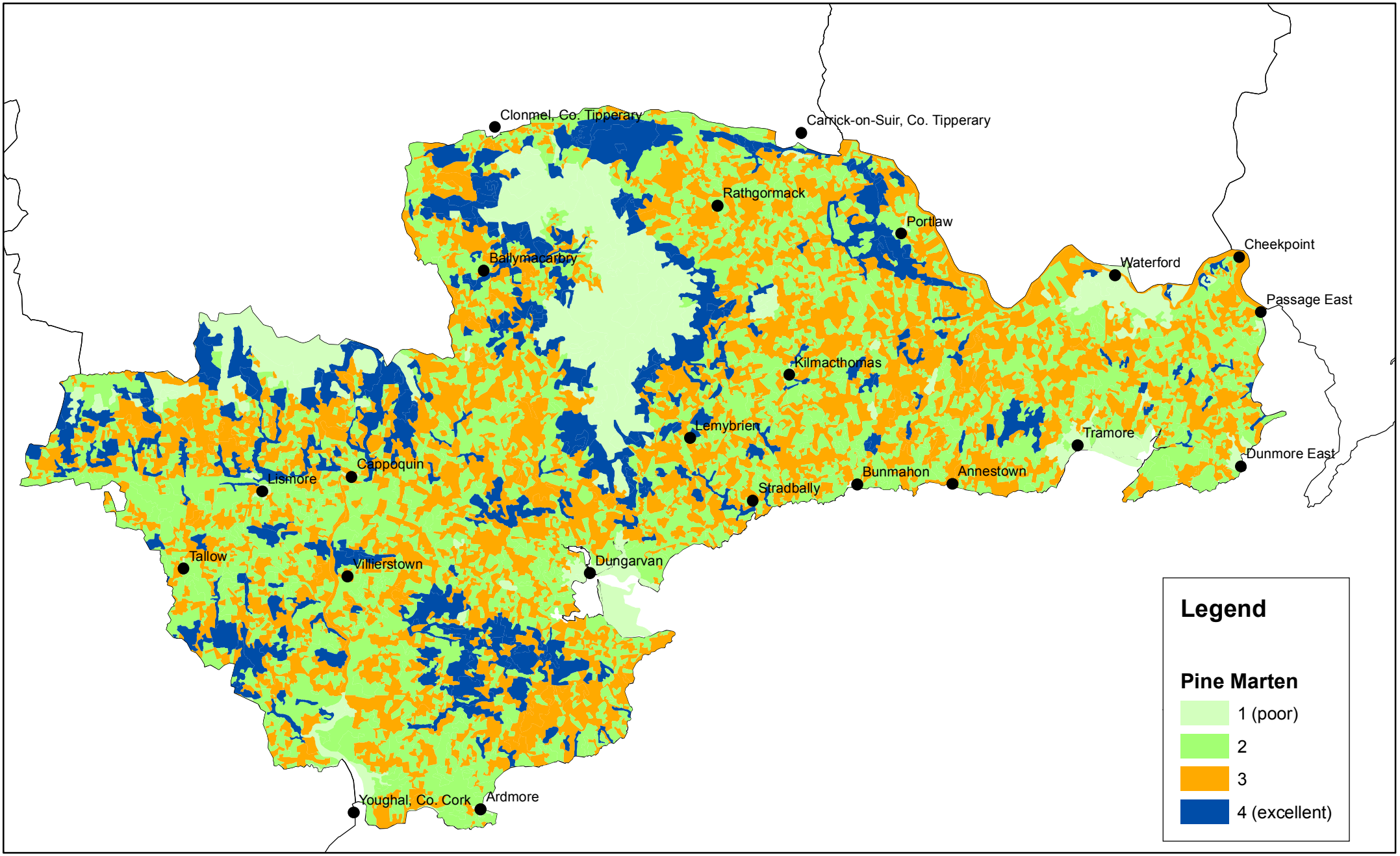


Figure 3: Habitat suitability for pine marten based on Corine Land Cover



0 3 6 12 18 24 Kilometers

N

Figure 4: Habitat suitability for bats based on Corine Land Cover

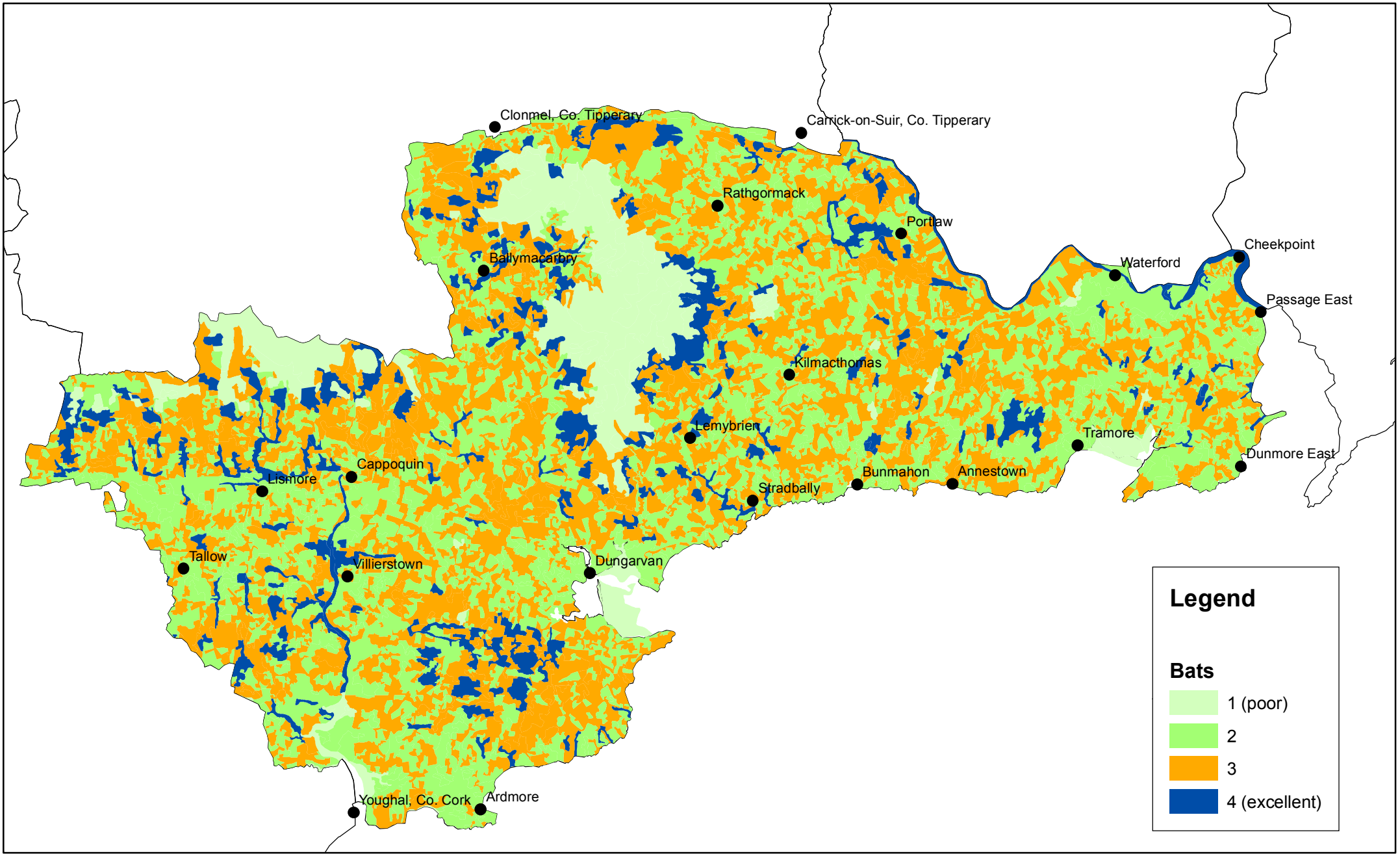


Figure 5: Habitat suitability for otter based on Corine Land Cover

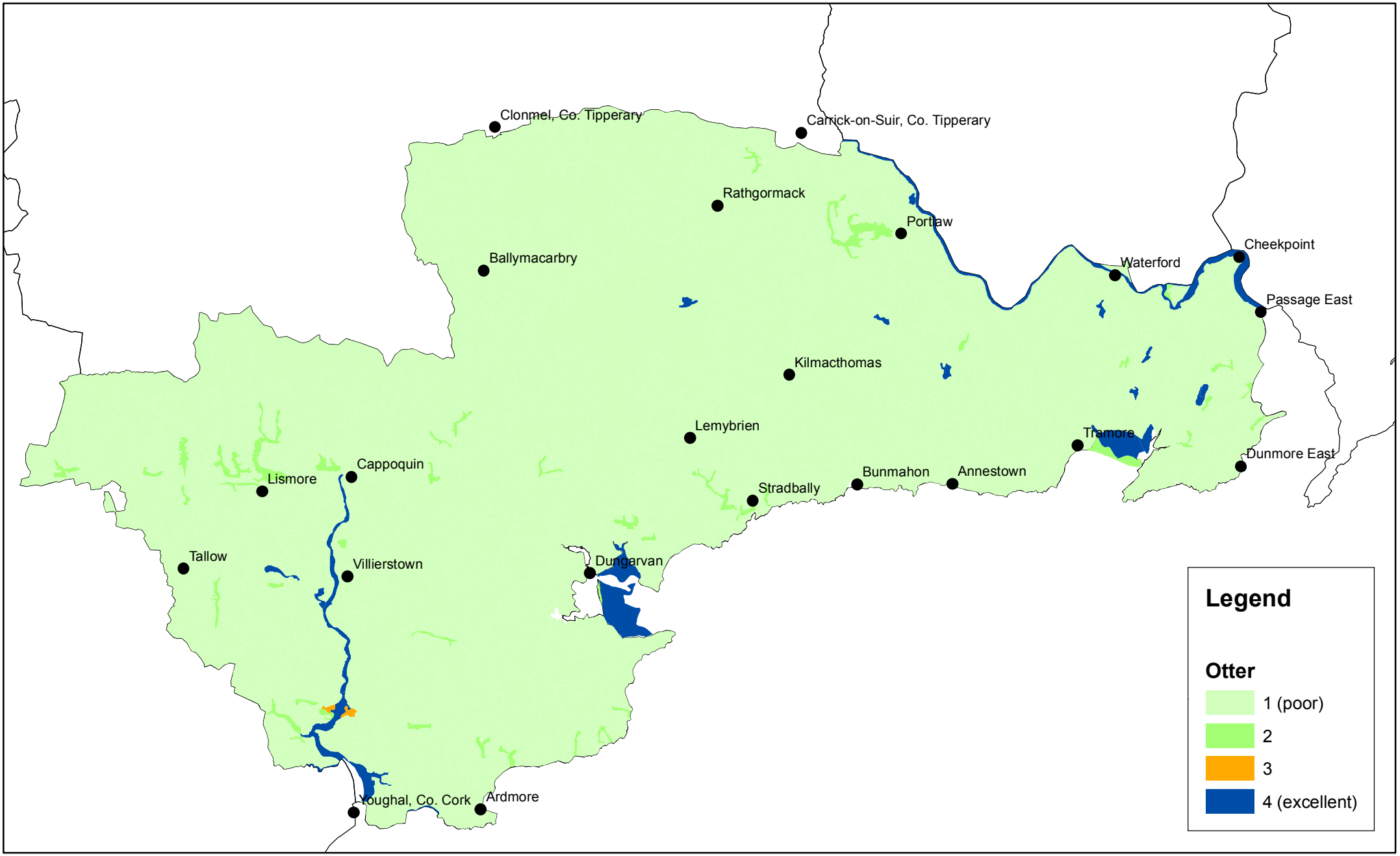
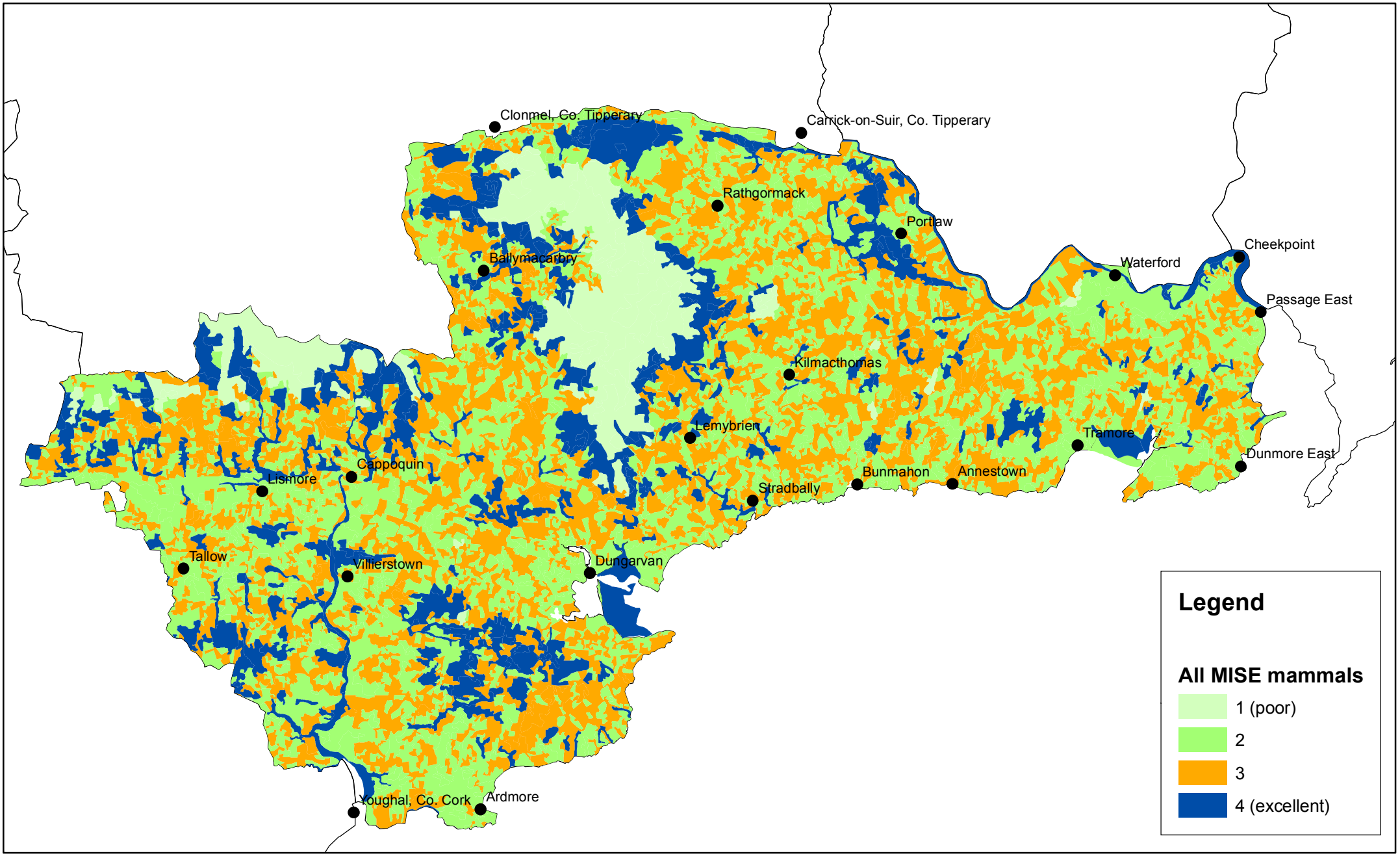


Figure 6: Combined habitat suitability for all MISE mammals based on Corine Land Cover



Mammal Corridor GIS

While the broad-scale mammal corridor map created for this project includes areas outside of the county to incorporate contiguous suitable habitat, particularly rivers, the following statistics refer to totals for Co. Waterford only, unless stated otherwise.

Table 5 shows the area in hectares of moderately suitable and highly suitable habitat for each of the target mammals. The total area of habitat represented on this corridor map is 40,336 ha, which is 22% of the total area of Co. Waterford. The habitat with the largest area is Highly modified/non-native woodland (WD), which represents 63% of the mapped total; most of this is highly suitable habitat for at least one target mammal. When combined with native woodland (WN), scrub (WS) and a small number of mapped hedgerows/treelines (WL), wooded habitats together account for 70% of the suitable habitat. Aquatic habitats such as marine water bodies (MW), watercourses (FW), lakes and ponds (FL), littoral sediments (LS), littoral rock (LR), brackish waters (CW) and salt marshes (CM), and including SAC areas, which primarily brought in additional aquatic habitats, together account for 16% of the mapped habitat in the county. The next most abundant corridor habitat is HH (heath), which together with dense bracken (HD) constitutes 12% of the mapped habitat, although none of this is more than moderately suitable, and then only for one species, the pine marten: heath is generally of low suitability as a corridor for the other three target mammals.

The mammal with the largest potential area of suitable habitat is pine marten (36,067 ha, of which 70% is highly suitable), followed by bats (33,940 ha, of which just 29% is highly suitable), squirrel (33,617 ha, of which 79% is highly suitable), and finally otter (6,776 ha, of which 76% is highly suitable). Pine martens are able to utilise scrub and heath habitats, including extensive areas of heath and bracken in the Comeragh Mountains, which for other species is excluded on the basis of altitude, exposure and unsuitable habitat.

Table 5: Area in ha of moderately suitable and highly suitable habitat for squirrel, pine marten, bats and otter in Co. Waterford, by Fossitt (2000) level 2 habitat category.

	Squirrel		Pine Marten		Bats		Otter		
Fossitt Category*	**Moderate**	**High**	**Moderate**	**High**	**Moderate**	**High**	**Moderate**	**High**	**Total area**
CM							215.6		215.6
CW/MW								0.8	0.8
MW								985.8	985.8
LR							9.3		9.3
LR/LS							0.1		0.1
LS							258.4		258.4
FL					0.1	124.1	3.1	155.8	159.0
FS						113.4	113.4		113.4
FW	1,853.4		1,853.4		923.7	929.8	930.0	946.4	1,889.3
GM						21.1	21.1		21.1
GS	653.2		653.2		653.2				653.2
HH/GS			3.2						3.2
HD			732.8						732.8
HH			4,118.7						4,118.7
PF					64.7		64.7		64.7
WL		7.2		7.2		7.2			7.2
WN	111.8	229.3		341.1		341.1	10.8	128.6	341.1
WN/WD		105.2		105.2		105.2	5.0		105.2
WN/WS	3.2		2.7	0.5	2.7	0.5		3.2	3.2
WD	21.2	25,331.4	21.2	25,331.4	21,199.9	4,152.7			25,352.6
WS/WD		0.4		0.4		0.4			0.4
WS	1,477.4	890.7	1,253.8	1,114.3	1,253.8	1,114.3			2,368.1
WS/GS		7.4		7.4		7.4			7.4
WS/GS/ HH		1.0		1.0		1.0			1.0
Additional areas from SACs	2,924.2		2,924.2			2,924.2		2,924.2	2,924.2
Total (ha)	*7,044.4*	*26,572.6*	*11,563.1*	*26,908.5*	*24,098.0*	*9,842.4*	*1,631.5*	*5,144.8*	*40,335.8*

* CW: Brackish waters; CM: Salt marshes; MW: Marine water bodies; LR: Littoral rock; LS: Littoral sediments; FL: Lakes & ponds; FS: Swamp; FW: Watercourses; GM: Marsh; GS: Semi-natural grassland; HH: Heath; HD: Dense bracken; PF: Fens & flushes; WL: Linear woodland/scrub; WN: Semi-natural native woodland; WD: Highly modified/non-native woodland; WS: Scrub/transitional woodland.

Field surveys

Description of pNHAs visited:

- 000660 Carrickavrantry Reservoir

  Carrickavrantry Reservoir pNHA (Plate 1) is of scientific interest largely for its aquatic flora. Mammal habitats of interest are primarily scrub and woodland, mainly coniferous. This site shows good connectivity with the surrounding landscape, particularly for squirrel and pine marten, while the lake itself is suitable for otter, and several MISE records have been made here.

Plate 1: Carrickavrantry Reservoir.

- 000666 Islandtarsney Fen

  Islandtarsney Fen was found to be in need of management, as its wetland habitat was showing signs of becoming rank: tussocky grasses such as false oat-grass were common. This site has undergone drainage and agricultural improvement in the northern section (which was described in the pNHA site synopsis as being a marsh habitat), and suffers from under-management in the south. Some areas in this southern section, described in the pNHA site synopsis as reed beds, now appear to be drying out, possibly as a consequence of drainage of the former marsh to the north, with some areas of the pNHA now having a closer affinity to rank dry neutral grassland than to wet grassland or fen. The site itself is now largely of little benefit to wildlife, although adjacent scrub, semi-natural grassland and river/stream habitats are of value.

- 001691 Ballin Lough (Waterford)

  Ballin Lough pNHA is situated in a heterogeneous landscape that comprises woodland (conifer, broadleaf and scattered trees/parkland), rivers, agricultural fields and hedgerows. The immediate surroundings of the site exhibit a good diversity of secondary habitats that are more permeable to movement of the target mammals than improved agricultural grassland would be (Plate 2). The presence of scrub and woodland of mixed age nearby should prove suitable for squirrel and pine marten, and to some extent for bats. Several roads nearby were also identified as providing good hunting habitat for bats (tunnel of tall trees on either side of the road), while suitable otter habitat was noted at the lake itself.

Plate 2: Swamp habitat at Ballin Lough, with woodland and hedgerows visible in the distance.

- 001695 Castlecraddock Bog

  Castlecraddock Bog was surveyed in 2008 for the Irish Semi-natural Grasslands Survey (ISGS) and part of it was classified as marsh at that time. There has been no recent management of this area, according to a local landowner. This has caused it to lose much of the broadleaf component that defines a marsh habitat, and with it much of its floral diversity. The current prevalence of a tall, rank sward of grasses such as Yorkshire fog, creeping bent and false oat-grass, together with

water horsetail, larger sedges such as bottle sedge and greater tussock-sedge, bulrush and common spike-rush, indicate a sward that is under-managed and in need of either grazing or cutting to restore structure to the sward and to increase both the structural and the species diversity of the habitat (Plate 3). The site is bisected by a farm track and drainage ditch and there is a slight difference between the habitats on either side of this division, with the area to the south having a higher proportion of greater tussock-sedge and meadowsweet, while the area to the north has a more rank, grassy and unmanaged appearance that is more in need of some form of restoration. The site is of moderate use for a number of species, including pine marten and bats.

Plate 3: Species-poor wet grassland at Castlecraddock Bog.

- 001705 Lissaviron Bog

Lissaviron Bog (Plate 4) is situated less than a kilometre south of Castlecraddock Bog, separated by improved agricultural grassland and cultivated fields of wheat. However, their habitats are not the same, and Lissaviron Bog has retained much of its botanical and habitat diversity. The site is a complex of wetland habitats grading into each other, including wet grassland, swamp habitats and transition mire. Local variation in species composition occurs, for example, with tussocks of greater tussock-sedge, royal fern and purple moor-grass found at various locations throughout the swamp. The type of swamp varies from tall-reed / sedge swamp to small areas of tall-herb swamp, which grades quickly into transition mire. It is noticeable that coarser, more tussocky grasses such as false oat-grass are absent from the main body of the wetland, and the species present are indicative of better quality habitat, including purple-loosestrife, greater bird's-foot-trefoil, meadowsweet and marsh willowherb, among others.

Plate 4: Hedgerow, scrub and wet grassland at Lissaviron Bog. Disturbance is visible in middle of photograph between distant scrub and grassland in the centre.

There has been a considerable amount of disturbance at the south-western edge of Lissaviron Bog, where it adjoins the adjacent road. Scrub removal has taken place, leaving expanses of bare ground several metres wide and over 50 m long, with the scrub brash deposited in a dry ditch adjacent to the wetland proper. Scrub with heathy elements such as western gorse, purple moor-grass, heather and bracken is still extant between two such cleared areas. Additional clearance has taken place at part of the southern boundary of the site, adjacent to a field of improved agricultural grassland. The division between the cleared area and the wetland is marked by a drop in height of 1-2 m going into the wetland.

- 001697 Fennor Bog

  Part of Fennor Bog pNHA is a complex of wetland habitats, including swamp, marsh and fen that grade into each other. The site is accessible to the public via a boardwalk that runs around a corner of the site and encompasses a lake and part of the swamp habitat. Floristically the site is similar to Lissaviron Bog. The main area of the site is comprised of a species-rich transition mire vegetation that includes greater tussock-sedge, purple-loosestrife, marsh cinquefoil, bogbean, greater bird's-foot-trefoil and water horsetail. Bulrush is locally frequent in one area, and the tussocks of greater tussock-sedge tend to occur as occasional plants rather than throughout the whole site. Meadowsweet is locally dominant. The main adjacent habitats are scrub (Plate 5) and improved agricultural grassland. This site appears to be in good condition and under suitable management, having excellent species diversity and sward structure, and with no areas showing signs of rankness. In terms of connectivity, the site is likely to be used as a corridor by bats as invertebrate diversity over the site is likely to be good, and otter may also use the area, although the site would be classed as moderately rather than highly suitable for this species.

Plate 5: Hill with scrub habitat behind swamp habitat at Fennor Bog.

Description of county wetland sites visited:

- Wetland site 1 Kilbeg

  Kilbeg wetland is much altered from the 2006 visit, as almost half of the site to the south has now been lost to drainage and agricultural improvement. The northern half still remains as wet woodland, although how long this situation will prevail, given the level of drainage in the adjacent section, remains to be seen. Furthermore, the recent habitat changes have made the wetland area less suitable for mammals than before. Conifer woodland is still present in the northwest of the site. This site is not immediately adjacent to further blocks of woodland or stretches of river, although some low hedges are present in the vicinity. Better prospects for mammal habitat exist to the south where large blocks of broadleaf and conifer woodland are found. However, some well-developed hedgerows are still extant to the north of the site (Plate 6). The surrounding woodland habitats, which include both broadleaf (sycamore) and conifer species, are likely to be more attractive prospects for foraging. The presence of a large field of cereal (recently harvested at the time of survey) means that the application of herbicides and pesticides is likely, rendering the area even less favourable. Hedgerows have also been

Plate 6: Tall, species-diverse hedgerow with stone wall base and dry ditch near Kilbeg.

removed from this cereal field since the 2005 aerial photographs were taken, representing a further loss of habitat from an area where suitable corridor habitat is relatively scarce.

- Wetland site 2 Kilmaloo Lough

There is no obvious watercourse either entering or leaving this wetland and there is no open water habitat on this site, even in the area marked as a lake on Ordnance Survey maps. On reviewing the overall habitat corridor map, it was found that this site is situated 500 m from the nearest habitat corridor, a stream to the southwest which feeds into the Blackwater River and Estuary pNHA. Some connectivity is, however, provided by hedgerows, which are frequently well developed, often forming treelines, and which link patches of scrub and woodland that were too small to appear on the broad scale habitat map. During the site survey, hedges were examined with respect to their species composition. A wide range of species was recorded, including blackthorn, willow, hawthorn, elder, ash and brambles. The presence of berry species such as hawthorn and elder add value to hedgerow habitats as they provide food sources, directly (berries) and indirectly (berry-eating birds and small mammals), for pine marten. The roads in the vicinity of this wetland are frequently lined by treelines (particularly of ash) on either side, providing suitable foraging habitat for bats (Plate 7). An ice house is located about 500 m south of the site, which may also be of use to bats as a roosting site, and this is adjacent to areas of mixed woodland and wet woodland/scrub and lake further to the south, which are likely to provide good habitat for several of the target mammals.

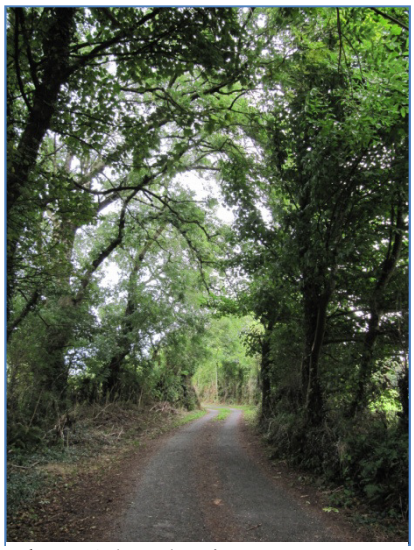


Plate 7: Ash treeline forming commuting tunnel near Kilmaloo Lough.

- Wetland site 3 Duffcarrick

The wetland at Duffcarrick, near Ardmore, in common with Kilmaloo Lough, appears to have no watercourse entering it. A field visit to the site in September 2013 confirmed that it is indeed isolated, lacking any visible, surface watercourses entering the site. The wetland is approximately 70 m from Ardmore Bay, and a drainage ditch runs from the swamp (Plate 8) towards the bay, possibly with an outflow under the beach itself. Natura Environmental Consultants (2006), who carried out the county wetland survey for WCC, suggest that the wetland may be partially fed by surface runoff and partially by groundwater, and rate the site as having limited local value.

Plate 8: Duffcarrick reed-swamp wetland with adjacent drainage ditch in foreground.

Despite the occurrence of an otter record close to the site, it is unlikely that the wetland itself provides much in the way of habitat, and it is more likely that the animal in question travelled along the strandline from a point further north, where suitable river habitat is found near Aughnaglara Bridge and beside the car park to the northeast, where otter was recorded by the MISE project in 2012. Older records of otter found at Ardmore also exist, with one NBDC record for otter dating from 1982.

- Wetland site 4 Monaneea Lake

Plate 9: Heath, scrub and conifer woodland habitat complex at Monaneea Lake.

Monaneea Lake has an interesting mix of habitats (Plate 9). As well as the lake itself, raised bog, wet grassland, heath, reed swamp, transition mire, scrub and coniferous woodland are present. Improved agricultural grassland is the main habitat surrounding the site, apart from conifer plantation, which stretches off to the north in an almost unbroken block for several kilometres. Such habitat diversity is beneficial, although the lack of an obvious river or stream entering or leaving the wetland could be a problem for otter, which would otherwise likely use the lake. The site seems suitable for pine marten, however, with sufficient connectivity to move out of the area into surrounding areas of woodland and scrub.

Description of MISE survey sites visited:

- Ballyeelinan Wood

Ballyeelinan Wood (Plate 10) is a broadleaf woodland that was included in the MISE survey as being of interest for squirrel and pine marten. Squirrel (species undetermined) was recorded in the woodland by the MISE project in June 2013. The woodland is a pNHA that occurs in a steep river valley. The river flows down to the sea, and the woodland edges onto coastal habitats, such as shingle beach and coastal cliffs. The wood is a mixture of native and non-native woodland with mostly broadleaf species. This woodland habitat, together with the adjacent scrub habitats and the river that flows through the site, is of high habitat value for all four of the species of interest. Connectivity to the wider landscape is achieved by means of streams, hedgerows and tall ash treelines, many of which line both edges of the roads and form tunnels ideal for bat foraging. Hedgerows usually

Plate 10: River and woodland corridors at Ballyeelinan Wood.

have a good species mix, including blackthorn, ash, hawthorn and gorse, with occasional rowan. Some of these are tall. A shallow valley occurs to the east of the site, with semi-natural grassland adjacent. This valley appears to be good habitat for all four species as it is undisturbed and contains a mix of species, including hawthorn, brambles, gorse, blackthorn, as well hazel for squirrel, and several habitats (woodland, scrub and semi-natural grassland). Bracken patches and possible heath also occur in the area. The stream at the bridge northeast of the woodland appears suitable for otter.

- Ballytrisnane Wood & Glenanna Wood:

The connectivity within the local landscape was examined for these two woods together. Ballytrisnane Wood is a conifer wood that was included in the MISE survey for squirrel survey. Squirrel (species undetermined) was recorded in the woodland by the MISE project (date of record unavailable). Glenanna Wood is a broadleaf wood that, like Ballyeelinan Wood, was included in the survey because of its potential for harbouring red squirrel and pine marten. However, neither mammal has, as yet, been recorded in this wood by the MISE project. This wood is similar in its configuration to Ballyeelinan Wood in that it is a steep river valley woodland that is adjacent to the coast. Again, habitat for all four species is to be found here, and signs of otter were recorded from the river that runs through the woodland in June 2013 by the MISE survey.

Plate 11: Species-rich roadside verge near Ballytrisnane Wood.

The area has a number of good features, including mature treelines of ash and sycamore; however, some hedgerows appear to be over-intensely managed and/or species-poor, in some places just consisting of brambles and bracken, with gorse dominating along some stretches. Roadside verges are relatively species rich, though, with purple-loosestrife, ragged-robin, bush vetch, meadow vetchling, meadowsweet, common fleabane and common dog's violet, as well as ferns and grasses such as cock's-foot, all growing in the verges along here (Plate 11). This adds structural as well as species diversity to the hedgerow and promotes the occurrence of a range of insect species, including butterflies. Connectivity in the area is relatively poor to the east of Glenanna Wood, with the landscape having many large, intensively managed fields, and little in the way of further scrub or woodland habitats. Hedgerows tend to be comprised of gorse and brambles. The nearest river is approximately 2 km to the east, linked by a road from Glenanna Wood.

Description of additional sites visited:

- Clodiagh River:

The Clodiagh River, as noted above, links the lower slopes of the Comeragh Mountains in the north/centre of Waterford with the Portlaw Woods/River Suir area in the east of the county. The section assessed in the field was a stretch approximately 3 km long centred on the Graigavalla

Bridge, southwest of Rathgormack. The survey was mainly carried out from the road. The area features a significant amount of suitable mammal habitat, with long blocks of woodland, both coniferous and broadleaf (ash, beech, birch, Sitka spruce and sycamore were noted, with gorse scrub occurring beside some blocks), complementing and sometimes running along the river corridor (Plate 12). Scrub, scattered trees and good quality hedges and treelines are also to be found in the area. There is a confluence of two tributaries of the river west of Graigavalla Bridge, and further confluences occur to the southwest. The river also meanders through the valley between a series of low hills, and the heterogeneity of the river's course means greater river system diversity (e.g. a range of water flow rates and river bed configurations such as riffles and cobbles), which is better habitat for salmonids than a smooth glide.

Plate 12: Cobble and gravel bed of the Clodiagh River.

Despite the prevalence of intensive agriculture in much of the landscape, hedgerow quality is often good, even between some large fields (> 2 ha). Along roads, treelines of ash were common, sometimes present on both sides of the road and thus forming a tunnel. A feature of many of the roadside-field boundaries was a stone wall base, usually covered with bracken, bramble scrub or other vegetation. At the time of survey many of these had recently been cut back.

Overall, this area shows a good level of connectivity between habitats in the area (e.g. agriculture to woodland via hedgerows) and with the wider landscape through the river itself, which is tree-lined for much of its length in this area.

- Aughgarra Stream:

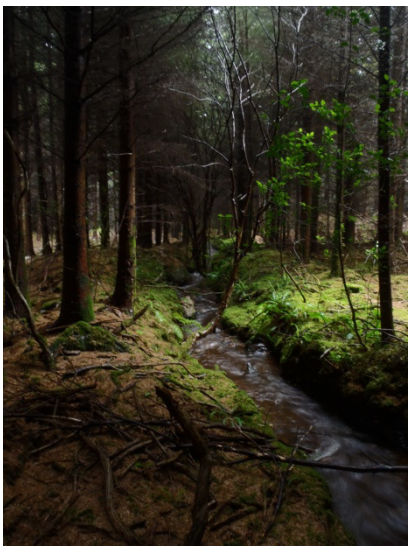


Plate 13: Part of the Aughgarra Stream running through conifer plantation near Kilclooney.

A section of the Aughgarra Stream was walked from the car park at Kilclooney to a point approximately 2 km to the northeast, near where a local track crosses over the stream. The stream runs off the mountains, through an area of Scots pine woodland and under the road at the car park, through more coniferous forestry (Plate 13) and semi-natural wet woodland, to join eventually with the Ire River and thence the Clodiagh River to the north. This area is characterised by blocks of mostly coniferous forestry, some of which runs up the lower slopes of the Comeragh Mountains to the west. The coniferous forestry eventually gives way to wet willow woodland that occurs on either side of the stream and adjoins semi-natural wet grassland. The value of the Scots pine woodland for squirrel was recognised at the time of survey, and squirrel records (species not determined) have been made during the MISE survey from this area of woodland, and from the conifer woodland on the east of the road. No

otter records have been made recently from this area (one record from 1981 occurs nearby, described in the data file as "a stream north of Ashtown", a nearby townland), but there does not seem to be any clear reason why otter should not be present. The quality of the water appears to be good, and the stream is quite wide enough and appears to offer suitable fishing and grooming areas for otter. However, with the abundance of otter records from other rivers to the southwest, further up the sides of the Comeragh Mountains, it may simply be that a greater quantity of better habitat exists close by.

- Rathgormack

The area around the village of Rathgormack was visited because of the lack of mammal records and apparent scarcity of suitable corridor habitat (as determined by the Mammal Corridor GIS created as described above) in the vicinity. The survey was carried out mainly from roads. The area has a number of small streams, but none of these reach a substantial size. The main connectivity is provided by hedgerows. Rathgormack is an agricultural area, in a predominantly lowland landscape. However, the fields are mostly separated by hedgerows or treelines with species such as hawthorn, ash and sycamore (Plate 14). Other less desirable species such as Leyland cypress also occur, but these are not common and are generally only found next to houses. Bracken and bramble are also frequent components of the hedgerows, which, as for those in the nearby Clodiagh River valley, often have a stone wall component at the base. Some less well-maintained hedges have more sparse hedgerow vegetation, and in some places hedgebanks are dominated by a species-poor mix of bramble and bracken, a situation which is probably only of some benefit to pine marten and of little use to squirrel.

Plate 14: Hedgerow corridors through an intensive agricultural landscape at Rathgormack.

One of the features noted just northwest of Rathgormack village is a ruined castle, adjacent to a farmhouse, and old church, either of which may provide bat or pine marten habitat. Hedgerows in this vicinity were of better quality, with a well-developed hedgerow of willow, elder, gorse and ash recorded at the side of a small stream.

- Newport East:

This townland was selected because it has a range of different habitats (e.g., river, woodland) as well as records of several of the target mammal species (squirrel, otter). The aim was to map connectivity of the townland, paying particular attention to the composition and quality of hedgerows, and in particular those at the townland boundary. While much of the townland is currently under tillage (mostly cereal crops such as maize and oats) or improved agricultural grassland, Newport East nonetheless provides good options for exploring habitat connectivity, as squirrel was recorded from woodland in the east of the townland, and otter was recorded in 2008 and 2010 near a locally used quay at the edge of the Blackwater.

Given that the majority of the townland, particularly the entire centre swathe, is intensively farmed, the best opportunities for mammal movement occur along the edges of the townland that are adjacent to the River Blackwater (east and south), the section in the south through which a tree-lined road runs, and a short section of the townland boundary that features a well-developed treeline of ash, sycamore and hawthorn. However, this treeline quickly becomes patchy, and less than half way up the west side of the townland all but disappears. This area is particularly intensively managed, however. The neighbouring townland of Newport West features a narrow band of broadleaf woodland along a river at its western boundary, so the boundary of Newport East is clearly not representative of all townland boundaries in the area.

Plate 15: Ruined stone house in Newport East, a possible bat roost.

The squirrel record from this townland was made in 2012, and further evidence of squirrel was found during this survey, where many spruce cones and hazel nuts with characteristic squirrel gnawing patterns were seen. The best options for squirrel movement from this area of woodland is to the north, where the woodland gives way to scrub or hedgerows before reconnecting with a large block of mixed woodland. Hedgerows are also better developed to the north. Opportunities for bat movement are provided mainly by the hedgerows and river, with a number of ruined houses also providing possibilities as bat roosts (Plate 15).

- Disused railway:

The section of disused railway between Durrow Bridge and Carrickarea was selected for its potential as a mammal corridor, particularly for bats and pine marten. However, the vegetation on this railway was found to consist of thorny scrub species such as blackthorn, hawthorn and brambles, rendering the corridor impenetrable to the surveyors, and the survey had to be abandoned on the grounds of health and safety.

Therefore, the local vicinity of the railway was viewed from the viaduct above Durrow Bridge, where a wide view of the surrounding countryside was obtained. The area was seen to be a complex of river and primarily broadleaf woodland habitat close to the railway line to its western side, where plentiful mammal corridors were in evidence, while further off to the west and east the main habitat is improved agricultural grassland, with fewer corridors available, and these dependent on hedgerow quality. The fact that the railway corridor is unused by people is in its favour as a mammal corridor, making it more likely to be used by species such as pine marten, and also by bats flying overhead. The presence of a diversity of berry-bearing thorn species means an abundance of food, both for prey and for pine marten. Smiddy (2013) surveyed stretches along this railway and confirmed that the Durrow tunnel is a habitat for bats but stated that more studies were needed to determine to what extent this was the case, although it is almost certainly used at least as a hibernation site (A. Harrington, pers. comm.). Smiddy also noted that squirrel and pine marten would be likely to be found along the line when woodland vegetation

was present nearby, and stated that the vegetation along this railway line provides an ideal habitat for foraging bats, particularly given its continuity.

Connectivity within/between pNHAs, county wetland sites and MISE survey sites

The connectivity within Co. Waterford between the sites of interest is shown in Fig. 7. Overall, Co. Waterford exhibits good connectivity for all four target mammal groups (Table 6). Across both corridor quality types (1 and 2) and taking in only the area within Co. Waterford, the area of contiguous habitat for squirrel, pine marten and bats was investigated. This contiguous habitat includes both linear habitats (e.g., rivers, streams) and non-linear habitats (woodland blocks, scrub). The area of contiguous habitat for squirrel, pine marten and bats was high, over 8,000 ha for all three species and highest for pine marten at almost 18,000 ha. However, the majority of this is medium-quality habitat, with just 1,558 ha (9% of available pine marten habitat) being high quality habitat. For squirrel, 1,559 ha of the contiguous habitat is high quality (18% of available squirrel habitat), while for bats, 1,778 ha of the contiguous habitat is high quality (19% of available bat habitat).

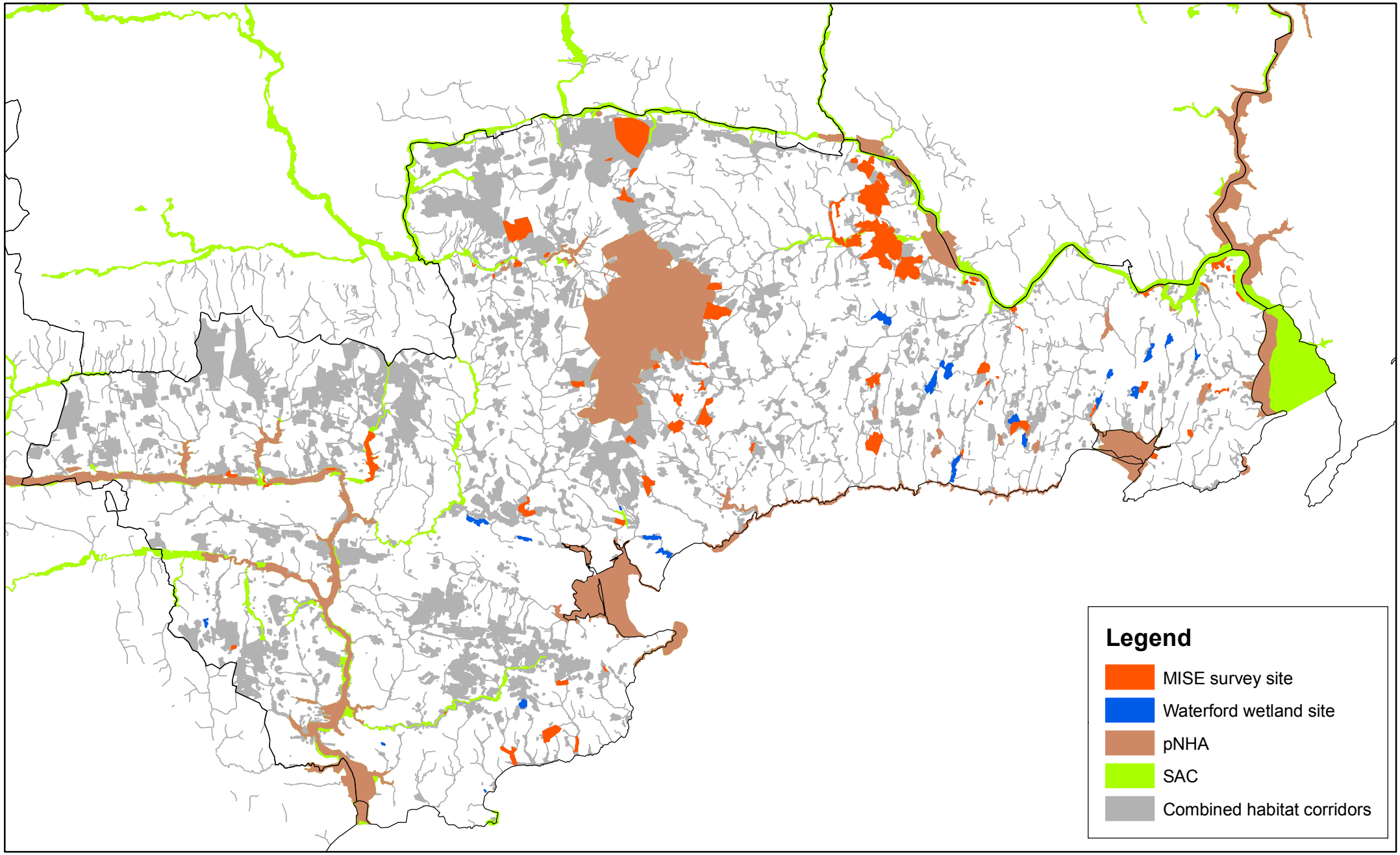
The area of contiguous habitat for otter is less, at 2,584 ha, as this species is more habitat-specific, having a requirement for rivers and streams, preferably with good water quality, or coastal waters that have a freshwater source nearby. The other species groups have a wider habitat range that includes woodland and scrub habitats as well as rivers with vegetated banks. However, 80% of the contiguous otter habitat is high quality habitat. Moreover, if the entire mapped area (which includes some of the large river SACs that extend beyond Co. Waterford) is examined, it can be seen that there is a large body of contiguous aquatic habitat feeding into Waterford from surrounding counties, most of it classified as high quality habitat for otter (Table 6).

Table 6: Area of largest contiguous suitable habitat for each target mammal group.

Mammal	Largest area (ha) of contiguous HQ habitat (CRDR_QUAL=2) in total mapped area	Largest area (ha) of contiguous habitat (CRDR_QUAL=1 or 2) in Co. Waterford only	Largest area (ha) of contiguous HQ habitat (CRDR_QUAL=2) in Co. Waterford only
Squirrel	1,558	8,901	1,558
Pine marten	1,558	17,919	1,558
Bats	7,896	9,348	1,778
Otter	13,326	2,584	2,077

When ecological connectivity was examined in relation to pNHAs, MISE survey sites and county wetland sites, it was seen that the county exhibits good connectivity among all of these site groups. Throughout the county, watercourses provide important connections between habitat patches, particularly between the smaller MISE sites and wetland sites in the east of the county.

Figure 7: Key site types and combined habitat corridor data



pNHAs:

The connectivity of the smaller pNHAs in the east of the county is described separately for each of the six pNHAs surveyed. For pNHAs as a whole, and particularly for the largest ones such as the Comeragh Mountains (001952) and the Blackwater River pNHAs (000072 and 000073), which cover a wide area, connectivity with the wider landscape can be said to be excellent, by virtue of the many tributaries that enter the large river systems, and due to the large area of woodland that occurs along both the River Blackwater and the Comeragh Mountains. The pNHAs themselves do not always directly link with each other, but connection is provided by rivers, such as the Clodiagh River, which links the Portlaw Woods and River Suir pNHAs to the Comeragh Mountains, or by a combination of woodland and rivers, such as the connectivity that exists between Dungarvan Harbour pNHA (000663) and Blackwater River and Estuary (000072).

Wetland sites:

Of the wetland sites, those that appear on the basis of the broad-scale habitat corridor map to be somewhat isolated are Duagh, Kilmaloo Lough and Duffcarrick, none of them being adjacent to a river, stream or large block of woodland. Castletown wetland is also isolated to some degree, although it does adjoin a block of woodland; the two together, though, are located more than 300 m from a river, stream or further block of woodland. Furthermore, the nearest block of woodland due east is over 300 m away, on the far side of Waterford airport's runway. Of more relevance, perhaps, is the presence of the R708 which curtails access to further woodland to the east. The area is reasonably well provided with hedgerows, however, although these appear from aerial photographs to be low in stature and possibly species poor, the best examples appearing to run alongside roads.

For Duagh, aerial photograph examination of the local vicinity of the wetland reveals that further small patches of woodland are present a short distance (350 m) to the north of the site, separated by what appear on the aerial photograph to be formal gardens. Further areas of woodland occur to the northeast in closer proximity to the site (300 m) but a regional road (the R675 into Waterford City) runs between the site and this habitat patch, so access by mammals to this area involves a larger risk and is therefore likely to be curtailed. The presence of the road here is unfortunate in that the opportunities for connectivity are better to the east of the road, as several woodland patches occur between Duagh wetland and two further wetlands to the northeast, Monamintra/Kilcaragh and Ballygunnermore, and between Duagh and Kilbarry Bog pNHA to the north, on the eastern side of the R675. However, some well-developed hedgerows near Duagh do provide links to other patches to the west, including both river and woodland habitats. A drainage ditch (which is lined on either side with a well-developed hedgerow that commences 300 m from the wetland) provides additional connectivity directly from the wetland to the wider countryside. Connectivity of Kilmaloo Lough and Duffcarrick are dealt with separately above, where the survey sites are described.

MISE survey sites:

The MISE survey sites examined in this study were those surveyed for pine marten and squirrel. As such, all 78 polygons are blocks of woodland, with the exception of one hedgerow/treeline and one clearfelled area. The largest area surveyed was in the region of Portlaw Wood, where blocks of

woodland at Brownswood, Curraghmore, Guilcagh, Kilbunny, Portnaboe and Tower Hill were surveyed. This area is known to be a pine marten stronghold, the area within Co. Waterford to which the population retreated and later spread out from when numbers recovered and conditions improved. Other important MISE sites include Kilsheelin Wood, Knockalisheen, Kilclooney Wood and Glenshelane Woods. The larger sites are well served in terms of connectivity, both with other large woodland sites and with other site groups, particularly with the larger pNHAs (Comeragh Mountains, Blackwater River and Estuary).

In general, even the smallest of the MISE polygons are close to or within a corridor mapped on the broad-scale habitat corridor map. Loughdeheen, a small area of hazel scrub in which squirrel was recorded, is one of the few to be located more than 300 m from a corridor, but examination of the aerial photograph indicates the presence of plentiful scrub in the locality that can act as stepping stones for either squirrel or pine marten, and possibly even core habitat for pine marten. The MISE site at Castletown is also located more than 300 m from the nearest block of corridor habitat, apart from Castletown wetland, which it adjoins. The situation of Castletown wetland has been described above; the best options here for connectivity to other blocks of woodland and scrub are afforded by hedgerows, particularly those that run alongside roads, with a number of small streams also found in the vicinity.

The larger MISE polygons are all part of larger woodland complexes, or are connected to other patches in the landscape via rivers or streams. Many of these form part of pNHAs, such as Portlaw Woods pNHA, or are adjacent to pNHAs, such as the Comeragh Mountains pNHA.

Analysis of habitat connectivity for target mammals

Squirrel

The best areas of habitat for squirrel, as defined by the frequency of records, are around Cheekpoint, in the east of the county, Portlaw in the northeast, Ballymacarbry (north), north of Lemybrien (centre) and between Lismore and Cappoquin, as well as the woodlands to the north of Lismore. Scattered records occur throughout the county (Fig. 8).

The main gaps for the species are the Comeragh Mountains, where the mountains form a natural barrier, and the area south of a line between Dungarvan/Cappoquin/Lismore and west to the county boundary, south of the River Blackwater. Some small areas of potentially suitable habitat do exist in the last area, but these occur along rivers and their suitability is predicated on the presence of hedgerows or treelines along the riverbanks. Areas dominated by sub-optimal, moderate-value habitat include the area around Rathgormack within a radius of approximately 3.5 km, Waterford City itself (with the exception of the wooded areas along the River Suir east of the city centre, where red squirrel was recently recorded), and the region west and south of the city within a radius of about 4.5 km.

Pine marten

Habitats for pine marten and squirrel are similar, and the highest frequency of pine marten records also occurs in some of the same areas as the most frequent squirrel records. Frequency of pine marten is less than squirrel, but this is likely to be due as much to their elusiveness as to their rarity; signs of

their presence are also less obvious than squirrel. The most notable areas for records are Portlaw Woods and Cheekpoint, with several records also from the area between Belle Lake and Woodstown, and another concentration of records in the eastern foothills of the Comeraghs, in the woodlands near Kilclooney and the Aughgarra Stream (Fig. 9). Further scattered records occur near Ballymacarbry, Cappoquin, Lismore, Villierstown, Stradbally, Lemybrien and Kill.

Similar gaps in suitable pine marten habitat occur as for squirrel. The main difference is that the Comeragh Mountains pose less of a barrier to pine marten movement than to squirrel, with heath and even dense bracken providing some measure of suitable habitat for pine marten in higher altitude areas.

Bat

Habitat preferences for bats were assigned on a group rather than a species-specific basis. On the whole, bat activity is fairly constant throughout the county, as shown by the number of records from various sources (Fig. 10). Habitat connectivity is generally good, due mainly to the coverage provided by the river systems. Bats, however, also favour situations where broadleaf woodland is frequent, and here Waterford is perhaps less well served. The best areas of broadleaf woodland can be found along the Blackwater River from Cappoquin west to the Cork border and at the south of the county near Youghal, along the River Bride at Tallow, and blocks of woodland in the east such as Portlaw Woods. Conifer plantations are a less suitable habitat for bat foraging and roosting, but many conifer plantations are fringed with naturally regenerating or planted broadleaves. Some conifer plantation edges can therefore act as moderately suitable habitat for at least some bats, but distinguishing suitable and unsuitable edges is not feasible at a county scale.

The most obvious gap in suitable habitat occurs in the uplands of the Comeragh Mountains. Because bats can fly, they have a greater ability than ground-based species to cross larger areas of unsuitable habitat. In addition, the position of the species record may be given according to the surveyor's location rather than the exact location of the bat. Several bat records occur in areas where no obvious suitable habitat is found, but this could be due to bats passing between two suitable areas of habitat (such as two large river systems), due to surveyor location, or due to suitable habitat being available at a local level, such as along a road with treelines on either side. The potential for roads, particularly smaller roads with well-developed treelines, to act as suitable habitat corridors for bats cannot be ignored, but is impossible to show at a county scale.

Otter

River connectivity throughout the survey area is generally good, aided by the presence of a number of large rivers flowing through Co. Waterford and along the boundary with other counties. The most important rivers are the River Blackwater and River Suir, and important tributaries of these, such as the River Bride, River Nier, Araglin River and Clodiagh River. The highest levels of otter activity, as evinced by the frequency of records for the species, are in the Comeragh Mountains, especially along the rivers that run from the corries of Knockaunapeebra Mountain, down to the River Nier in the northwest and the Rivers Tay and Mahon in the southeast (Fig. 11). Otter activity is also frequent along the River Suir, from Cheekpoint west to Waterford City, and where the river turns south at Mount Congreve.

However, there are a number of areas where river connectivity is less comprehensive. The main areas where habitat connectivity is lacking are south of Lismore (the area between the Rivers Blackwater and Bride) and an area that runs west of Dungarvan as far as Villierstown. Small gaps in habitat occur where river systems are separated by ridges of hills or mountains, such as Drum Hills and the ridge of hills that runs between the Araglin River and the River Blackwater. Records for otter are lacking from the cluster of wetland sites that includes Pickardstown, Duagh, Castletown, Monamintra/Kilcaragh, Ballygunnermore and Ballinakina. While this does not necessarily mean that they are definitely absent from the area, it suggests at a minimum that numbers are low. Movement into these wetlands west from Belle Lake pNHA, north from Tramore Dunes and Backstrand pNHA, and south from King's Channel pNHA in Waterford City, all of which locations are known to have otter, does not appear to be occurring regularly, despite the presence of potentially suitable connecting habitat in all cases except Duagh and Castletown. Pickardstown is linked by contiguous habitat corridors to Tramore Dunes and Backstrand pNHA, where several otter records have been obtained. The reason for the lack of movement in the vicinity of these wetlands in unclear; in most cases, the cause does not seem to be a lack of suitable connecting habitat, so it may be that the wetlands themselves do not provide suitable habitat for otter, or at best provide sub-optimal habitat, given the occurrence of large areas of eminently suitable habitat nearby.

Figure 8: Squirrel records and habitat corridors for squirrel

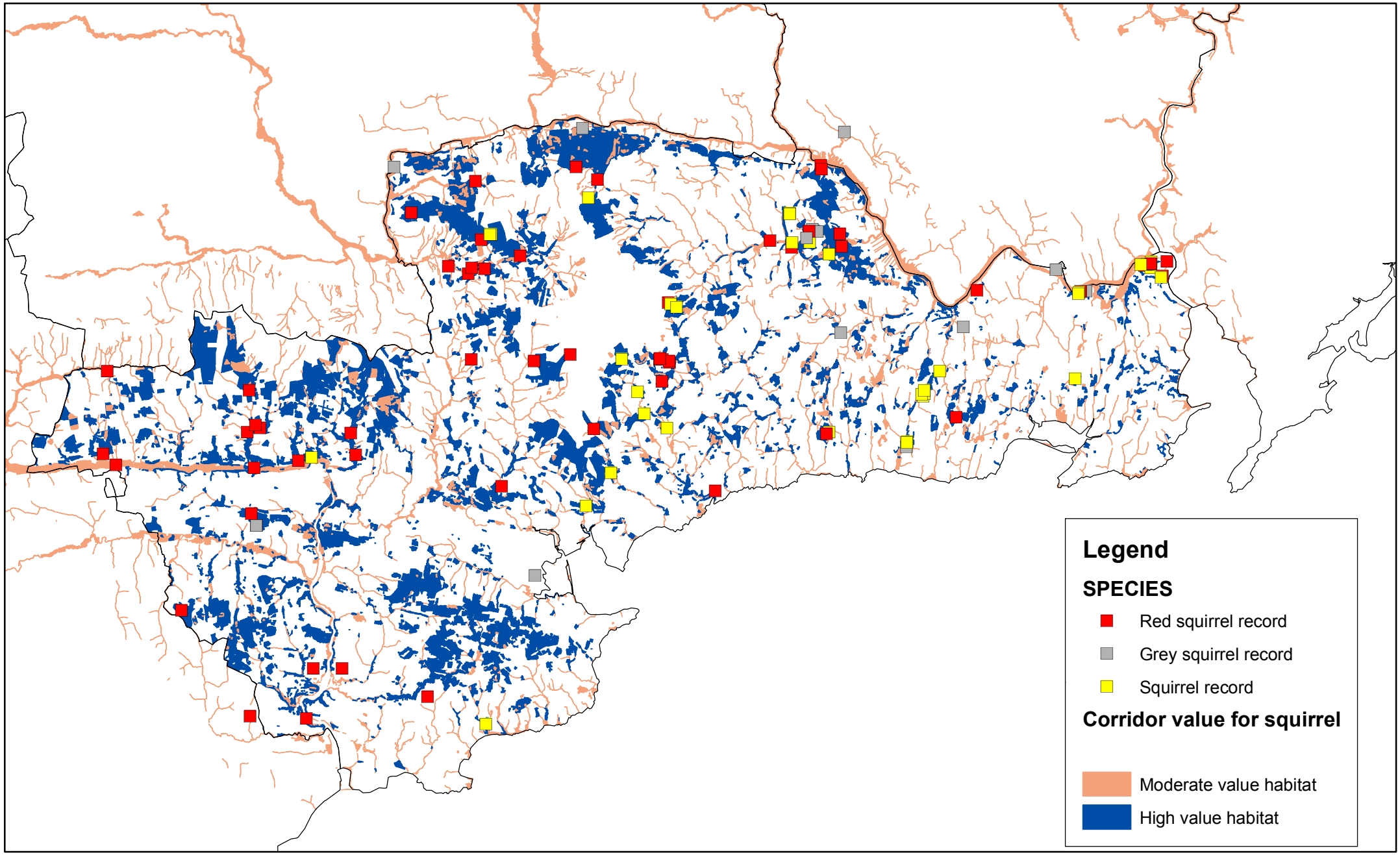


Figure 9: Pine marten records and habitat corridors for pine marten

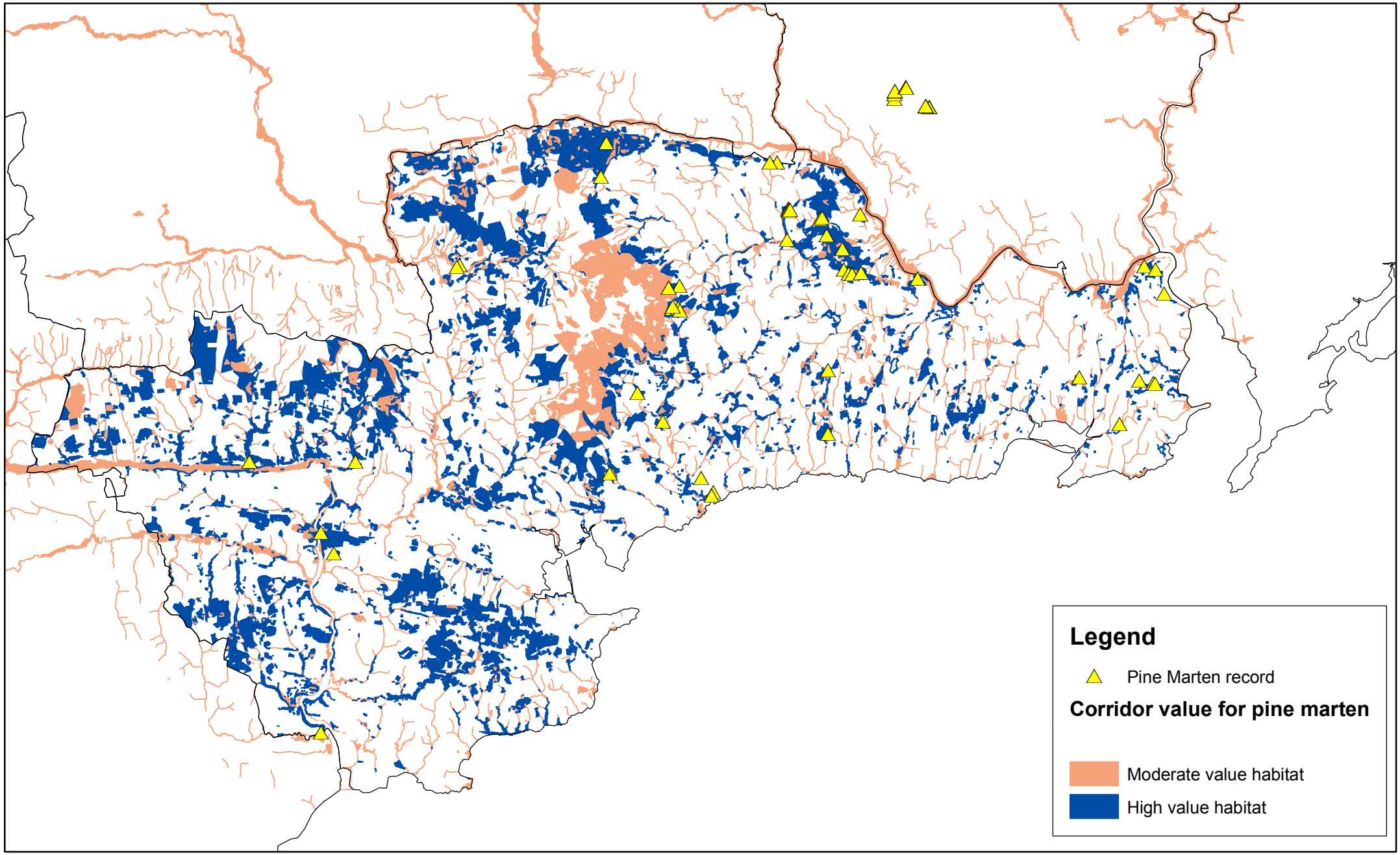


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Figure 10: Bat records and habitat corridors for bats

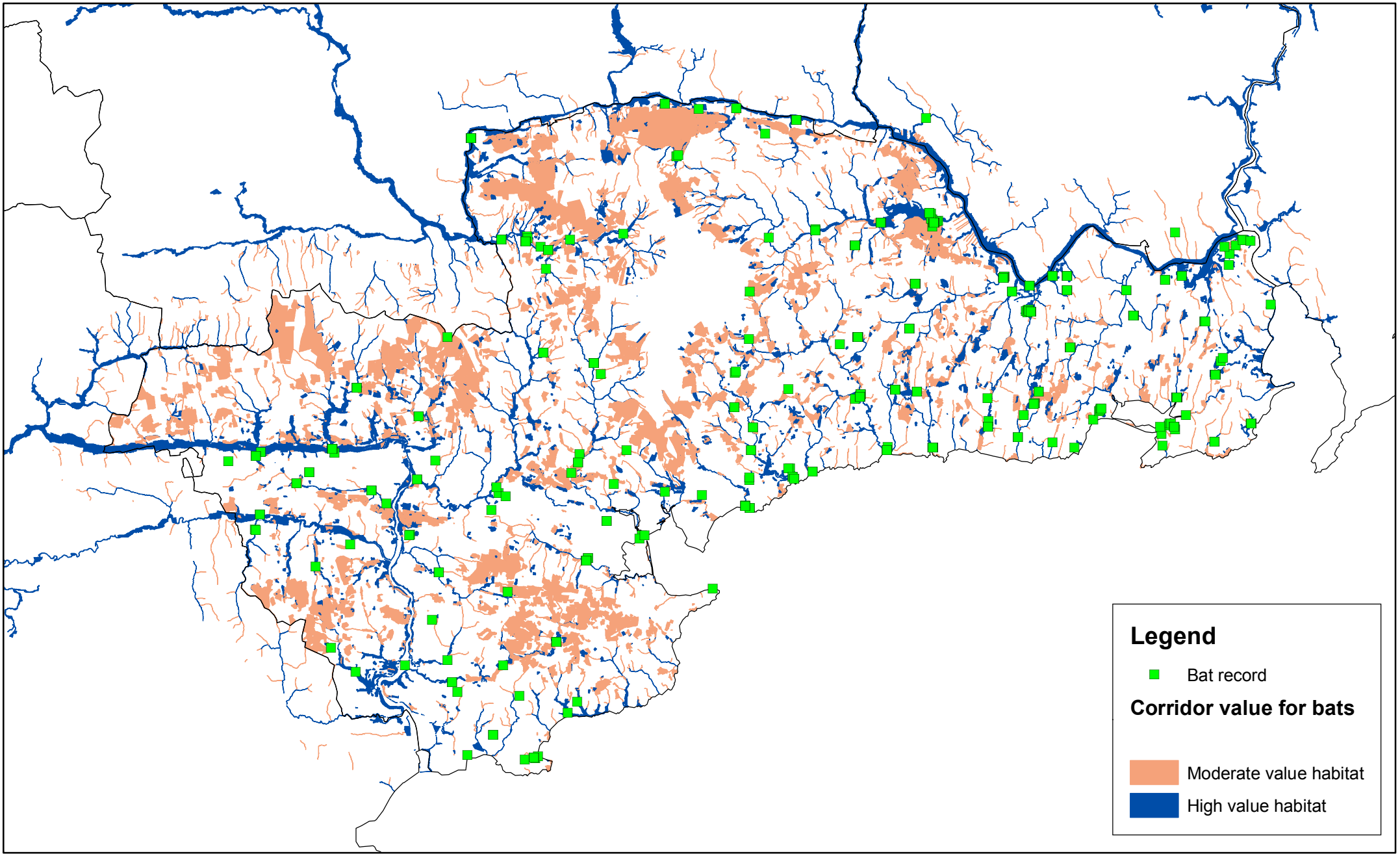
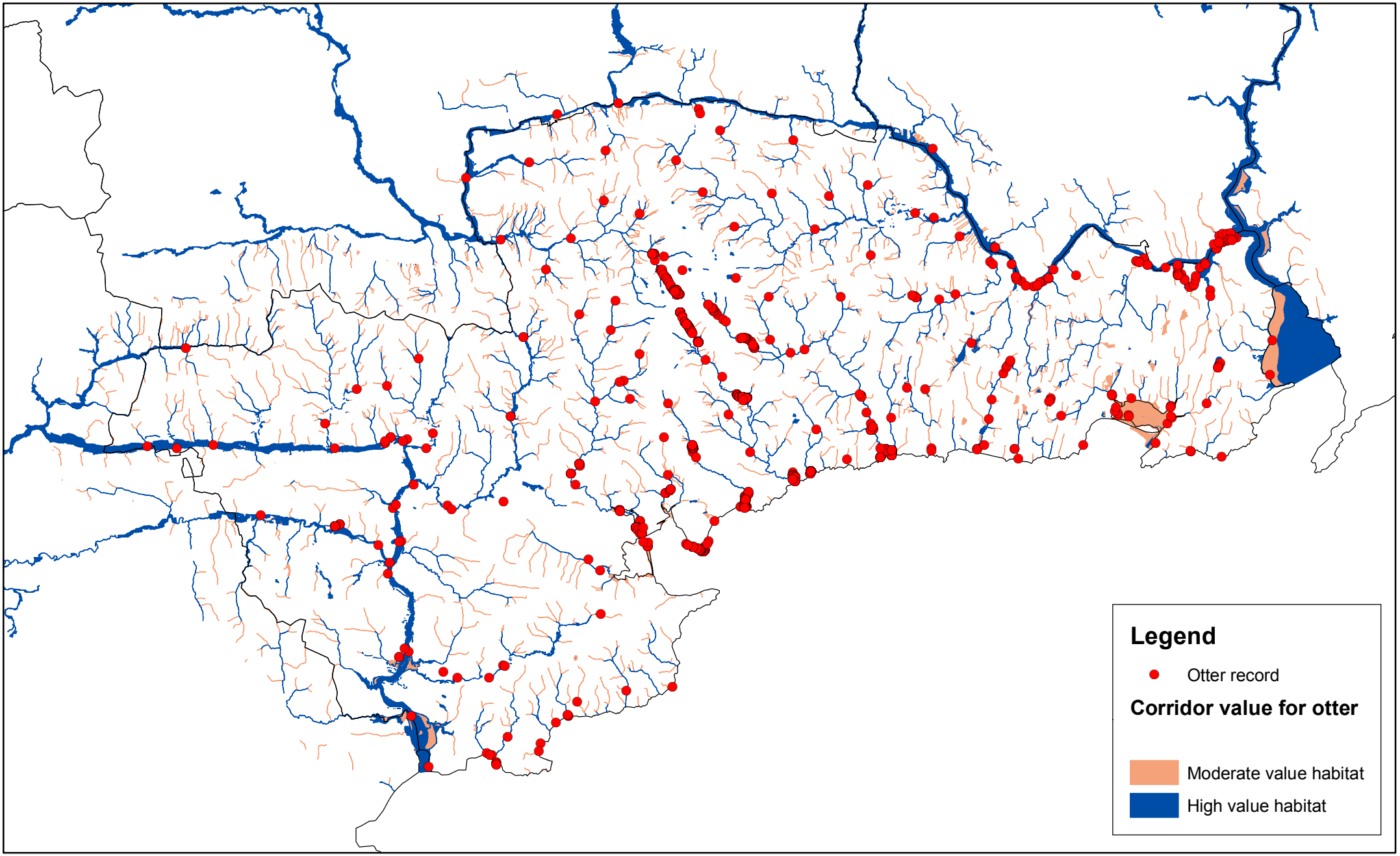


Figure 11: Otter records and habitat corridors for otter



DISCUSSION

From the analysis of river, woodland, scrub and other available habitat data collated in the present study, it is clear that Co. Waterford is well provided with a range of potentially suitable mammal habitats which have a satisfactory level of connectivity between them. The geography of the county combines several large river systems with hills and mountains. Many of these upland areas have, over the last century in particular, become vegetated either naturally or artificially with broadleaf and conifer woodland. There are few areas in the county from which either a stream or block of woodland is absent. Field surveys have confirmed that, even where apparent gaps between habitat patches exist at a broad scale, connectivity exists at a local level in the form of hedgerows, treelines or vegetated stone walls, albeit of varying quality and diversity.

The Corine landcover (CLC) gives an overall view of habitat suitability for the target mammals in the county. An alternative approach to taking the highest score for each species, as done for this project, would be to present a cumulative score, thereby indicating the areas of greatest value to all mammals. The value of the habitat in Co. Waterford generated using the CLC dataset could be further explored by comparing it with habitat availability in other counties in Ireland and, as CLC is a pan-European dataset, comparison could also be made with the counties in Wales which are within the INTERREG IVA area.

Defining habitats of high ecological value is context-specific to some degree, as a habitat's value may be linked to a particular target species. For example, conifer plantations are regarded by many ecologists as being of relatively low ecological value, largely because of their low species diversity. However, in the context of red squirrel, conifer forests may be regarded as being of high ecological value because of their value as a habitat for this species, and perhaps more importantly, because of their unsuitability for grey squirrel. In general, however, it is safe to conclude that areas (or, on a larger scale, landscapes) that support a range of different semi-natural habitats are more likely to be of high ecological value as they will support a greater range of plant and animal species. As such, most of the sites visited during field surveys for this project can be regarded as being of high ecological value, with even the more habitat-poor areas like Duffcarrick wetland providing some measure of landscape heterogeneity.

The conservation management of high ecological value areas needs to be sharply focused on what the conservation objectives for the area, or target species, are. This is particularly true for issues of connectivity. The creation of this broad-scale habitat map, bringing together as it does over 15 data sources, is an important step to help conservation managers to focus on particular areas of interest. It should be the first data source consulted for any ecological project in Co. Waterford, particularly where the target mammals are concerned, as it contains a wealth of habitat information in one place. It will allow a more efficient use of resources by preventing some areas from being needlessly resurveyed. In addition, when viewed in conjunction with the species distribution data for the target mammals, it will permit managers to focus on areas that may need corridor enhancement, or to recognise where data may be deficient and further surveys needed.

Above all, what should happen, following any measures to improve habitat connectivity, is monitoring to ensure that the measures are having the desired effect and, just as importantly, that

they are not having a detrimental effect. A monitoring programme should be planned and implemented as part of any measures that aim to address deficiencies in habitat connectivity.

Recommendations

Below are some general and species-specific recommendations for the conservation management of high ecological value areas in the context of habitat connectivity.

General

- *Assessment prior to establishment of new habitat corridors:* From the literature consulted on establishing or improving habitat connectivity, a number of clear caveats emerge. The first is that habitat connectivity is neither good nor bad, and seeking to enhance connectivity between two habitat patches may have unexpected and not always desirable consequences (Kettunen *et al.* 2007). For example, establishing small copses or lines of broadleaf trees as stepping stones or habitat corridors between a patch of woodland containing only red squirrels and a patch of woodland that contains both reds and greys will facilitate movement of the grey squirrels to the area where they previously were absent, potentially leading to the eradication of both populations of red squirrels rather than just one. Furthermore, although corridors have been found to benefit relatively large, mobile mammals, such as those included in the MISE study, the benefits of regional-scale corridors for other animal and plant species are largely undemonstrated (Good, 1998). Careful assessments of the risks, costs and benefits therefore need to be carried out before any new corridors are established.

- *Hedgerow and treeline management:* Because much of the habitat connectivity at a local level is provided by these linear woodland habitats, which are important for squirrel, pine marten and a range of bat species, it is important to maintain these habitats in good condition. Gappy or species-poor hedges do not provide much ecological benefit to the target mammals. Many of the hedgerows seen on field visits were composed of a diversity of native species such as hawthorn, blackthorn, elder, brambles, dog-rose and occasionally hazel, with many treelines comprising a mix of these species with taller species such as ash or mature hawthorn. The enhancement of hedgerows by the planting of native berried species, or other native species such as hazel, should benefit a range of wildlife species, including both birds and mammals, and increase diversity and abundance of these species, by providing food for berry- and nut-eating species as well as (indirectly) for carnivorous species such as pine marten. Further advice on hedgerow management is provided by the Heritage Council (2002) and Teagasc (2009a, b).

  Roadside and townland boundary hedges often contain a higher diversity of native shrub species than internal hedges (Foulkes and Murray 2005). This is likely to be due to historical or cultural factors; for example, historically, landowner properties often stopped at the townland boundary, so proper hedging would have been important to prevent their stock breaking into a neighbour's pastureland (or vice versa). A hedgerow survey throughout the county, such as those that have been carried out in fourteen counties or regions in Ireland to date, would be an objective worth pursuing as a means to promote the diversity and importance of hedgerows as mammal and bird habitats throughout Waterford county. A hedgerow survey should follow the recently

consolidated and updated *Hedgerow Appraisal System* (Foulkes *et al.* 2013) to enable comparisons with previous hedgerow surveys.

Practices such as hedgerow removal should be discouraged, and mitigation of any such impacts by replacement with compensatory habitat should be enforced.

- *Habitat extension:* In general, increasing the area of existing habitat where the target mammals are known to be present, even if connectivity is not extended, will be beneficial for the target species, particularly where there is a good population already present, as it will improve conditions for the existing population. A review of regional corridors in an Irish context concludes that, for most species, conservation and enhancement of existing habitat is likely to be a less costly and more successful measure than establishment of new, landscape-scale corridors (Good, 1998). Core populations of target mammals tend to form the nucleus from which populations spread to other areas. Improving the chances of the success of the core population, or improving conditions so that a larger core population can thrive, would increase the chances of the core population dispersing to another habitat patch. One example of this would be to extend the boundary of a woodland by planting a line of trees around the entire edge, or planting a block onto one side of the woodland.
- *Detailed survey of additional areas:* The area around Cheekpoint has numerous records from all four target mammal groups, and should be regarded as being of county importance for mammals. Further characterisation of this area, by habitat and mammal survey, would help to inform any future conservation work to be done here. This area is discussed further below in relation to squirrel. Detailed surveys of other MISE survey sites could also provide useful information, particularly where more than one species has been recorded.
- To obtain a more complete assessment of the distribution of the target mammals throughout the county, particularly of squirrel and pine marten, it is recommended that surveys be continued, and increased in the west of the county, where fewer data on these species, particularly pine marten, are available.

Squirrel

- The Cheekpoint area may well become a last refuge for red squirrel in the future if grey squirrel continue to spread through the county and red squirrels become more marginalised. This area is somewhat cut off by the meanders of the Rivers Suir and Barrow, and by urban Waterford to the west. However, grey squirrel was recorded in Maypark Village in January 2013 (NBDC data), located only 4 km west of Cheekpoint. As the population of reds in Cheekpoint appears to be strong, and greys have not yet reached the area, action should be taken quickly to prevent influx by the greys. This may require some swift, drastic and potentially controversial measures. It could even require the removal of possible habitat corridors into the area to halt the progression of grey squirrel into the area; this option would need to be carefully thought through, planned well and risk-assessed beforehand. Appropriate Assessment screening for potential impacts would also be necessary in the case of significant habitat removal in proximity to Natura 2000 sites.
- Carey *et al*. (2007) make reference to Red Squirrel Protection Areas (RSPAs), as does the all-Ireland species action plan for red squirrel (Anon. 2008) (referred to here as Red Squirrel

Preferred Areas). It may be feasible to pursue the idea of seeking to have one or more of the more important red squirrel areas in the county identified as RSPAs.

- The next County Development Plan for Waterford should consider giving the Cheekpoint area special consideration because of its squirrel population. This could take the form, for example, of closely scrutinising any proposed forestry developments in the area, particularly where these may affect the balance between red and grey squirrels. One suggestion could be to favour planting schemes in this area that give red squirrels an advantage over greys, such as planting conifer species only, as suggested by Carey *et al*. (2007) and Lawton (2009). Because this is contrary to the objectives of the National Biodiversity Plan, in which broadleaf planting is actively encouraged and implemented through afforestation grant schemes, this could result in lower levels of grant aid available to landowners from the Forest Service if single-species conifer or diverse conifer mixes were required. A modified Native Woodland Scheme mix including Scots pine and small-seeded broadleaves, such as birch and willow, could also be suitable with Forest Service agreement. Consideration should be given to these options, and solutions to allow their implementation should be explored by all stakeholders, possibly including a top-up scheme provided by the Forest Service or Waterford County Council. Education and awareness-building would also be very important in this context.
- Any enhancement of connectivity designed to benefit squirrel should be closely examined and monitored, to ensure that connectivity is not also being established for grey squirrel.
- Active management of grey squirrel populations may be required to stem their progression, particularly in the region of habitat corridors. This could involve unpalatable options such as licensed trapping or killing, which is likely to be a contentious issue, and one where sensitive handling would be required. Even if this option is not pursued in the short term, it should be considered and kept in reserve, especially if areas of county importance such as Cheekpoint or Portlaw Woods become more at risk. Lawton (2009) notes the difficulty of balancing the dispersal of red squirrel populations with deterring the movement of grey squirrel, and concludes that "the only possible solution is the targeted control of grey squirrel in these vital thoroughfares and the use of local and regional planning in managing squirrel populations."
- A causative link has been suggested between healthy populations of pine marten and healthy populations of red squirrel, especially where grey squirrel are known to occur (Carey *et al.* 2007). Recent research has found that grey squirrel populations have disappeared from large areas of the Midlands, coinciding with an increase in pine marten abundances in these areas (Sheehy 2013). It has been postulated that the success of these red populations may be due to the fact that the pine marten preferentially predates the heavier and less agile grey squirrel, thus lessening the amount of grey squirrel competition. An alternative mechanism may be avoidance displacement of grey squirrels when pine marten move into an area (E. Sheehy, pers. comm.). As this link is not yet proven, more research on this aspect of the animals' behaviour would be useful to clarify the situation with regard to the red-grey balance in the presence of pine marten. If a link is indeed established, efforts should be made to increase pine marten populations where grey squirrel is a problem.
- Carey *et al.* (2007) state that grey squirrel control is still one of the most important and beneficial conservation measures available, and that this should be carried out in conjunction with conservation measures that promote the red squirrel. They further state that control of grey

squirrels should be carried out in a targeted fashion, concentrated in areas where they threaten current red squirrel populations, and should take cognisance of grey squirrel ecology to anticipate periods of dispersal and breeding. Supplementary feeding of red squirrels, while beneficial, should only be implemented in areas where the grey squirrel is absent, as they would also benefit from the supplementary food (Carey *et al*. 2007).

Pine marten

- *Education and raising awareness:* The Red Data List for Ireland (Marnell *et al.* 2009) lists the main threats for the species as being the threat of poisoning and trapping from gun clubs and game keepers because of the recent recovery in pine marten populations. A recent information leaflet published by NPWS (2013) underlines the possible conflict between humans and pine martens, as it is entitled "How to exclude pine martens from game and poultry pens". Information campaigns should be run to minimise conflicts where possible and emphasise the importance of pine martens, the part they play in wildlife ecology, and the possible link between pine marten populations and the red/grey squirrel balance.
- Many of the general enhancements suggested above, such as hedgerow management, would benefit pine marten as well, as habitat destruction has played a part in the decline of this species in the past.

Bats

- Road construction projects can affect bats because of removal of linear corridors (such as treelines), alterations in light levels, and topographical changes to the landscape. However, because bats are protected as a species listed on Annex IV of the EU Habitats Directive, provisions are usually put in place to mitigate any habitat damage as part of the overall development.
- *Woodland management:* Kelleher (2009) recommends a number of measures to enhance woodland habitats for bats, including allowing old, dead and mature trees to remain in managed woodlands, the implementation of rotation cutting rather than clear-felling, and increasing habitat diversity within woodlands, for example, by the creation of large ponds within managed forests, as has been done in the UK. Because bats may move 4-5 km between roosts in any one night, and even up to 40 km or more during seasonal movements, Kelleher (2009) recommends that management of habitats for bats should be considered in a landscape management context rather than simply at a local level.
- *Maintenance work:* McAney (2006) and Kelleher (2009) make further general recommendations in relation to maintenance work that may affect bats. Bat surveys are recommended to be carried out before felling trees, particularly old or rotten trees, and prior to repointing brickwork of structures where bats may be present (e.g. bridges, old buildings). Old structures where bats might be present should be maintained and strengthened if necessary, while retaining bat access through existing entry points. Several old structures were noted during field surveys for this project, such as an ice house south of Kilmaloo Lough, an old castle at Rathgormack and a ruined stone house at Newport East, all possible roosting sites for bats.
- Artificial bat roosts / bat boxes should be considered.

- A general recommendation for bats is to discourage the use of pesticides or insecticides that reduce insect diversity and abundance in habitats adjacent to hedges and treelines, where bats are likely to forage. Because open habitats such as intensively managed grassland is generally avoided by bats, it follows that any means that allow this to decrease in extent, such as by relaxation of grazing regimes or reduction of chemical inputs, will be good for bats (Buckley *et al.* 2007).

Otter

- Little can be done to increase the length of rivers and streams in the county. However, good water quality is essential for good otter habitat, so the aim must be to maintain existing levels of water quality, and if possible, to improve it, as required under the Water Framework Directive. This will likely have benefits to other target species too, such as bats, as good water quality will lead to greater botanical diversity and, as a natural consequence, to greater insect diversity and abundance.
- As noted for bats, large road construction projects can affect otter populations, cutting off existing habitat corridors, with provisions usually put in place to address this as part of the overall road project (NRA 2006). Recent large road developments in Co. Waterford have more than likely incorporated habitat / corridor disturbance mitigation measures for otter (e.g. the R675 Tramore Road upgrade through Kilbarry Bog pNHA). However, it is of vital importance that any measures such as underpasses should be checked to see that they are functioning as planned. For example, are the underpasses in need of maintenance? Is the fencing intact? Are the animals using them or are incidences of road-kill high or on the increase? If the latter, then the cause should be investigated and corrected.

Improving ecological connectivity within a policy framework

- *Watercourses:* The current Waterford County Development Plan (2011-2017) (CDP) has as one of its objectives the protection and conservation of the quality, character and distinctiveness of landscape, including, among other things, waterway corridors. Policy NH 15 of the CDP is "to maintain good ecological status of wetlands and watercourses in support of the provisions of the water framework directive and Ramsar convention", while Policy NH 16 of the CDP states that "the preservation of riparian corridors is a requirement for the protection of aquatic habitats and facilitation of public access to waterways", and prohibits developments within a buffer zone of 15 m of the top of the riverbank. Implementation of the EU Water Framework Directive (2000/60/EC) (WFD), which aims to achieve a status of "good" for all water bodies by 2015, will improve the quality of rivers, streams and lakes and make them more suitable as corridors for otter and bats in particular.
- *Hedgerows:* Hedgerows are also protected under the CDP, with Policy NH 17 relating to the protection of hedgerows in all new developments, particularly species-rich roadside and townland boundary hedgerows. Policy NH 18 similarly relates to hedgerows, specifically their protection, preservation and, if removal is necessary, their replacement with new native hedgerows with species of local provenance. These measures should all serve to improve habitat

connectivity at a local level, and bring about a general improvement in habitat conditions for a range of animal species.

- *Trees and Woodlands:* Policy NH 19 and Policy NH 20 of the CDP relate to the replanting and extension of woodland cover in the county, in particular mixed forests and broadleaf woodland, an aspiration that is in line with the National Biodiversity Plan. However, as noted above with regard to habitat management for red squirrel, current planting recommendations and guidelines may be in conflict with requirements for conifer-only plantings to discourage influx by grey squirrels, and it may be necessary to adopt a flexible approach with regard to these policies, but only in this particular context.
- *Forestry:* Commercial forestry is addressed by policies NH 21 to 23, in which the linear felling of trees in scenic areas is discouraged, and phased felling rather than clear-felling is promoted, which is in line with management practices noted above that are beneficial for bats.
- In relation to Cheekpoint, it is suggested that exploratory talks be opened with NPWS regarding the designation of this peninsula as a pNHA because of its importance as a habitat for several important mammal species, and even for inclusion within the River Barrow and River Nore SAC (002162) or Lower River Suir SAC (002137) by amendment of the SAC boundary. (It is noted, however, that the area where frequent otter records were made is already within the Lower River Suir SAC). Recognition of its county importance in this way would afford it some sort of special status so that developments or habitat management could be more strictly controlled.
- As noted above, using the international Corine dataset, the situation with regard to habitat availability in Waterford could be compared with other counties in Ireland and also with the counties in Wales that are within the INTERREG IVA area.

CONCLUSIONS

- The county-scale habitat map created by this project is a valuable data resource that will allow the more targeted and efficient use of other resources (e.g., financial, personnel, time) to achieve ecological objectives. It should form the starting point for all ecological projects in Co. Waterford, and will also be useful for issues connected with planning, for example.
- It will prevent double-surveying of areas and will therefore allow work to be more focused on the main areas of interest, such as wetlands, pNHAs, etc., and will help decision-making with respect to habitat management and enhancements that may be required.
- The resource should be regarded as a work in progress: as habitats change, the resource will have to be updated and should be added to and amended as new records are gathered, as more areas are visited or surveyed in detail. It can also form the basis of detecting change, with this first version of the dataset forming the baseline against which future changes can be compared.
- When addressing habitat connectivity issues at a local and county level, creative solutions may need to be found.
- If the issue is more complex and is not confined to habitat connectivity but is linked to species ecology, some of these solutions may also be unpopular. In such cases, education awareness campaigns are of high importance to address any concerns or questions that stakeholders, such as members of the public, may have.
- Any programme to introduce or change habitat corridors should be preceded by a risk assessment, to assess the likelihood of success and the possibility of unwanted consequences, and should be followed by a monitoring programme, to verify if the measures are having the desired effect.

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APPENDIX 1: List of abbreviations to accompany Tables 1 and 2.

CFP: Commonage Framework Plans

CMP: Coastal Monitoring Project (Ryle *et al.* 2009)

CPU: Conservation Planning Unit of National Parks & Wildlife Service

CT: Coillte database

EPA: Environment Protection Agency

FS: Forest Service

ISGS: Irish semi-natural grasslands survey (O'Neill *et al*. 2013)

NSNW: National Survey of Native Woodland (Perrin *et al.* 2008)

NSUH: National Survey of Upland Habitats (Perrin *et al.* 2013)

SAC: Special Area of Conservation

SMP: Salt marsh Monitoring Project (McCorry & Ryle 2009)

SSCO: Site-specific conservation objectives of SAC management plan.

WCC: Waterford County Council

WWS: Waterford Wetland Survey